“An exploration of computer-mediated skill acquisition in concept mapping by in-service Panamanian public elementary schoolteachers”

Norma L. Miller

Director:
Dr. Alberto J. Cañas

Doctoral Program on the Information and Knowledge Society
Universitat Oberta de Catalunya

March 2008

to my parents
who taught me that true wealth lies in the mind and in the heart

to Doug
who believed in me long before I ever did

to Ernesto Regales
whose unshakable faith will forever remain a source of inspiration

to the children of Panama
that they may come to delight and grow in learning meaningfully

"…a teacher in search of his/her own freedom may be the only kind of teacher who can arouse young persons to go in search of their own…"

Maxine Greene

The dialectic of freedom, 1988, p. 14

Acknowledgements

I can not possibly begin to express my gratitude to my thesis director, Alberto Cañas. He may not realize it, but his words at a job interview over three years ago, when for the second time in my life I was an ABD without a dissertation, shone a glimmer of light at the end of a very long tunnel. Permanently available, totally approachable, honest and direct in his feedback, but always encouraging and supportive … he has been the true *Teacher*, helping me to finally become the researcher I always was …

I have been further blessed by the tender mentorship of Joseph Novak. His love for learning and education, his devotion to the Conéctate Project, and his excitement and confidence in my work from the first day I entered into contact with him, sustained me through many days of hardship. I am forever thankful and indebted to him. My deepest thanks are due to Carmen Collado, for accompanying me along this path, sharing ideas, patiently reading through everything I wrote, and always *being there*, as a professional and as a friend.

I extend my warmest appreciation to the teachers and facilitators who participated in this study, and to the many colleagues and friends at Conéctate and at the IHMC who supported my research. In particular, I want to acknowledge my colleagues Miguel Rodriguez and Loreto Suárez for many stimulating conversations, especially regarding the evaluation of semantic content of concept maps; Silvia Chacón for going through my results and providing ideas about how to organize and present my work; Leda Beirute for clarifying important relationships between topological and semantic structure; Eleonora Badilla for many fascinating discussions about constructivism; Larry Bunch for developing and debugging the CmapTools Recorder; and Néstor Arguea for generously sharing his expertise in statistics.

I wish to express my gratitude to Gaspar Tarté, for giving me the opportunity to join Conéctate. You were right when you said that this Project required 150% commitment. As deputy executive director, Fernando Lasso de la Vega afforded me during the last several months the leisure to finish writing this dissertation; thank you for believing in and valuing this kind of work.

Luis Basañez, how can I forget that casual stride through the Hotel Washington in Colón City seven years ago, when you told me about to the Universitat Oberta de Cataluyna's doctoral program? Thank you for showing me a possibility that now has become real. I thank my UOC classmates, especially Miriam Cárdenas and Antoni Morante, for making a virtual experience very real, and my UOC tutor Josep Duart for always responding promptly to my questions and guiding me through the ropes.

My respect and gratitude goes to the authorities of the Technological University of Panama, for supporting Conéctate and working towards a more prosperous and just society for all in Panama. I wish to thank Hernando Ponce for helping me realize that my Ph.D. was unfinished business I needed to complete; and Cristina Romero de Cedeño, for guiding me to find within me the courage and strength to complete it. I am thankful to Ceferino and Julita Sánchez for being my patrons early on in this endeavour. I will always be grateful to Victor Sánchez for his help and encouragement during the greater part of this journey.

I am of course indebted to my family and to my dearest friends for their unconditional love and support throughout the years. Finally, I thank my beloved children, Dani and Hannah, who probably can no longer remember a time when their mother wasn't working on her doctorate, for their patience and love. And to answer your question, Dani, yes … you can still call me *Mom*.

Abstract

Since the development of concept maps over thirty years ago, a vast body of research has accumulated on their use and impact in education. This research has provided much evidence that concept mapping, by providing a graphic representation of aspects of learners' cognitive structure, *can* indeed support meaningful learning in numerous ways. In particular, concept maps help to establish what a learner already knows, which is, from the perspective of Ausubel's Assimilation Theory, "the single most important factor influencing learning."

In spite of the popularity of concept maps, hardly anything is known about how learners acquire the ability to construct concept maps. Research involving concept maps focuses on the application of the skill to a given cognitive task, rather than its acquisition. During the studies, subjects are provided with a certain amount of training, which varies greatly from study to study. After the training period subjects are assumed to be proficient mappers, and data involving the application of the technique is collected. However, many researchers have noted that learners generally require months to reach the point where they are able to accurately represent their knowledge and understanding of a topic in a concept map. Aside from this fact, namely, that effective concept mapping requires time and practice, little else is known about how learners actually acquire this skill.

This dissertation explored the process by which learners acquire skill in concept mapping, specifically, computer-mediated concept mapping. The study took place in the context of Panama's Conéctate Project, where elementary public schoolteachers are being trained in concept mapping in 2-week workshops. In view of the time required by average learners to become proficient mappers, the two-week period considered in this study would correspond to the very beginning of the training phase; hence, the study's results tell only a small fraction of the story. This tale constitutes, nonetheless, a solid starting point. It helps us understand the difficulties that novice mappers confront, and explain the initial resistance they often display. This understanding, in turn, can assist in developing more effective concept mapping training programs, as well as in guiding trainers' expectations towards more realistic goals, as they work with apprentice mappers to achieve increasingly better representations of the latter's knowledge structures, and to make better use of concept mapping to sustain meaningful learning processes.

Table of Contents

List of tables

List of figures

1 Introduction

"…children who have been provoked to reach beyond themselves, to wonder, to imagine, to pose questions are the ones most likely to learn to learn."

Maxine Greene

The dialectic of freedom, 1988, p. 14

In what has come to be known as the *Information and Knowledge Society*, individuals will need to be able to adapt to rapid, continual and unpredictable change, both in their personal lives and in the workplace. Gone are the days when a person could thrive, personally and professionally, by mastering a finite and relatively unchanging body of knowledge. New information and communication technologies, the main force driving these changes, have ushered in an era characterized, among other things, by an unstoppable deluge of information. A study from the University of California at Berkeley, (Lyman & Varian, 2003) estimated the total world 2002 production of *original* information, stored digitally, at around 5 exabytes or 5×10^{18} bytes. A more recent study (IDC-EMC, 2007), which included copied data as well, placed the total amount of digital information "created, captured and replicated" in 2006 at 161 exabytes or 161 billion gigabytes … roughly 3 million times the information in all the books ever written. This same study forecasts that between 2006 and 2010, the new and replicated information added each year to the digital universe will increase more than six times, to approximately 988 exabytes.

In such a setting, it is generally agreed, the ability to construct new knowledge, to be creative, and to work collaboratively, will prove to be, perhaps more than ever before, invaluable and indispensable skills. Phrases such as "life-long learning," "continued education," "just-in-time learning," "on-the-job learning," and other similar buzzwords attest, in particular, to the heightened realization and concern that, in a mutable environment, the ability to retrieve, process, and apply new information, will be (and in some places already is) an essential ingredient for a gratifying and productive personal and professional life. Thus, foremost among the skills that education in the twenty-first century must strive to foster is *learning how to learn meaningfully* (Castells, 2001, p. 259; UNESCO, 1996).

Up to the 1960's the prevalent ideas about learning derived from behaviorist educational paradigms (Novak, 1998, pp. 49-50). This school of thought viewed the mind and its cognitive processes as a black box, beyond the reach of human understanding; the only possible way to ascertain whether learning had resulted from some educational intervention, it was argued, was to observe and measure changes in a learner's *behavior*. As constructivist epistemologies were developed and began to take hold, this behaviorist notion of learning was called into question. One major contribution was David Ausubel's Theory of Meaningful Learning (1963; 1968). *Meaningful learning* refers to "a process in which new information is related to an existing relevant aspect of an individual's knowledge structure" (Novak, 1998, p. 51). According to Ausubel's theory, learning is not a monolithic phenomenon but rather something that takes place along a continuum, with mechanical, disconnected, *rote* learning happening at one extreme and thoughtful, connected, *meaningful* learning at the other (Novak, 1998, pp. 19-20). The connectedness or interrelatedness property of knowledge learned meaningfully, moreover, appears to be what enables its application, by direct or by analogical transfer, to concrete cognitive tasks such as solving problems, making arguments, or generating designs (Jonassen, Beissner & Yacci, 1993, pp. 3-4).

Ausubel's idea of meaningful learning, along with numerous other constructivist ideas, have gained ample acceptance, as evidenced by documents such as the Report to UNESCO of the International Commission on Education for the Twenty-first Century (UNESCO, 1996). Unfortunately, implementing constructivist epistemologies has proved to be harder than many reformers anticipated (Windschitl, 2002); in general, education reform efforts have succeeded mostly at the level of rhetoric but have failed to reach down into the classrooms, to change the way teachers teach and the way learners learn (Labaree, 2007; UNESCO, 2007). Thus, many countries' educational systems have continued to operate in accordance with long-standing transmission, curriculum-driven models, where teaching, learning, and evaluation all continue to be centered on students acquiring information. Specifically in Latin America and the Caribbean, this situation has been diagnosed and reported by UNESCO (2007).

This model of education, though deficient, has nonetheless been sustainable … until recently. In the new era ushered in by computers, Internet and the World Wide Web, an era of global networks and unlimited access to unlimited amounts of information, this paradigm is finally collapsing; content-oriented educational programs are becoming more and more pointless by the day, not only because the amount of information is growing at unimaginable rates, but because the nature of much of this information is such that it soon becomes dated or obsolete (Castells, 2001, p. 91).

Faced with this reality, nations must confront the momentous responsibility and challenge of restructuring their educational systems in order to adequately prepare their children for the changing world they will be living in. Schools must focus on empowering children by teaching them to learn meaningfully. In the words of Coffey & Cañas (2003, p. 275), "it is critical that the educational experience promote meaningful learning that fosters integrative thinking based on integrated structural knowledge ...." Properly used, pedagogical tools such as *concept maps* afford children the opportunity to acquire meaningful learning skills (Novak, 2003). Research has shown that concept maps, by aiding in the organization and representation of knowledge, can support meaningful learning and knowledge construction (Novak & Cañas, 2008). Concept maps may also prompt the discovery of new and unsuspected relationships among concepts, thereby stimulating the learner's creativity (Novak & Gowin, 1984, p. 17). Furthermore, with the advent of concept mapping software and their integration with the Internet, a wealth of new possibilities for concept mapping have become viable, including linking concept maps to all sorts of digital resources, and many novel forms of collaboration (Novak & Cañas, 2008). For all these reasons, concept mapping constitutes an important educational tool that should be taken advantage of to support efforts towards more meaningful forms of learning.

1.1 Concept maps – basic notions

"Word meanings, or concepts, are like mathematical points: they have few qualities other than their relationship with other concepts."

Alan R. White

In Mapping cognitive structure: A comparison of methods, P. F. W. Preece, 1976.

Concept maps are made up of *concepts* joined to one another by *linking phrases* to form *propositions.* A concept is defined as "a perceived regularity in events or objects, or records of events or objects, designated by a label" (Novak & Cañas, 2008, p. 1). More informally, concepts may be thought of as the mental images that are conjured up in our minds by a particular label or lexical item, independently of whether we hear it, read it, or perceive it by any other means. Labels may be words or symbols. Word labels need not be limited to single words. Often more than one word is needed to convey the particular regularity one wishes to express. For instance, the expression "junk food" conveys a mental image that is entirely different from the images brought to one's mind by the words "junk" and "food" taken separately.

Propositions, sometimes referred to as *semantic units*, are structures consisting of two or more concepts joined by a *linking phrase* to create a unit of meaning. In Ausubel's cognitive theory (1963; 1968), concepts and propositions constitute the smallest units of knowledge. They are, to use Novak's analogy, the atoms and molecules, respectively, of our cognitive structure. A *propositional concept map* is a network of interrelated propositions addressing some question, problem or issue, which may be implicit in the concept map, or may have been stated in an explicit manner in a *focus question*.

Within a proposition, the linking phrase expresses the relationship that exists between the joined concepts in the specific context being considered. As with concepts, there is no rule as to how many words a linking phrase must contain; one should strive, however, to express the relationship as clearly and succinctly as possible. Figure 1 below shows an example of a concept map explaining what concept maps are.

Cross-links are a special kind of proposition joining concepts from different subdomains or regions of a concept map. These "horizontal" relations generally require greater effort and creativity than ordinary "vertical" propositions, since the relationships they establish are less common or obvious.

In a hierarchical concept map, concepts are organized vertically, with more general concepts higher up in the map, less general concepts lower down, and examples at the bottom. The convention is to read propositions from top to bottom. Thus, for vertical, top-down propositions arrows may or may not be included since their direction is clearly understood; in any other case arrows should be included to eliminate any possible ambiguity as to the intended direction.

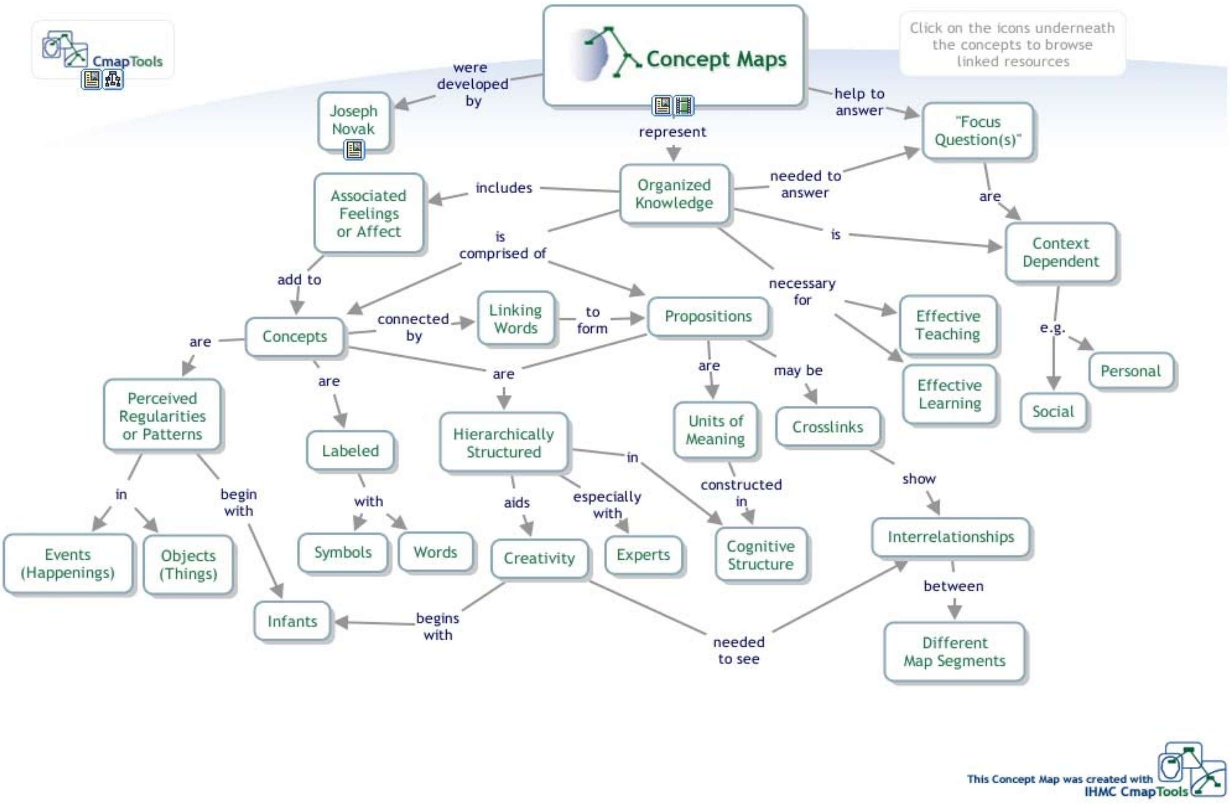


Figure 1. A concept map describing concept maps, by J. D. Novak.

1.2 Problem statement

Since their development, a vast body of research on the use and impact of concept maps in education has accumulated. This research has provided much evidence that concept mapping *can* indeed support meaningful learning in many different ways (Coffey et al., 2003; Novak & Cañas, 2008; Novak & Gowin, 1984, Ch. 2). And yet, aside from the fact that effective concept mapping requires time and practice (Lin, Strickland, Ray, & Denner, 2004; Pankratius, 1990; Wandersee, 2001, pp. 135-137), little else is known about how learners actually acquire this skill. Moreover, to the best of our knowledge, there are no studies that expressly investigate this question.

The purpose of this dissertation was to explore the process by which learners acquire skill in concept mapping, specifically, computer-mediated concept mapping. By making the *acquisition* of skill in concept mapping its focal point, we have set this study apart from most other studies involving concept maps, whose focus is not the acquisition of the skill itself, but rather its *application* to some particular cognitive task.

In tackling the main research problem we were at once confronted with the concomitant problem of how to *measure* learners' progress in acquiring concept mapping skills. Thus, the present investigation actually includes three preliminary studies. The first of these dealt with our population's preconceptions regarding concept mapping; the second involved the development and validation of a topological taxonomy to rank concept maps according to structure; and the third involved the development and validation of a semantic taxonomy, to rank concept maps according to content. The first of these studies (chapter 5) provided valuable background information on our population, while the other two (chapter 6) afforded the basic measurement tools to answer the research problem undertaken in this study.

The population for this study consisted of in-service public elementary schoolteachers participating in Panama's *Conéctate al Conocimiento* Project, a nationwide education project described in detail in the following section.

It is our hope that this investigation will contribute to a better understanding of the cognitive processes learners go through while acquiring skill in concept mapping. However, given the context in which the study has taken place, we expect it will provide valuable information which, if taken into account, will not only improve the effectiveness and efficiency of Conéctate's teacher-training workshops but, perhaps more importantly, will provide participating teachers with better strategies to help their students develop effective concept mapping skills.

1.3 Backdrop for the study: The *Conéctate al Conocimiento* Project

"Conéctate is a net we have cast to capture the country's talent, wherever it may be."

Alberto Cañas
Personal communication, 2005.

"Conéctate al Conocimiento, es un proyecto que pone en las manos de los niños de las escuelas públicas, las más poderosas herramientas para construcción, representación y publicación de conocimiento hasta hoy inventadas. Es la resultante de los esfuerzos de un equipo prodigioso de personas, animadas por una sola fuerza: El futuro de la niñez."

Gaspar Tarté

Conéctate al Conocimiento:
Una estrategia nacional de Panamá basada en mapas conceptuales, 2006.

Panama is a small Caribbean country, extending East-West for about 400 miles from the border with Costa Rica to the border with Colombia. Its gradual emergence from the seas during the Miocene and the Pleistocene eras, over 3 million years ago, permitted the great American interchange of animal species between North America and South America and, much later, the migration of humans to the entire continent. In modern times, the California Gold Rush motivated the construction of the Transisthmus Railway, which again created a bridge for human transit and brought new migrations to the land. Less than a quarter of a century later the story repeated itself with the construction of the Panama Canal. Within the last decade Panama has become the telecommunications hub for Latin America, serving as a junction point for numerous submarine fiber-optic cable networks. This in turn is attracting new business and immigrants to the country. Thus, "bridges," "crossroads," and "migrations" have been recurring leitmotifs in Panamanian history since prehistoric ages.

Like most other underdeveloped Latin American countries, Panama faces problems of extreme poverty, unequal distribution of wealth, lack of access to affordable quality health care, and an ineffectual educational system (Programa de las Naciones Unidas para el Desarrollo [PNUD], 2002). Problems are aggravated by high population dispersion, with a significant proportion of the population living in communities with fewer than 500 members, often in remote and inaccessible areas (Herrera, 2003, pp. 60-61).

According to a report by the National Council on Education (Consejo Nacional de Educación [CONACED], 2006), a body created to recommend public policies to improve the Panamanian educational system, and comprised by prominent Panamanian intellectuals, Panama has achieved important goals in education, such as 100% coverage at the elementary level; high completion levels of elementary schooling everywhere in the country, except in the Darien Province and some Indian reservations; 92.4% literacy rate; and increasing percentages of Gross Domestic Product devoted to education.[1] In spite of these achievements, the country's educational system is plagued by numerous problems in critical areas which include: quality of education; equal opportunity; administrative and financial management; infrastructure, technology and equipment; among other problem areas. Pertaining to quality of education, the Council identified the following specific problems: low quality learning; deficiencies in teacher training and cultural background; lack of continued education programs; short academic calendar; curriculum-driven educational policies; institutionalized model of rote learning; lack of access to books, technology, and other didactic resources; inefficient supervision and little accountability for results; and a lack of education quality standards and a national evaluation system.

Nevertheless, with a relatively small population (scarcely 3 million inhabitants), major transportation and telecommunication infrastructure, an economy based largely on services (primarily trade, banking, and insurance) and a population accustomed to dealing with foreigners, Panama today is in an enviable position to tap into the new opportunities offered by a global economy to permanently solve many of its problems. The current government, moreover, has recognized the role education can play in human development and societal change, and has made education one of its top priorities (Tarté, 2006).

As mentioned above, the present study took place in the context of an ambitious education project of the Panamanian Government called *Conéctate al Conocimiento.*[2] Conéctate seeks to bring about a profound and enduring transformation of Panama's educational culture (Tarté, 2006), where rote learning has traditionally been the norm at all levels (CONACED, 2006).

According to Tarté (2006), in the past in Panama education reform projects involving computers typically adopted a technocentrist approach. These efforts, he argues, were a double failure: first, because they never achieved their goals; and second, because the investment and enthusiasm they generated were wasted (ibid). Unlike these projects, Conéctate is not a technology-centered project. Conéctate is about building bridges for learners to migrate over into new realms of knowledge and collaboration; it seeks to empower students to use technology to learn meaningfully and collaborate, generating in the process a national network of knowledge and collaboration among participating schools (ibid). To this end, teachers are being trained in the use of pedagogical tools and strategies, as well as technological tools, oriented towards helping them foster meaningful learning and

[1] In 2006, 5.8% of the GDP was destined to the educational sector. Source: CONACED, 2006.
[2] In English, *Connect to Knowledge.*

collaboration among their students. In its initial phase, concept maps constitute the key pedagogical tool used at the Conéctate Project, since properly utilized, concept maps are known to facilitate the organization and representation of knowledge, and stimulate creativity and divergent thinking (Novak & Cañas, 2008).

At Conéctate most concept maps are built using *CmapTools*[3] (Cañas et al., 2004), a knowledge modeling and sharing environment developed at the Institute for Human and Machine Cognition (IHMC)[4] and freely available for educational institutions and for individual non-commercial use. Using programs such as CmapTools, concept maps can be constructed and revised much more easily than pencil-and-paper maps. Additionally, CmapTools allows users to enrich their concept maps with numerous resources available on the Web such as documents, Web pages, images, videos, among other digital resources, and to link them to other concept maps. Furthermore, CmapTools is designed to enable local and distance collaboration with other learners. Collaborative work via CmapServers, may take place synchronously or asynchronously, and may adopt a number of modalities, from the simple exchange of critiques and suggestions to joint, real-time concept map construction. Figure 2 shows an example of a concept map created by a student from the Conéctate Project using CmapTools and enhanced with resources from the Web.

CmapTools was designed to be at once simple but powerful. In the words of its designers, "the software was designed to have a *low threshold*, making it easy to learn for new and naïve users, but at the same time to have a *high ceiling*, enabling sophisticated and expert users to develop large, complex knowledge models" (Cañas, Hill, et al., 2006, p. 304). One example of such an expert knowledge model is the collection of concept maps on Mars[5] developed at the Center for Mars Exploration (CMEX), and discussed in Briggs et al. (2004).

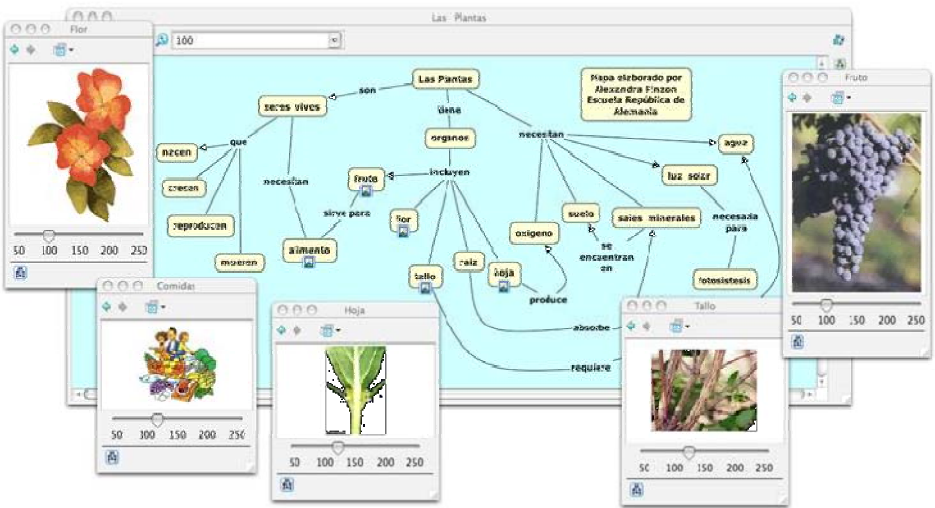


Figure 2. A concept map created using CmapTools by children from the *Escuela República de Alemania,* a school participating in the Conéctate Project. Images are examples of the resources that can be linked into concept maps and accessed by clicking on corresponding icons on concepts (Image courtesy of A. J. Cañas).

[3] http://cmap.ihmc.us
[4] http://www.ihmc.us
[5] http://cmex.ihmc.us/cmex/Map%20of%20Maps.html

The Conéctate Project commenced in February 2005 with the training of the first group of 17 *facilitators*,[6] a diverse group of professionals whose job would be to help bring about a new educational culture in Panama, where innovation and technology become the basis of a national strategy for socioeconomic progress and development (Tarté, 2006). Their specific responsibilities range from designing workshops and training teachers of participating schools in technology supported pedagogical strategies conducive to meaningful learning and collaboration, to visiting schools for onsite support, to collecting data and providing the Project with indispensable feedback regarding progress towards its goals.

The first group of teachers was trained a month later, in March 2005. The Project has targeted 4th, 5th and 6th grade teachers, since it is believed that it is at these levels that the greatest impact can be attained in the shortest time. To begin, teachers travel to the Project's headquarters in Panama City for a 2-week workshop. While attending the workshop, substitute teachers back home carry on with participating teachers' work in their respective schools. Up to December 2007, more than 5,000 teachers from over 550 schools had attended the Conéctate workshops. Considering that teachers work with an average of about 25 students,[7] we estimate that approximately 125,000 children have been touched in some way by Conéctate. This represents 72% of Panama's 173,034[8] 4th, 5th and 6th grade students. Thus, one can begin to appreciate the Project's potential impact nationwide.

Given the profound changes in teachers' roles sought by Conéctate, and given the enormous deficiencies in Panamanian teachers' cultural and educational backgrounds (CONACED, 2006), a 2-week workshop alone could not possibly be sufficient to attain these goals. Hence, Conéctate has had to take into account other aspects, the most outstanding of which are the following:

1. **Training of principals and supervisors.** If educational supervision is to be the backbone of an efficient and effective educational system as CONACED (2006) urges, it is of vital importance to familiarize principals and supervisors with the pedagogical, technological, and methodological tools educators will be using, so that they may be better prepared to supervise and support the process of change.

2. **The innovation classroom.** Schools integrated into the Conéctate Project are provided with an *innovation classroom*, equipped with technologies whose specifications have been established by the Project. All students of participating schools have access to computers and broad-band Internet.[9] The construction or rehabilitation of the innovation classroom, and its outfitting with the required equipment and technology is accompanied by the transformation of the subject of *informática*,[10] from a subject area completely dissociated from all others, to one which is instrumental to and supportive of individual and common goals for all

[6] At present the project has a total of 42 facilitators.
[7] Source: *Ministerio de Educación, Estadísticas Educativas 2005, Educación Primaria*. Retrieved March 12, 2008 from: http://www.contraloria.gob.pa/dec/Aplicaciones/EDUCACION.
[8] Source: *Ministerio de Educación, Estadísticas Educativas 2005, Educación Primaria*. Retrieved March 12, 2008 from: http://www.contraloria.gob.pa/dec/Aplicaciones/EDUCACION.
[9] At the time of this writing, approximately 300 of the 550 schools have been connected to Internet. Of these, one half uses hardwire technology, while the other half is connected via satellite.
[10] This term could be variously translated as "informatics," "computing," or "information technology." Regardless of the name, in the context of Panamanian schools it refers to a subject in which students are taught about computer parts, learn to use popular computer programs such as Word and Power Point, and may also learn to surf the Web to search for information.

subjects. The above involves redefining the role and responsibilities of the informatics teacher, who becomes the innovation classroom coordinator or CAI, (the Spanish acronym for *coordinador del aula de innovación*), and the liaison among teachers and their projects.

3. **Follow-up visits**. Post-training visits to schools are intended to provide pedagogical, technical and emotional support in order to maintain schools' interest, enthusiasm and involvement in the Project. During these visits, facilitators may work with individual teachers or organize group sessions. Teachers who did not attend the workshop often become involved and participate as well. If a teacher is willing, facilitators may work directly with the students.

4. **Online support.** Up to now, except for occasional emails or phone calls, support has almost always been given face-to-face: Project facilitators and technical staff travel to the schools to provide assistance. At present, however, the Project is very close to being able to provide online support as well. Conéctate's support Web site, known as *Punto de Encuentro*,[11] will offer an environment where teachers will find support from facilitators and other teachers, as well as resources to enhance their teaching and carry out projects.

5. **Research.** Any project of Conéctate's magnitude and nature inevitably needs to readjust or modify its course along the way. Accurate and timely feedback is indispensable to make necessary adjustments to specific practices or general strategies in order to guarantee the Project's success. Useful information, in turn, requires the development of measurement tools to systematize and standardize individual observations. Research at Conéctate, hence, is aimed largely to developing and validating data collection tools, and using them to provide feedback to support decision-making.

[11] The translation is "Meeting Point."

2 Literature review

This chapter provides a review of the literature relevant to our study. The review is divided into the following sections: 1) theoretical foundations for concept maps, 2) computer-mediated learning, 3) cognitive skill acquisition, and 4) educational technology research.

2.1 Theoretical underpinnings for concept maps

2.1.1 Concept maps and meaningful learning

Concept maps emerged within the framework of a constructivist epistemology, specifically, Ausubel's Assimilation Theory (1963; 1968). A key notion of this cognitive theory is that the process of learning new knowledge takes place somewhere along a continuum ranging from *rote learning* on one extreme, to *meaningful learning* on the other. Novak points out that "rote learning occurs when the learner makes little or no effort to relate new information to relevant knowledge she/he already possesses or when the learner has little organized relevant knowledge" (Novak, 2003, p. 124). Thus, in rote learning new information is not integrated into the learner's knowledge structure; rather, it is memorized, word for word, in a rather arbitrary manner (Moreira, 2000). As a result, the learner will be less able to retain, recall and avail him or herself of this new information for application in novel situations, since such a transfer process would require, first, that the learner "see" an analogy between two apparently dissimilar situations, and second, that he or she understands how to fit the information into the new context. Both of these tasks will be harder to achieve for someone who never truly understood how the new information fit into the original context in the first place (Novak, 1998, pp. 12-16). Moreover, according to Suppes & Ginsberg (in Novak, 1998, p. 61), information learned by rote (even when it is forgotten) inhibits future learning of similar new information. Rote learning makes it more difficult to identify and clarify misconceptions, since this entails detecting contradictions or ambiguities, which in turn requires the learner to conscientiously strive to relate the newly acquired information to his or her previous relevant knowledge structure. Finally, rote learning interferes with the acquisition of positive feelings of self-worth on the part of the learner, associated with the realization of his or her own understanding of the topic being studied (Novak, 1998, pp. 12-26).

In contrast, in meaningful learning new information is fully integrated and firmly anchored (subsumed) into the learner's previous relevant cognitive structure (Rodriguez, 2004). The building blocks of this knowledge structure are *concepts* and *propositions*. As Novak (2003, p. 124) indicates, "meaningful learning occurs when the learner deliberately seeks to relate and incorporate new information into the relevant knowledge structure she/he possesses." When meaningful learning takes place, the new information is readily available for recall and use in similar yet new situations; knowledge learned meaningfully, moreover, facilitates the learning of additional new material similar to what was previously learned (Novak, 1998, pp. 60-61).

Learning meaningfully involves modifying and improving cognitive structure, by latching new concepts and propositions onto more general, less differentiated aspects of this structure called *subsumers*. The result of this meaning making process is the mutual modification of both the new and old knowledge (Moreira, 1997). However, as Moreira (1997) cautions, though verbs like "anchor" and "latch" are helpful to visualize this process they may lead to the incorrect idea of a rigid, static cognitive structure. In fact, cognitive structures are highly fluid and dynamic, with relationships becoming reconfigured as new knowledge is constructed.

Two important processes that take place during meaningful learning are *progressive differentiation* and *integrative reconciliation*. Progressive differentiation refers to the increased precision and specificity that accrues to the meanings of concepts in the cognitive structure as a consequence of subsumption. As meanings are refined, new interconnections can be established, a process referred to as integrative reconciliation. In a sense, integrative reconciliation is a form of progressive differentiation that occurs at a more global level within a cognitive structure.

Three conditions are necessary for meaningful learning of new information to take place (Novak, 1998, p. 19):

1. The learner must already possess some relevant knowledge.

2. The new information must be conceptually clear, and accessible to the learner, i.e., it must be presented in such a way that the learner can relate it to his/her prior knowledge.

3. The learner must be motivated and make the effort to learn in a meaningful way.

Of the above three conditions the first is the most important one. In Ausubel's own words: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Novak & Gowin, 1984, p. 40). But how can one ascertain what a learner already knows? In his extensive writings, Ausubel provides no tool to make this previous knowledge public (ibid).

As a graphic device for the organization and representation of knowledge, concept maps provide a simple means to make Ausubel's ideas operational and foster meaning making. To begin with, they furnish a concrete means to tap into and reveal the learner's knowledge structure, that is, to "ascertain what the learner already knows" on a given topic or subject. Though the representation may not be complete, it is, nevertheless, a reasonable approximation from which learners and teachers can move forward (ibid). The visual structure thus provided serves as a template or scaffold into which a student can integrate new concepts and propositions, whilst re-examining previous ones.

Learners generally agree that coming up with appropriate linking phrases to join concepts is the most challenging part of constructing a concept map. Determining the relationship that exists between a pair of concepts being connected, and stating it as precisely, accurately, and succinctly as possible, following basic rules of grammar is no minor task. The quality of the linking phrases is a measure not only of the learner's previous knowledge base and ability, but may also reflect the learner's effort to integrate new knowledge. This outward struggle with linking phrases, and in general the effort to integrate new concepts and propositions (or previous knowledge learned by rote) into a concept map, in some sense mirrors the internal assimilation process taking place in the learner's mind. In this manner, concept mapping helps identify areas that require further study, and contributes to a heightened awareness of the learning process itself. It is interesting to note the similarity between these ideas and other constructivist notions. For instance, those concepts and propositions which a learner is able to include in his or his concept map would seem to correspond to Vygotsky's (1978) "zone of proximal development," since they represent precisely those ideas the learner is "ready" to learn, either independently or with the support of able others.

Due to their simple proposition-based structure, it is easier to detect misconceptions in a concept map than in a linear piece of writing, where often the language itself obscures clear ideas, or disguises erroneous ones. Additionally, the search for relevant and interesting cross-links stimulates divergent thinking. Cross-links are relationships that connect concepts from distinct subdomains of a concept map.[12] These horizontal propositions tend to be less evident than the standard vertical relations; hence, forming good cross-links generally requires greater effort on the part of the person constructing the map. Cross-links are thought to be evidence of integrative reconciliations and creativity on the part of the learner and it is recommended that learners be encouraged to find and include cross-links in their maps (Novak & Gowin, 1984, p. 84). Nonetheless, it is important to keep in mind that although cross-links can be formed between multiple pairs of concepts, many of them could be trivial and not necessarily evidence of higher order thinking.

Map content and structure can be augmented by the inclusion of various kinds of resources (e.g., images, documents) and links to other concept maps. These features are associated primarily with concept maps generated by means of some computer software. Computer-based concept mapping also makes possible a number of different forms of collaboration, which affords opportunities for sharing and negotiating meanings among learners, as well as for the development and practice of valuable social skills.

In the last few paragraphs we have underscored and summarized some of the ways in which concept maps can support meaning making. These ideas constitute the essence of the *New Model for Education Centered on Concept Maps*, proposed by Novak & Cañas (2008).

2.1.2 Historical background and uses of concept maps

Concept maps are not new in education. They were developed in the early 70's by Joseph Novak and his colleagues at Cornell University, in the course of a 12-year comparative research project that investigated science concept learning in children who received instruction through audio tutorials (Novak & Musonda, 1991). During this study, a group of first and second graders, with their respective controls, were followed throughout their elementary and secondary education. Concept maps arose early on in the study as a tool to help record and understand changes in these learners' comprehension of studied science concepts ((Novak, personal communication, July, 2007; Novak & Musonda, 1991). Over the years, their potential to involve students in significant learning processes became more and more evident. This fact was eloquently presented in Novak & Gowin's *Learning how to learn* (1984), a book which contributed greatly to extending the use of concept maps throughout the world.

[12] A more formal definition of *cross-link* is given in section 6.3.

Concept maps have proven to be an extremely versatile tool, having been applied to business, government, computer science, and practically all domains of knowledge. Business and government applications include knowledge elicitation (e.g., Coffey & Hoffman, 2003; Gordon, Schmierer, & Gill, 1993; Ford et al., 1991; Ford et al., 1996), preservation of organizational knowledge (e.g., Huff & Jenkins, 2002; Johnson & Johnson, 2002; McNeese et al., 1990), training and performance support (e.g., Cañas et al., 1998), and knowledge management (e.g., Kingston & Macintosh, 2000), among other uses. In the field of computer science, applications have been found to software-assisted knowledge acquisition (e.g., Cañas, Leake, & Wilson, 1999; Ford & Bradshaw, 1993; Regoczei & Plantinga, 1987). Nevertheless, concept maps arose in an educational context, and it is in education that they are still most widely used today. Consequently, the vast majority of concept map research and applications are in this field.

There is no doubt that concept maps *can* enhance education. This fact has been well established in a review of studies of the educational effectiveness of concept mapping, conducted over a decade ago by Horton et al. (cited in Coffey et al., 2003). Horton's study shows that, overall, concept maps have had a positive impact on education. Like any tool, however, the effect of concept maps may vary from positive to null to negative, depending on how and under what conditions they are used. Thus, the crucial question ought not be *whether or not* concept mapping is useful, but under what conditions of use are they most effective (Coffey et al., 2003).

In their review of the literature, Coffey et al. (2003) conclude that concept mapping is most useful when 1) used as an integral, on-going feature of the learning process, 2) used to establish and clarify relationships among concepts, and 3) accompanied by an active, deep and questioning approach to learning. Concerning the first point, Pankratius' (1990) investigations of the use of concept maps in learning high-school physics suggest that greater achievement is obtained when mapping is used prior to, during, and subsequent to instruction. This manner of use is also consistent with the making and remaking of concept maps advocated by Novak & Gowin (1984, p. 19), during which there is a "pushing and pulling of concepts, [and a] putting them together and separating them again," which is the essence of reflective thinking (ibid).

With regard to the second point, we might add that concept mapping appears to be somewhat more effective than other forms of engaged learning, such as concept defining and outlining, for establishing relationships among concepts (Coffey et al., 2003). In this respect, there is also some evidence suggesting that lower ability learners reap the greatest benefits (ibid).

As for the third condition, an important example of the synergy that develops when deep questioning accompanies concept mapping is provided by Chacón (2006). Her work, with both university students and preschoolers, examines the mediating role of pedagogical questions in the construction of concept maps. In her studies, learners were able to restructure their concept maps and carry out metacognitive reflections about them, but only with the teacher's mediation. This mediation was through the posing of different kinds of pedagogical questions, which induced in the learners alternate states of cognitive disequilibrium and equilibrium, and ultimately an awareness of their own learning experience (ibid).

Cañas & Novak (2006) have called attention to the fact that the effective use of concept maps in education has been limited by a generalized tendency, pervasive among mappers, to construct descriptive concept maps as opposed to explicative maps. This in turn appears to be the result of focusing on objects rather than events. According to Cañas & Novak (2006), concept maps that deal with objects generally end up being descriptive maps, characterized almost entirely by static propositions, i.e., “relationships between concepts [that] help to describe, define and organize knowledge for a given domain” (Safayeni, Derbentseva, & Cañas, 2005, p. 10); in contrast, concept maps that involve events are usually more explanatory and contain more dynamic propositions.

Derbentseva, Safayeni, & Cañas (2004), for their part, have pointed out that in general adequate knowledge representation requires both static and dynamic propositions, as it is the latter that capture covariation and changing relationships among two or more concepts. This assertion is especially true for scientific and mathematical knowledge, where causal relationships and interdependencies among two or more variables often show up. In view of the above, propitiating dynamic propositions in concept maps is considered a most desirable goal.

Novak & Cañas (2008) assert that the nature of the focus question influences the type and quality of the resulting concept map. Experiments conduced by Derbentseva et al. (2006) have shown that dynamic focus questions significantly increase the presence of dynamic propositions in concept maps. In their research, Derbentseva, Safayeni, & Cañas (2006) compared a focus question asking “what is concept X?” with a focus question asking “how does concept X work?” Their results showed that the “how” condition produced significantly more dynamic propositions than did the “what” condition. Hence, posing good focus questions is, along with the recommendations offered by Coffey et al., another way to enhance the usefulness of concept maps as a cognitive tool.

2.1.3 Concept maps as a tool for evaluation

The application of concept maps in educational settings has led to their use as an assessment tool, for both formative and summative assessment. Essentially three kinds of evaluation systems based on concept maps have been designed: component-based scoring (e.g., Novak & Gowin, 1984, p. 37), comparison to expert or criterion maps (e.g., Ruiz-Primo & Shavelson, 1996), and hybrids or combinations of the previous two systems (e.g., Rye & Rubba, 2002). Interestingly, McClure, Sonak, & Suen (1999) found that, all else being equal, distinct scoring methods have different levels of reliability. They attribute this to the relative cognitive complexity of the scoring methods, some of which provide greater guidance to the evaluator than others.

But what is it that concept maps assess anyway? Novak, Gowin, & Johansen (1983) found a nearly orthogonal relationship between performance on a concept mapping task and standard measures of student ability. This led them to propose that high performance in concept mapping taps different cognitive abilities than do conventional psychometric instruments (such as multiple choice exams) used in standardized tests or classroom exams. Markham, Mintzes, & Jones (1994) interpreted this finding as evidence that traditional assessment methods do not distinguish well between knowledge acquired by rote and knowledge acquired by a more meaningful learning process. Since then numerous studies (e.g., Markham, Mintzes, & Jones, 1994; Ruiz-Primo, Schultz, Li, & Shavelson, 2001) have provided further support for concept mapping as a valid alternative assessment method measuring connected understanding. The Markham, Mintzes, & Jones (1994) study, in particular, also showed that differences in concept mapping performance correctly predicted divergent results in a knowledge application task, which is consistent with Smith's contention (in Markham, Mintzes, & Jones, 1994) that knowledge application is closely linked to knowledge structure.

Ruiz-Primo & Shavelson (1996) have characterized concept map assessments in terms of 1) a task or assignment, 2) a response format, and 3) a scoring system; they refer to a given combination of task and response format as a mapping technique. Ruiz-Primo, Schultz, et al. (2001) and Ruiz-Primo, Shavelson, Li, & Schultz (2001) demonstrated that different concept mapping techniques do not provide equivalent information about learners' knowledge structures, since apparently they impose different cognitive demands on the learner and tap different cognitive abilities. In terms of the mapping assignment, greater cognitive loads correspond to the less directed tasks, for example, constructing a map from scratch; more directed assignments, such as, fill-in-the-map techniques (filling in nodes or linking phrases), demand less cognitive effort on the part of the learner. Accordingly, the construct-a-map technique appears to better reflect learners' cognitive structures (Ruiz-Primo, Schultz, et al., 2001).

Reliability and validity issues have been the object of a great deal of research, and are much more relevant for summative assessments. These concerns are greatly diminished when concept maps are used for formative assessment. Conlon (2004) aptly notes that research in this area seems to have been neglected, in spite of the fact that concept mapping is "most naturally seen as a developmental tool" (p. 164), ideal for formative evaluation. His work has led to the development of an analyzer program called the Reasonable Fallible Analyzer (RFA) that compares student concept maps to a master map, and gives an initial, provisional score based on concept and proposition matches, as well as tips for improving the map. The system's fallibility is due to the absence of language restrictions; its reasonableness lies in that it allows students to "argue" with it and "make their case" for a better score. We shall have more to say about this below.

2.1.4 Features of a "good" concept map

Although there is no unique formula for assessing concept maps, one can enumerate certain featuresse that make for a good map. We end this section by listing these elements, followed by a brief discussion of those that have not been considered in earlier segments and which are not self-explanatory.

- Hierarchically ordered (top-down), relevant concepts
- Satisfactory response to focus question[13]
- Predominance of binary propositions[14]
- Precise and accurate linking phrases
- Presence of static and dynamic propositions
- Presence of relevant and thoughtful cross-links
- Adequate use of examples
- Appropriate use of resources and links to other Cmaps[15]

---

[13] If one is present.

[14] Binary propositions are propositions consisting of *triads*, that is, two concepts and the linking phrase joining them.

[15] This applies to computer-based concept maps.

From the beginning, Novak and his colleagues advocated a hierarchical structure for concept maps, that is, a configuration in which the most general or inclusive concepts are at the top of the concept map and the most specific, least inclusive, at the bottom. The reason was their belief that meaningful learning is facilitated when new concepts are *subsumed* under more inclusive ones (Novak & Gowin, 1984). Thus, hierarchical structure came to be considered by many as a premise for the construction of a good concept map. It must be pointed out, though, that other arrangements (e.g., circular or spider-like structures) are certainly possible. Moreover, some authors (e.g., Ruiz-Primo & Shavelson, 1996; Dutra, Fagundes, & Cañas, 2004; Safayeni et al., 2005) have questioned the original preference towards hierarchical concept maps. In the opinion of Ruiz-Primo & Shavelson (1996), for instance, "methodologically and conceptually there is no need to impose a hierarchical structure" (p. 578), since different types of content structure lead naturally to different types of concept map structures. Taking a more Piagetian approach, Dutra et al. (2004) place greater emphasis on linking phrases between concepts and the resulting propositions, than on hierarchical structure. From this perspective a concept map is seen as a "representation of the set of interrelationships which support the different concepts it contains" (Dutra et al., 2004, p. 224).

During a study with 7th and 8th graders using concept maps and Vee diagrams (Novak et al., 1983) it became clear that a concept map ought to respond to some specific question (Novak, personal communication, July, 2007). From the beginning, research questions were an integral part of Gowin's Vee heuristic, developed initially to help clarify the nature and purpose of laboratory work in science (Novak & Gowin, 1984, p. 60). It was the participating children who chose to call this question the "focus question." In constructing knowledge during a laboratory experiment, known concepts are used to observe objects and events, and to make records of these observations (ibid). What is recorded depends on the observer's particular interest. The focus question helps direct the observer's attention to the relevant aspects of the object or event under observation. In a similar way, when used in concept mapping focus questions direct the learner's attention to the issue under consideration. Additionally, since hierarchies among concepts and relationships are highly context dependent, focus questions help establish a specific context within which to rank concepts, thereby guiding concept map construction.

In this study, focus questions were classified into three types: 1) closed or classificatory, 2) open-static, and 3) open-dynamic. Closed or classificatory questions tend to have a universally accepted answer and therefore do not allow much variation among respondents. Maps responding to this type of question tend to be quite similar to one another, as room for personal input is minimal. Examples of this type of question are *"What are the layers of the Earth?"* or *"How is Panama divided politically?"* Open-static focus questions generally request descriptions of concepts. They admit a variety of responses, since personal experience can be incorporated into these descriptions; however, they tend to lead to maps that depict unchanging relationships, i.e., maps that are basically static in nature. Examples are *"What is magnetic resonance?"* or *"Who was Picasso?"* Finally, open-dynamic focus questions generally deal with events, rather than objects, go beyond requiring mere descriptions to demanding reasons and explanations for these events, be they situations or happenings. Maps responding to this type of question account for changing relationships and interdependencies among concepts, hence their overall dynamic nature. Furthermore, responses vary greatly among learners, since personal experience and understanding plays a major role in map construction. Examples of open-dynamic questions are *"Why do birds migrate?"* or *"Why is it important for pregnant women to ingest folic acid?"*

Although propositions are required by definition to state a meaningful relation, the definition does not require that the relation involve a fixed number of concepts. Most of the time, statements, even complex statements, may be broken down into several propositions each involving a pair of concepts. The advantage of building up a concept map using binary propositions is that, as new relations are discovered and links between concepts are added, the concept map as a whole continues to make sense. On occasions, however, more than two concepts are needed to state the desired relationship.[16] In such instances, the binary components of a proposition need not be meaningful when taken separately. To sum up, propositions involving two concepts are to be preferred whenever possible. If more than two concepts are required, the proposition should use as few concepts as necessary to convey the desired meaning clearly and unambiguously, taking care not to introduce in the process ambiguity in other propositions in the concept map.

2.2 Computer-mediated learning

For over 40 years now, educational theory has been divided between constructivist, student-centered approaches, on the one hand, and behaviorist, information-centered approaches, on the other.[17] Computers have sharpened these existing cleavages in educational theory (Papert, 1987). Computer-based learning, for the most part, has been modeled on a behaviorist paradigm. Implicit in this viewpoint was the idea that the role of technology was to transmit knowledge to students, just as was the role of teachers; the role of students was to passively accumulate this knowledge. The metaphor of the "empty vessel" waiting to be filled is often used to describe the behaviorist view of the human mind implied by these instructional strategies. In keeping with this model, technology was used to deliver instruction to students in the form of drill-and-practice and simple tutorials. As Jonassen, Peck, & Wilson (1999) assert, the "underlying assumption [was] that people learn *from* technology" (p. 2).

In a polemic article, Clark (2001) stated clearly and explicitly what others before him had said only tentatively: "The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (p. 2). He based this conclusion on results of several meta-analyses of the extensive body of comparison studies which showed that either there is "no significant difference" between using technology to deliver instruction versus using more conventional forms of delivery; or, if there is a difference in favor of the technological medium, the studies are not reliable due to confounding. He advanced the hypothesis that "it is the method of instruction that leads more directly and powerfully to learning" (p. 7), not the medium transporting that method.

Clark's controversial statement sparked a lively debate that continued for years. In an article published over a decade later, Kozma (2001a) reframed and extended his own earlier counterargument. He begins by suggesting that "perhaps the appropriate question is not *do* but *will* media influence learning" (p. 179). He goes on to point out that "educational technology is a design science. ... If there is no relationship between media and learning it may be because we have not yet *made* one. ... if we preclude consideration of a relationship in our theory and research by conceptualizing media as 'mere vehicles,' we are likely to never

---

[16] For example, the relationship $E= mc^2$ among the physical variables *energy*, *mass*, *and speed of light*, can not be expressed by any single proposition involving two concepts only.

[17] In Europe, where Piaget's ideas were adopted much earlier than in the United States, the schism has been in existence longer.

understand the potential for such a relationship" and hence never make one (pp. 179-180). To his rhetorical question – why is it that we have failed to establish a relationship between media and learning – he answers that this failure is due largely to the fact that our theories, research, and designs have been constrained by vestiges of the behavioral roots from which the discipline sprang.

By the end of his article, however, Kozma (2001a) advises a more integral approach to the question of media and method: "both are part of the instructional design … media must be designed to give us powerful new methods, and our methods must take appropriate advantage of a medium's capabilities" (p. 193). Others concur. Morrison (2001), for instance, states that "rather than reframing Clark's question, it seems more productive to consider the effectiveness of the whole unit of instruction rather than the individual components" (pp. 201-202). And he adds: "as the interdependence of instructional strategy and utilization of a medium's capabilities ... increases in strength with interactive technologies ... [media comparison] research has less and less relevance" (ibid, p. 203). As Joy & García (2000) put it, "the question ought to be … 'What combination of instructional strategies and delivery media will best produce the desired learning outcome for the intended audience?'" (p. 38)

Pea (1985) has a different take on things. From Pea's perspective, "computers are commonly believed to change how effectively we do traditional tasks, amplifying or extending our capabilities, with the assumption that these tasks stay fundamentally the same" (p. 168). He asserts that education appears to have committed itself to the computer as "amplifier" idea, in order to forward more effectively its traditional fact-oriented agenda, and cites the prevalence of fact-oriented computer-assisted instruction as evidence. And yet, as Papert (1987, Technocentrism section, ¶ 8) insists, the "role that [computers] can play most strongly has little to do with information." Computers, like other cognitive technologies before them (e.g., written language and mathematical symbolism), have the potential to redefine the very nature of the cognitive tasks we perform by reorganizing our mental functioning, not just amplifying it. In so doing, they serve as instruments for redefining human nature and culture (Pea, 1985).

Specifically, the call has been for computer technologies to be developed and used so that they may serve as instruments for developing thinking skills, transferable among different domains and applicable throughout a lifetime of learning and problem solving. The specific cognitive skills being stressed are: 1) information management; 2) written communication and critical inquiry skills; 3) metacognitive and self-regulatory skills; 4) creative thinking and problem solving; and 5) collaborative problem solving and negotiation skills (Pea, 1985).

Thus, the current movement in the design of educational technologies is to create cognitive tools and learning environments that are adapted and developed for intellectual partnerships (Young, 2003). The numerous dialogues and debates within the educational community, along with new technological developments, have helped to fuel this paradigm shift in educational technology design, towards more constructivist learning environments and tools. The conception that has gradually been gaining greater acceptance is that students learn *with* technology, as opposed to learning *from* technology. This shift embodies a conceptual change from technology as *teacher*, as source of knowledge, and as the *cause* of learning; to technology as *intellectual partner*, as a means for learners to represent what they already know and what they are learning, and hence, as a *support* for meaning making.

One important class of cognitive learning tools that has evolved is known as Mindtools. Coined by Jonassen, the term refers to "knowledge construction tools that learners learn with, not from" (Jonassen & Carr, 2000, Introduction section, ¶ 2). Mindtools have been designed to engage students' active participation and manipulation of the technology in order to foster thinking skills (creative, logical, and critical) and to increase their self-knowledge. Moreover, the skills promoted by these tools are not limited to any domain-specific knowledge contained in the resource; they are generalizable and transferable to other knowledge domains (Slangen & Sloep, 2005). These mind-extending, mind-reorganizing tools enable learners to think about things in ways that they otherwise might not be able to. In using them, "the learner can enter an intellectual partnership with the computer in order to access and interpret information, and organize personal knowledge" (Ip & Morrison, 2001, p. 294), engaging in the process in a variety of forms of higher order thinking.

Concept mapping tools, sometimes also referred to as semantic networking tools, constitute in the opinion of Jonassen et al. (1999) one of the easiest to learn and most popular Mindtools.[18] Concept maps are tools for "intentionally organizing what the learner knows … [concept mapping] specifically engages learners in relating new ideas to what they already know, which is the basis for meaning making" (ibid, p. 163). By externalizing both what is known and what is being learned, concept maps enable teachers and learners to exchange views and negotiate meanings. If done thoughtfully, the discussion and the ensuing reworking of the concept maps can lead to a modification and expansion of a learner's cognitive structure.

Unfortunately, creating pencil-and-paper concept maps is cumbersome, and does not lend itself to the restructuring that such an exchange and negotiation process would call for. If concept maps are to be effective as tools for negotiating meaning, they should be easy to modify (Anderson-Inman & Ditson, 1999). Concept mapping software invites the reworking of concept maps by facilitating and speeding up the manipulation and revision of content and structure – addition, deletion or rewriting of concepts and propositions; reorganization of concept map elements; personalization of styles; and inclusion of digital resources – thereby increasing teachers' and students' motivation to use concept mapping as a learning tool (ibid).

Some research has explored the added benefits of computer-based concept mapping. Lin et al. (2004), for example, have looked at computer-based concept mapping as a prewriting strategy. Their findings indicate that students in the computer-based concept mapping condition generated more ideas than those in the paper-and-pencil concept mapping condition. Furthermore, computer-based concept mapping enhanced students' prewriting argument structure, compared to paper-and-pencil concept mapping, as measured by the quality of the students' thesis statements. The electronic approach also improved the quantity and quality of the relationships between reasons and examples and the quality of the planned attention getters. Interestingly, though, the paper-and-pencil group scored higher in the state-authorized writing scoring rubric (ibid).

Computer-based concept mapping environments make possible multiple forms of dialogue among learners, and of joint construction of concept maps, that transcend the traditional barriers of space and time. It is thought that learning through manipulation of Mindtools is better supported when the learner makes his or her thinking explicit via a language dialogue with another learner (Slangen & Sloep, 2005). The evidence so far remains inconclusive, though, and despite a substantial body of literature examining the question of whether computers facilitate or hinder collaboration, a definitive consensus has not yet been reached (Coffey et al., 2003). With regard specifically to concept mapping, some (e.g., Chung,

[18] Other examples of Mindtools include: spreadsheets, databases, microworlds, expert systems, and computer-supported collaborative argumentation tools.

O'Neil, & Herl, 1999) have found them not to be effective for collaboration, while others (e.g., Fischer, Bruhn, Gräsel, & Mandl, 2002) have found the opposite. This is perhaps not surprising given the multiplicity of factors involved and the variety of collaboration scenarios that are possible. Stoyanova & Kommers (2002), for instance, investigated the dependence of the effectiveness of computer-supported concept mapping in collaborative learning on the group mode of interaction; while Khamesan & Hammond (2004) looked at the effect on collaborative concept mapping of different communication channels. Other innovative technology-based collaboration modes, such as "Knowledge Soups" (see Cañas et al., 2001) have been designed. Much more research will be necessary to determine the best computer-based collaborative concept mapping strategies.

In spite of the many potential benefits for teaching and learning of concept mapping, particularly computer-mediated concept mapping, certain factors interfere with their extended use, and dampen the willingness and enthusiasm for the tool, particularly for teachers, but also for students. On the student side, there is the difficulty in building concept maps, especially when first acquiring the skill (Novak & Cañas, 2008). Novak & Cañas (2008, Psychological foundations of concept maps section, ¶ 14) contend that this appears to be the "result primarily [of] years of rote-mode learning practice in school settings." They acknowledge that it is not easy to help students accustomed almost exclusively to a rote learning mode to commit and move towards a more meaningful mode of learning. In their view, concept maps can help, but it would be wise to accompany their use by teaching students something about brain mechanisms and knowledge organization so that they may become aware of and come to appreciate the reasons for and value of their efforts (ibid). A second factor for student resistance is the feeling that concept maps add little to their understanding (Pankratius, 1990). Pankratius (1990) speculated that this attitude might also have its roots in memoristic learning habits, and wondered about the relationship between concept mapping and student learning styles. At a more practical level, students generally receive little or no feedback about their maps (Conlon, 2004); this most likely undermines their motivation to rework their maps. Conversely, learners who receive timely, quality feedback may be more inclined to conscientiously revise their concept maps (Conlon, 2004).

From the educators' perspective, a major concern is the classroom time taken up by activities related to concept mapping. Many authors have drawn attention to the importance of redrawing maps (e.g., Novak & Gowin, 1984, p. 35; Novak & Cañas, 2008; Jonassen et al., 1993, p. 162), since *good* maps, that is, maps that include sufficient relevant concepts, show depth of understanding and breadth of knowledge, establish and accurately express important and pertinent vertical and horizontal relationships, commonly only result after 3 or more revisions (Novak & Cañas, 2008). Thus, the time involved in working with concept maps, even when aided by computer-based mapping tools, is a concern for teachers, especially if the maps are to be used to monitor changes in students' concept formation (Anderson-Inman & Ditson, 1999). A related issue is the time required to provide learners with adequate feedback on the quality of their maps (Conlon & Bird, in Conlon, 2004). Programs like Conlon's Reasonable Fallible Analyzer (mentioned earlier), would seem to be a valuable step towards solving this important logistical problem.

Teacher resistance, however, often goes beyond specific concept mapping issues to more general ones such as attitudes towards technology and level of computer training. With regard to training, Willis & Mehlinger (as cited in Schrum, 1999) contend that teachers, but especially pre-service teachers, are not being trained to serve in technology-enriched classrooms. Inadequate teacher training in ICT-related pedagogy leads to a disinclination on the part of educators to work with technology. The reasons range from being fearful of technology, in the worst case, to being enthusiastic about technology and sometimes even using it in their own everyday lives, but not knowing how to integrate it into their classes (Schrum, 1999), in the best scenario. The latter situation occurs even in developed countries like the Netherlands where schools are well equipped with hardware and software, and teachers are quite comfortable and competent with ICT use (Slangen & Sloep, 2005).

Given the key role of teachers in transforming teaching and learning, teacher technology training programs have been the object of close examination. An analysis by Joyce and Showers (in Schrum, 1999) has revealed that the most effective teacher development models, that is, the ones that result in the highest level of technology implementation in teaching (up to 90% success), are those which include: 1) theoretical rationale; 2) demonstrations by experts or relative experts in the model; 3) practice and feedback in a caring, nurturing environment; 4) peer-coaching; and 5) ongoing follow-up. To these elements, Schrum (1999) adds a sixth: teachers should have the opportunity to try the technology in their work environments accompanied by a mentor. Even so, adoption of technology takes time. In one example, the Apple Classroom of Tomorrow Project described by Schrum (1999), it took 3 years before teachers were able and willing to apply technology to innovative activities such as collaborative learning and integrated (interdisciplinary) projects.

2.3 Acquisition of cognitive skills

Extensive research has been conducted on the topic of cognitive skills acquisition.[19] The following brief summary of the literature on the subject is based on VanLehn's (1996) review. Researchers have identified three phases for cognitive skill acquisition: early, intermediate and late phase.[20] The early phase is the period when the learner attempts to gain a general understanding of the domain knowledge, but does not try to apply this knowledge; emphasis is on studying the material. Very little is known about this phase, since most investigations have concentrated on the intermediate and final phases. In contrast to the early phase, the intermediate phase is characterized by learners trying to use their newly acquired knowledge to solve a specific problem. During this phase, the learner may seek the teacher or facilitator's help, as domain knowledge is still incomplete and/or includes misconceptions. Learners enter the final phase when they succeed in removing all knowledge flaws (missing knowledge and misconceptions). This stage is marked by an increase of performance speed and accuracy, though domain knowledge remains unchanged.

The literature further distinguishes between cognitive skills that necessitate learning a *single* principle versus skills that require learning *multiple* principles. The distinction lies in the quantity and complexity of the material to be learned. Single principles correspond roughly to the amount of information discussed in a few textbook pages, and often summarized in a colored box; multiple principles would require more like an entire chapter's worth of content.

It is important to keep in mind that the 3-phase learning sequence is a model, and hence, an idealization. In practice, there may be overlap between phases, and boundaries may not be well defined. This is particularly true of skills based on multiple principles: one may be at a

[19] VanLehn defines *cognitive skill* as "the ability to solve problems in intellectual tasks, where success is determined more by the subjects' knowledge than by their physical prowess" (1996, p. 514).
[20] These are the same 3 stages distinguished for motor skills acquisition.

late phase with respect to some skill component and at an early or intermediate phase with respect to a different component.

The time required for a learner to acquire a cognitive skill depends on the amount and difficulty of the prerequisite domain knowledge that must be learned. However, a rudimentary version of a single principle skill can generally be taught in an hour or less, whereas it may require days or months to teach even an elementary version of a multiple-principle cognitive skill (VanLehn, 1996).

2.4 Educational technology research

We end our literature review with some remarks about educational technology research, specifically, computer-related research. Computers have been a part of the educational scenario for over 25 years. In the interim, a large fraction of the computers-in-education research has focused, as it did earlier with television and other media, on finding out whether this new media influences learning. The results of this type of inquiry, as we mentioned earlier, have been essentially the same for all media: "no significant difference." These disappointing results are compounded by the fact, evident even to the lay person, that computers have *not* yet revolutionized education, whereas they *have* transformed medicine, design, communications, commerce, travel, and a number of other fields. Why?

A simple and lucid explanation was given by Solomon (2000). Solomon contends that research regarding computers in education has been misguided. One way in which it has been misled has been by posing over and over again the "medium comparison" question; the consistent lesson that technology by itself, "with no regard for human or situational factors," does not make a difference "seems to be continuously ignored" (ibid, Disappointments and their reasons (III) section, ¶ 3). A second way in which educational research has proved unwise, concerns the types of outcomes that are observed and/or measured. Even studies that investigate technology-supported innovative learning environments and strategies consistent with constructivist premises generally end up measuring traditional achievement indicators. In his view, this is misguided because different means tend to serve different rather than the same ends. Moreover, "the search for the same old kinds of achievements fails to show in what ways technology can and does make a genuine difference" (ibid, Disappointments and their reasons (III) section, ¶ 6).

A related fact is that much of educational research, computer-based or not, depends almost exclusively on products. Little research examines, in addition to outcome data and completed products, the *processes* involved in producing them. And yet, part of the marvel of computer-supported educational technologies rests in the possibility they afford of recording learners' interactions with the learning environments, and hence, in making available a greater diversity of data. Researchers can thus retrace the cognitive paths followed by learners during the learning process and learn from them "in a dynamic, interactive way never possible through more static instructional media" (Bruner, as cited by Pea, 1985, p. 173). "Particularly useful is the computer's ability to collect moment-by-moment, time stamped log files of key presses, typed responses, menu selections, etc. These data ... can be used to examine the effects of media on learners' mental representations and cognitive processes" (Kozma, 2001b, p. 171). And not only researchers benefit; students also stand to gain by being able to "analyze and learn from an explicit written history of their problem-solving moves in searching for [a solution]" (Pea, 1985, p. 173) or in completing a task.

Misguided research, however, is just one factor that contributes to explaining the disappointing results returned so far on society's computers-in-education investment. The major factor, of which misdirected research is also a manifestation, is our technocentric focus, prevalent even among those who do want a profound change in the educational system (Solomon, 2000). Those who pay tribute to technocentrism believe that computers, all by themselves, will cause the desired change. This near worship of technology leads them to embrace the notion that "technology … needs to be mastered as an end in and of itself not as a means for the acquisition of something such as knowledge or social skill" (ibid, Disappointments and their reasons (II) section, ¶ 4). In this argument, the pedagogical rationale for developing computer skills is nowhere in sight.

Returning to the subject of research, the recommendations are clear: it behooves all researchers, first of all, to maintain a balance as we walk "the tight rope between technocentrism and pedagogy," to use Solomon's (2000) eloquent phrase (Technology – the promise section, ¶ 1). Only then can we avoid being misled in our efforts to identify and understand the reasons behind the most effective instructional strategies for specific educational goals.

3 Research questions and scope of research

In spite of a rather large and growing body of research on the use of concept maps in educational settings, we have found no formal studies that focus on the *training process*, that is, on the phase during which the learner is acquiring skill in concept mapping. This observation has subsequently been confirmed by both Cañas (personal communication, April, 2005) and Novak (personal communication, April, 2005). Anecdotal information, however, has been collected and in some cases has been published (e.g., Pines et al., 1978).

In this study we focus precisely on the training phase, the period during which individuals are learning to become proficient concept-mappers. Thus, what for others is nothing more than a preliminary stage, an interlude prior to the actual intervention, for us constitutes the main target of our investigation.

Training programs for studies involving concept maps tend to begin by giving subjects a brief introduction to concept mapping, some as short as 13 minutes (e.g., Chung et al., 1999), others as long as 6 weeks of instruction (e.g., Pankratius, 1990; Rice, Ryan, & Samson, 1998), but typically between 1-2 hours long. Following this introduction, generally based on written and/or expository material, subjects are asked to construct one or more practice concept maps. In some cases, researchers employ a verification technique at this stage to ascertain their subjects' understanding and grasp of concept mapping, an action that may lead to certain subjects being excluded from further analysis (e.g., Herl, Niemi, & Baker, 1996).

At this point the training stage is formally over; the subjects, assumed to be sufficiently adept in concept mapping, are given a certain concept mapping assignment, and collection of the experimental data begins. It is not clear, however, that at the end of this preparation period subjects are always able to accurately represent their knowledge and understanding of a topic in a concept map. It is known that learning to concept map effectively requires practice (Lin et al., 2004; Wandersee, 2000, p. 135-137). Pankratius (1990), for instance, considered the 8-week period of his study too short. Novak et al. (1983) concluded that after more than five months experience, more than half the students participating in their study did not master the strategy. Novak (in Pankratius, 1990) recommended as long as six months to master the skill. In fact, "the degree of facility with the concept mapping procedure necessary to optimize the benefits of constructing concept maps from scratch is an issue open for investigation" (Coffey et al., 2003, p. 108).

Evidently, greater attention needs to be paid to the training phase. Wandersee (2000) does not mince any words when he states that "perhaps the biggest flaw in concept mapping research is the failure to dedicate sufficient time to assure that the students actually become proficient in concept mapping prior to collecting research data" (p. 138).

Concept mapping (in our case, computer-mediated concept mapping) is a complex cognitive undertaking, involving an array of cognitive skills. The research considered in VanLehn's (1996) review discussed above is different from our situation in at least one important respect: in our case, the intellectual problem to be solved corresponds to answering a question – the focus question – derived from some situation or event the learner is trying to understand. Unlike the problems considered in VanLehn's review, concept mapping "problems" have neither unique nor closed "solutions." Concept maps are personal and idiosyncratic constructs; hence, there are as many maps as there are individuals building them. Moreover, concept maps are never finished; they can always be improved and augmented, as learners' understanding of a topic becomes increasingly differentiated and integrated.

Nonetheless, certain elements in this cognitive skill acquisition framework could be useful as a reference in attempting to understand how learners develop and perfect their concept mapping skills. For instance, concept mapping involves learning and simultaneously applying multiple "principles."[21] Some of these principles pertain to the domain of concepts maps themselves, others to the topic being represented in the map, and still others to the realm of technology.

One notices also that training programs for most concept mapping studies generally only go as far as the second or intermediate phase of VanLehn's cognitive skill acquisition framework. At this point, it is not clear that learners have mastered the skill sufficiently to accurately reveal their knowledge structure in any given area. Moreover, if concept mapping is to serve as a tool for meaningful learning, the learner must learn to activate creative, logical, critical and reflective (metacognitive) thinking modes during the process of constructing/revising a concept map. However, at least with regard to metacognition, Patry & Bourgeoys (2004) found that short-term training in concept mapping had no measurable effect on the development of this ability.

To recapitulate, given what little is known about how learners acquire skill in concept mapping, in this dissertation we set out to investigate, in an exploratory manner, the following general research question:

> *What overall patterns of skill acquisition in computer-mediated concept-mapping are observed in Panamanian schoolteachers participating in the Conéctate Project?*

We were interested in examining the following specific questions:

1. *What actions, and changes in actions, are observed in teachers' interaction with the concept mapping program during the Cmap[22] construction process?*

2. *What changes are observed in the structure and content of completed Cmaps?*

3. *To what extent are observed actions and results a function of previous experience with computers, prior experience with concept maps, and preferred learning style?*

Dutra et al. (2004) have indicated that, in spite of the voluminous amount of research on concept maps, there is a need for studies that consider the mechanisms involved during the construction process. The fact that we had available a tool like the CmapTools Recorder, enabled us to register and analyze many details of the human-machine interaction, and

[21] Here we are using the term "principle" in a looser way than originally used by VanLehn (1996) to refer to any conceptual or procedural knowledge used in meaningful concept mapping.
[22] In what follows, the term "Cmap" will be used to refer specifically to a concept map generated using CmapTools.

afforded us the possibility to begin to understand the mechanisms of skill acquisition in concept mapping.

The subjects of our research were in-service Panamanian public elementary schoolteachers attending the Conéctate Project's workshops. Throughout the workshop teachers experienced a caring, learner-centered environment, in which the use of computer technologies and collaborative work played a key role.

By and large, schoolteachers in Panama are familiar with concept maps; however, the results of preliminary surveys we conducted revealed that most of them have many misconceptions regarding their correct structure and usage (see chapter 5). Thus, in order for teachers to be able to use concept maps as a tool for meaningful learning, they must discard previous erroneous concepts and replace them by correct ones. This necessary conceptual change was further complicated by a rote learning style, which as was noted earlier appears to be quite prevalent among Panamanian schoolteachers.

This is, in short, the scenario in which our research on concept maps took place. Several factors, however, have limited the scope of our work. First, subjects represent a fairly restricted universe: Panamanian teachers from public elementary schools. This population may well have a great deal in common with elementary schoolteachers in other countries, particularly, underdeveloped countries with similar educational systems; in general, though, care must be taken in extrapolating results to other populations. Second, our setup was quasi-experimental. We had no control over the way schools were chosen to be included in the Project, or over the way participating teachers were grouped. Furthermore, different training groups were exposed to different facilitators, and once again we had no control over the assignment process. Third, the two concept mapping tasks we analyzed, namely the initial and final Cmaps constructed during the workshop, were "one-shot deals." It would have been preferable to follow the evolution of teachers' concept maps over the course of two or more sessions, rather than a single map-construction session, but this would have required facilitators not to offer teachers any feedback, which evidently was not an option given the purpose of the workshops.

In spite of these qualifications, it is our hope that this work will allow us to begin to understand how our teachers acquire skill in concept mapping, along with the factors that seem to bear most on this process, and that this will enable us to further assist them in their efforts to acquire, and help their students acquire, skills for meaningful learning.

4 Methods and procedures

4.1 The Conéctate workshop

The goal of the Conéctate Project is to bring about profound changes in the way children in Panamanian public schools learn. Perhaps the single most important change would be to discard the time-old, obsolete model of learning by rote in favor of a meaningful learning approach. However, any such change necessarily begins with the teachers. The workshop therefore has a dual mission: it must simultaneously motivate teachers to become actively engaged in bringing about this revolution, whilst providing them with methodologies and tools, pedagogical and technological, that can help them accomplish this enormous task.

Concept maps constitute the main pedagogical tool used throughout the Conéctate workshop. Except for one or two, all concept maps in the workshop are constructed using CmapTools. Internet and collaborative work play key supporting roles in helping teachers clarify and expand their knowledge about the questions considered in their maps. Throughout the entire training process teachers experience, some perhaps for the first time in their lives, a supportive, learner-centered education model, one which it is hoped they will want to take back home with them and recreate in their respective schools.

4.1.1 Workshop program

Conéctate workshops are 2 weeks long. The schedule is Monday through Friday, from 8:00 a.m. to 4:00 p.m. A snack, beverages and a hot lunch are offered daily to everyone. Teachers from schools in the greater Metropolitan Area, travel every day to the Project's facilities, located in the *Ciudad del Saber*,[23] on the former U.S. Army Base of Fort Clayton. Teachers coming from schools elsewhere in the country are provided with room and board for the duration of the workshop. The overall workshop program (content and order) was worked out by facilitators. In what follows we describe the most salient and relevant points of the program.

With the exception of a brief period during which teachers are introduced to e-mail and given their own Conéctate accounts, the first week is entirely devoted to concept mapping. On the first day of the workshop facilitators give a brief presentation of concept maps, along with the theoretical framework supporting their use as a tool to promote meaningful learning. Teachers then create their first map using paper and pencil. Presentation of CmapTools takes place on the second day, when teachers are less apprehensive about the workshop and anxiety levels are somewhat lower. After a short introduction to CmapTools, during which the basic actions needed to create a concept map are explained and demonstrated (e.g., how to create a concept box, how to write in a box, how to join concept boxes), teachers proceed to construct their first computer-mediated concept map.

[23]The translation is "City of Knowledge."

For the study at hand, the first map teachers constructed with CmapTools served as a baseline against which we measured the skill they acquired in the course of the workshop. For this reason facilitators were asked to abstain from giving any feedback or help concerning map structure or map content while teachers were engaged in the construction process. Comments and suggestions for map improvement were given only *after* the completed maps had been saved. However, facilitators did answer questions and solved problems regarding the use of the computer itself and/or the software program.

As pointed out earlier, CmapTools supports many forms of distance collaboration, which teachers learn about during the rest of the first week. The simplest form of collaboration is through *annotations*, an option which allows a person to add comments or suggestions to someone else's Cmap. Annotations are generally used in an asynchronous collaboration mode. They appear in a Cmap as yellow icons, rather suggestive of post-it notes. Like post-it notes, once created annotations may be repositioned to any point on the map; unlike post-its they can be attached to one or more concepts, linking phrases, or propositions. *Discussion threads* constitute another asynchronous collaboration mode, more akin to e-mail. They are intended for interchanging extended remarks over periods of time, in contrast with annotations which are more appropriate for one-time comments.

A simultaneous form of collaboration can be achieved via the *synchronous collaboration* option, where two or more learners actually work together in real time to construct or modify the same Cmap. Communication between those collaborating takes place via a chat window. *Knowledge Soups* (Cañas et al., 1995; Cañas et al., 2001) are a more sophisticated form of collaboration, in which those collaborating do not see other participants' complete Cmaps, but only those propositions that have been "published" in the soup pot, and that contain elements in common with the propositions (called *claims* in the Soup context) they themselves have published. We will not discuss this modality any further, though, since it was not included in the training programs of the groups from which we obtained our data.

The total number of concept maps teachers construct during their training varies from group to group, and from workshop to workshop, but generally lies in a range from 4 to 6 maps. This range may seem somewhat low, but it is important to keep in mind that concept maps are often reworked as feedback is given, and as new features of the software are introduced. This serves to reinforce a fundamental idea that the training program tries to convey, namely, that a concept map may be continually improved and expanded as our knowledge and understanding of the subject matter increases.

During the second week of the workshop the focus changes from concept maps to *collaborative projects*. The idea is to take advantage of the large (and growing) network of connected schools resulting from the CmapServers (Cañas, Hill, Granados, Pérez, & Pérez, 2003) set up by Conéctate[24] to carry out joint projects that otherwise would be difficult or impossible to do. Generally the last day of the workshop is used to cover any topics that were missed, and to wrapping up. For this study, however, all teachers were asked to create a final map using CmapTools. Once again, facilitators were required to refrain from giving any help during the construction process. This final Cmap was used to determine the level of competency at the end of the workshop, and was compared against the baseline Cmap to measure progress throughout the workshop.

[24] Each school incorporated into Conéctate is provided with its own CmapServer.

4.1.2 Cognitive load of concept mapping tasks

Teachers attending the Conéctate workshop develop skills in concept mapping through a variety of activities and in a variety of settings. In all cases, though, maps are constructed from scratch, shared and discussed publicly, and often reworked. It has been proposed (Ruiz-Primo, 2004) that a *concept map assessment task* should be rated along a "directedness continuum," based on how much information is provided to the learner for the task. High-directed mapping tasks provide the learner with elements such as concepts, linking phrases, map structure, or various combinations of these elements. At the opposite end of the continuum, a low-directed mapping task gives little or no information and places practically no constraints on the learner. The least directed task of all is one where the map is made completely from scratch; the learner is therefore totally free to construct the entire map as desired. As noted in chapter 2, low-directed assignments impose a higher cognitive load upon the learner but are thought to elicit higher levels of thinking, and to provide greater opportunity for learners to demonstrate conceptual understanding and misconceptions (Ruiz-Primo, Shavelson, et al., 2001). In view of this, it is clear that the concept mapping activities in which teachers at Conéctate engage are high cognitive load activities.

4.2 The Sample

The data for this study was collected over a period of three months beginning in July and ending in September, 2006. This period covered 3 consecutive workshops, numbers 8, 9 and 10. The reasons for choosing these particular workshops were partly technical, and partly related to local events that affect the academic calendar. On the technical side, our main data collection instrument, the CmapTools Recorder,[25] was still being debugged. We could not begin to gather data until all problems with the Recorder were resolved; sampling began in July, as soon as we ascertained it was functioning properly. On the other hand, sampling could not extend beyond October because workshops would run into Panamanian Independence celebrations[26] and the end of the school year, both of which cause irregularities in the workshop schedules. The three workshops included in the sample were the ones that satisfied both these constraints.

Each of the 3 workshops considered in this study involved the participation of approximately 160 teachers, divided into 8 training groups of roughly 20 teachers each. Our study included all eight training groups from workshops 8 and 9, and two from workshop 10, namely, those guided by facilitators who had not participated teaching workshops 8 or 9. Thus, the total number of training groups considered in our study was 18.

Methodological considerations concerning the sample involved school and teacher selection method, on the one hand, and assignment of teachers to training groups, on the other. We next examine each of these in turn.

[25] Its features are discussed in section 4.3.3.
[26] November is *Independence Month* in Panama.

4.2.1 School and teacher selection

A major consideration in the selection of schools to be incorporated into the Conéctate Project during the first three years has been the feasibility of delivering a fully functional innovation classroom. This includes the physical room, the equipment, and access to broadband Internet.[27] Evidently, cost was also a major consideration. The annual budget was distributed among schools that required small, moderate and large investments. In a given year, more small-investment schools were incorporated than large-investment schools. Given two schools with equal or comparable conditions, the decision of which school would participate and in what order was a Project decision. Nevertheless, as a matter of policy, schools were generally chosen so that workshops would bring together teachers from different types of schools (urban, urban-marginal, and rural) and from different areas of the country. Hence, we were confident that, in spite of not having direct control over the school selection, our sample would include teachers from a variety of settings, as indeed turned out to be the case.

Regarding the selection of teachers from enlisted schools, once again this was determined by the Project. As a general rule, all 4th, 5th, and 6th grade teachers were invited, and most of those invited attended. Occasionally, though, teachers declined and the invitation would be extended to teachers of lower grades. In any case, the participation of teachers of different grade levels conferred a further element of diversity to our sample.

4.2.2 Assignment of teachers to training groups

As with school and teacher selection, the Project was responsible for the distribution of teachers to specific training groups, and therefore was beyond our control. Aside from a general policy of guaranteeing that teachers from the same school were spread throughout all 8 training groups, assignment of teachers to training groups was arbitrary. The net effect of all these decisions was that training groups ended up with a considerable amount of internal diversity and external consistency; that is, there was significant heterogeneity within groups but much homogeneity amongst groups (see chapter 7).

4.3 The data

As in most studies involving concept maps, data about *products* was obtained from teachers' completed initial and final Cmaps. However, two other types of information were also collected for this study: *information about the teachers*, gathered via a teacher questionnaire, and *information about the construction process* of the initial and final Cmaps, obtained via the CmapTools Recorder. The data collection protocols we employed, as well as the teacher questionnaire and the CmapTools Recorder are discussed below.

4.3.1 Data collection protocol

The week before we began collecting data, facilitators were convened at a general meeting in order to go over data collection procedures. During this meeting, a written document containing the data collection protocol was handed out and discussed point by point.

[27] In some remote rural areas of Panama there is no electricity or the electrical infrastructure is insufficient to support the computers. This has been an obstacle to including certain schools in the Project.

To begin with, facilitators were instructed to apply the teacher questionnaire on day 1 of the workshop, as soon as teachers were gathered in their respective classrooms, or shortly thereafter, before commencing workshop activities. Teachers were to be given 30 minutes to complete the survey.

As previously indicated, the first and final Cmaps were to be used to determine skill acquisition in concept mapping throughout the workshop. In particular, the first map was to serve as a baseline against which to measure skills acquired during the workshop, as demonstrated by changes in the last Cmap relative to the first one.

Facilitators were instructed to give teachers 20-30 minutes to explore the CmapTools program prior to building their first computer-mediated concept map on day 2 of the workshop. During this time, they were to be guided in a relatively free and relaxed manner through the mechanics of creating concept boxes, joining one concept box to another one, and writing inside concept and linking phrase boxes. Since we would be analyzing every action performed during map construction, the idea of this practice was to give those teachers who had little or no computer experience a chance to get some exposure to the program before beginning map construction, in the hopes of reducing somewhat the effect due to lack of computer expertise.

Construction of the first concept map with CmapTools was to begin immediately after this practice. It was to be an individually constructed map. The map's topic could be freely chosen by the teachers or based on an assigned reading provided by the facilitators.[28] Facilitators were requested to refrain from any form of intervention that might affect Cmap content or structure. They were instructed to limit their participation, during the construction of this first map, to giving technical support regarding the use of the computer or CmapTools. Though it might have been preferable not to offer any help whatsoever, this was not an option, as it would have resulted in a great deal of frustration on the part of the teachers, many of whom, owing to their lack of experience with the machine, were quite anxious during the first days of the workshop. Failure to offer any support might have turned them off entirely from the Project, a risk we could not take.

Instructions for the final Cmap were similar to those for the first, as far as facilitator intervention was concerned: facilitators should avoid giving any kind of non-technical feedback. The final concept map was to be an individual map and its topic chosen freely by each teacher. Teachers were free to use Internet to search for information and/or add resources, but this had to be their own decision; facilitators were not to suggest the use of Internet or the inclusion of resources.

No effort was made to try to rigorously control the time spent building the maps. At Conéctate, facilitators ordinarily allot anywhere between 1 to 2 hours of actual construction time before proceeding to discuss the concept maps. Prior to the discussion facilitators saved the original, unmodified maps for analysis. Copies of the Cmaps were used for the discussion.

All other maps created during the workshops were entirely open to facilitator input; that is, facilitators could provide as much advice as they deemed appropriate during and after map construction, and respond to all questions and requests for help posed by the teachers. They

[28] In practice, all groups had to construct a concept map based on this same reading; however, some facilitators had this be the first map constructed on CmapTools, while others had it be the second Cmap.

could, for instance, comment and make suggestions on proposition structure and content, point out misconceptions, and propose ideas or resources to improve the maps.

4.3.2 Teacher questionnaire

The teacher questionnaire[29] (appendix A) used to collect information on the participating teachers was comprised of two parts. Part I consisted of a series of questions that inquired about basic personal and demographic information, along with questions requesting information about previous knowledge and practices vis-à-vis concept maps and their use. The format for this part was a mixture of short-answer and multiple-choice. Part II of the survey consisted of 10 questions with a 5-point Likert response format, which attempted to elicit information about preferred learning style. In general the questionnaire was very similar to the survey developed and applied during the study of teachers' preconceptions on concept maps (chapter 5).

4.3.3 CmapTools Recorder

The CmapTools Recorder is a new feature, recently incorporated into the program. It generates a record of every action taken by the user in the process of constructing his or her Cmap (Daley, Cañas, & Stark-Schweitzer, 2007). The entire recording can then be played back continuously, at various speeds, or in a step-by-step manner, forward or backward, starting at any desired step. This gives a visual reconstruction of the map creation process. Simultaneously, the Recorder generates a text log file which can then be exported, saved, and later imported into a spread sheet or statistical analysis package for data processing (figure 3).

[29] In two training groups the survey was not given on the first day of the workshop. For these groups, questions involving prior knowledge about concept maps and their use were eliminated to avoid bias resulting from teachers being exposed to workshop content.

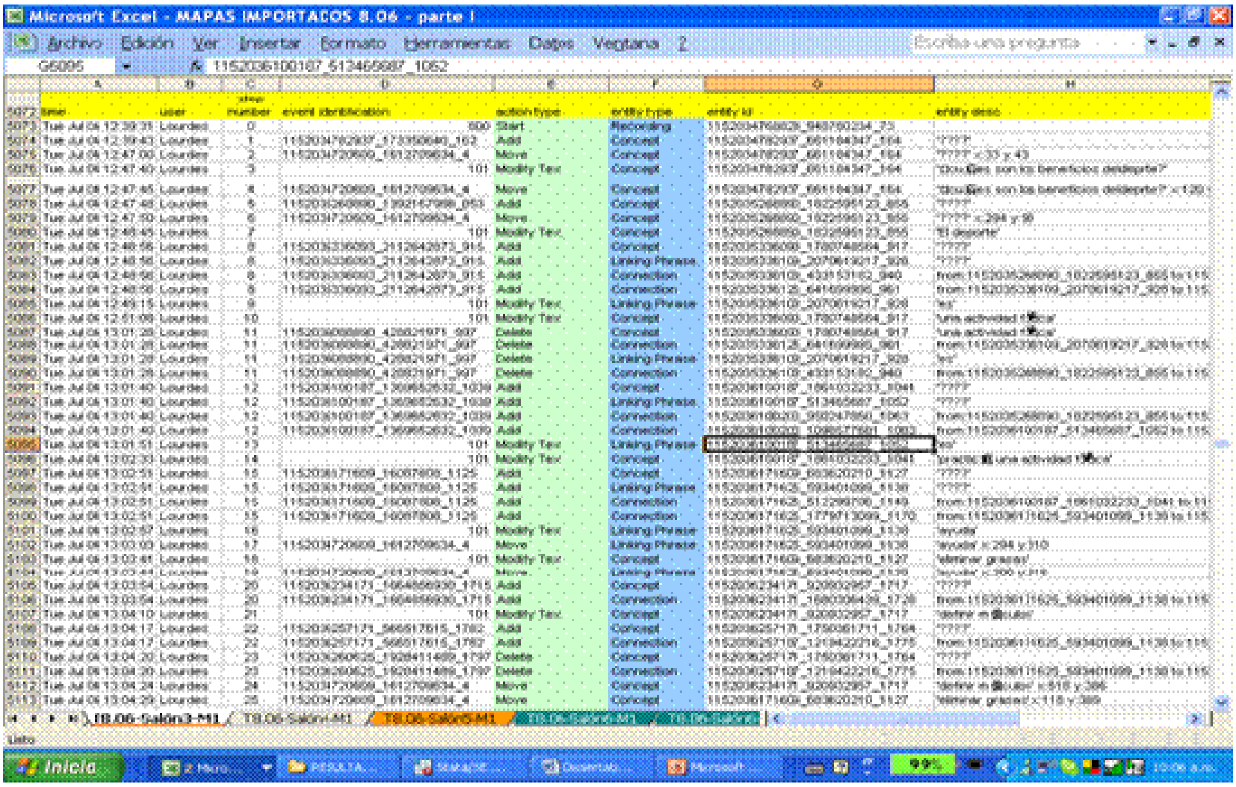


Figure 3. Extract of a text log file generated by the CmapTools Recorder, and imported into Excel for analysis.

CmapTools can be configured so that the recorder goes on automatically as soon as the program is opened, or it can be left to the user to turn it on at any point during Cmap construction. In Conéctate, a high-level decision was made to configure all computers in such a way that the Recorder starts automatically when CmapTools is launched. Regardless of the initial configuration, though, the program allows users to turn off the Recorder at any moment during map construction. Indeed, a number of Cmaps were lost as a result of teachers, purposely or inadvertently, turning the Recorder off. All the data gathered during the course of our studies were processed using a combination of Excel and the statistical analysis software package STATA. In the preliminary studies, as well as in the main study, results were considered "significant" at the 0.05 level.

4.3.4 Factors inherent to the study influencing sample data

In our quasi-experimental setting, different training groups were not subjected to identical treatments, mainly because each group had a different pair of facilitators. Consequently, throughout the workshop teachers from different training groups were exposed to different instruction methods and styles, received varying amounts of feedback, and dedicated different amounts of time to constructing, critiquing and revising their concept maps.[30] Even content may have varied slightly from group to group.

[30] Evidently, some of these differences were true for teachers *within* any given training group as well.

4.4 Elements for determining concept mapping skill acquisition

Acquisition of skill in concept mapping was measured along three dimensions: 1) use of CmapTools, 2) structural complexity of completed Cmaps, and 3) semantic complexity of completed Cmaps. In what follows we consider each of these dimensions separately.

4.4.1 Use of CmapTools

At the most basic level, the ability to produce good computer-mediated concept maps is a function of the level of mastery of the computers in general, and the specific concept mapping program being used, in particular. Lack of proficiency with the concept mapping tool, in this case CmapTools, can have an impact on the resulting concept maps in at least two different ways: 1) teachers may never consider doing something if they do not know it can be done; and 2) teachers may not do what they actually want to do, but what they feel most secure in doing. Nonetheless, we believe that the use novice mappers made of the concept mapping tool during map construction can help understand, to a certain extent, learners' cognitive *processes*, just as finished concept maps help understand learners' cognitive *structures*.

As discussed in chapter 2, computer-based learning environments give us the opportunity to examine, in addition to "finished" products, the individual steps taken to produce them. In the case at hand, the CmapTools Recorder proved an invaluable instrument, allowing us to examine actions carried out by teachers in the course of constructing their Cmaps. From a practical viewpoint, this step-wise breakdown gave us a simple way to operationalize the "use of CmapTools" variable. At a deeper lever, it allowed us to describe teachers' action patterns whilst interacting with the machine, and to identify changes in these patterns in the course of the workshop. Our hope is that detailed information like this will help us gain some insight into what actually goes on in the minds of mappers developing skill in computer-mediated concept mapping, and suggest actions that could be taken to optimize the acquisition of this skill.

The exported text log file generated by the Recorder included nine different data categories: time, user, step number, event identifier, action type, entity type, entity identifier, and entity descriptor. Two of these were particularly relevant in trying to understand the events that took place during Cmap construction: action type and entity type. Action type refers to the actual operation carried out: adding, deleting, moving, modifying text, etc. Entity type refers to the object upon which that operation was performed: concept, linking phrase, connecting line, and Cmap, principally. Since we were interested in being able to trace simultaneously both the action *and* the entity, we concatenated the data in these two categories into a single new category. From now on, the phrase *action type* will refer exclusively to this combined category.

Within the action type category we focused on nine operations, though many others were possible: concept addition, concept text modification, concept deletion, linking phrase addition, linking phrase text modification, linking phrase deletion, object movement,[31] styles addition, and resource addition. We proceed to describe the result of each of these actions, as well as the mechanism for producing them.

[31] Objects generally being moved were concepts and linking phrases; other objects, like annotations, were included as well, but these would have been few and far apart.

- *Concept addition*: This action creates a box into which concepts can be entered. Concept boxes are created by double-clicking the left mouse button, or by selecting the option "new concept" available with the right mouse button when applied on the background canvas. A box with question marks in its center appears. The box is highlighted, indicating that the object is selected and waiting for the user to type in the concept. Upon introducing text (or anything else, for that matter) the question marks automatically disappear.

- *Concept text modification*: This action is used to change the content of a concept box. A concept may be modified by selecting the box and typing in the new concept in its entirety, or by introducing the cursor in the desired position, erasing the old text and typing in the new text.

- *Concept deletion*: This operation allows the user to delete unwanted concept boxes. The box is selected by a single click of the left mouse button and eliminated by pressing the "del" key. Alternatively, the user can select the box and then choose the "delete" option from the pop-up menu on the right mouse button. For either of these methods to work the cursor must not be inside the box.

- *Linking phrase addition*: Linking phrase boxes appear automatically whenever two existing concepts are joined. This feature is built-in to CmapTools in order to compel users to think about the relationships between linked concepts, thereby emphasizing the propositional nature of concept maps. As for the mechanics of joining two concepts together, one must begin by selecting the first concept in the proposition to be formed. A small rectangle with arrows appears above the highlighted concept. One then places the tip of the pointer inside this rectangle, and, with the left-button pressed, drags out the connecting arrow. One releases the button when the second concept in the proposition is reached and becomes highlighted. This procedure requires a certain amount of care, though. If the tip of the pointer is not completely inside the rectangle, one ends up moving the concept instead of pulling out the connecting arrow. Also, if one releases the mouse button before the second concept box becomes highlighted, a new concept box will be created. This is actually another way to create a proposition.

- *Linking phrase text modification*: This action is used to change the text in a linking phrase box. The mechanics are identical to those used for concept text modification. First the linking phrase box is selected. One can then type the entire (new) linking phrase, or introduce the cursor, position it appropriately, erase the unwanted text and type in the new text.

- *Linking phrase deletion*: As with concept boxes, to eliminate a linking phrase box one first selects the box, and either presses the "del" key or chooses the "delete" option from the right button pop-up menu. For either of these methods to work, however, the cursor must not be in the linking phrase box. Yet another possibility is to delete either of the concepts to which the linking phrase is connected. The link will be deleted as well.

- *Object movement*: Any object (or collection of objects) that has been selected can be moved rigidly, i.e., without changing its internal configuration, by simply pressing the left mouse button while the tip of the selecting arrow is in contact with any part of the highlighted object (or collection of objects), dragging it to the desired location, and releasing the button.

- *Styles addition*: This operation is used to change the default styles applied by CmapTools. Styles may be applied to text, lines, objects, or to the entire Cmap. Options include changing shape, color, and size, among other possibilities. Available options may be accessed through the styles window, opened via the format menu, or by choosing the desired option from the right button pop-up menu.

- *Resource link addition*: This action allows users to link all kinds of digital resources, such as documents, images, Web pages, videos and sound bytes, to their Cmaps. Resources may be located locally in the machine's hard drive or online. Though details may vary somewhat, the general maneuver to attach a resource is to left click on the resource, drag it to the object (concept or linking phrase) to which it is to be linked, and releasing it. A window will open up for the user to specify relevant resource information, including a label, a description, and key words.

The above typology of actions constitutes the set of mechanical operations performed with CmapTools that we examined. The reason for limiting our investigations to these 9 action types is that they constitute the basic operations needed to create a complete concept map. Other actions (e.g., adding nested nodes or adding annotations) may certainly contribute to improving a Cmap, and may provide interesting and useful information about the thinking that goes on during the construction process. For this first exploratory study, however, we chose to restrict our attention to the most indispensable and common actions.

4.4.2 Concept map topological structure

The ability to build structurally complex concept maps is the second element we considered in assessing teachers' acquisition of skill in concept mapping. Concept map structure is influenced by various factors. Lack of proficiency with the software, for instance, can have an impact on the resulting Cmap, particularly on its topology. Difficulty joining concept boxes to one another, or joining linking phrases to concept boxes, might cause the user to desist from creating an additional proposition or a cross-link, thereby affecting overall map structure.

Previous notions held by teachers regarding "proper" concept map structure also may influence Cmap topology. As our preliminary study on teacher preconceptions (chapter 5) shows, some teachers considered it unacceptable to link concepts from different sections of a concept map, which would seem to dismiss the possibility of cross-links altogether. All else being equal, concept maps with no cross-links are structurally less complex than maps with cross-links. This is just one illustration of how previous knowledge held by teachers regarding concept mapping may bias a concept map's configuration.

Structural complexity of concept maps was determined using the topological component of a taxonomy for concept maps developed by a group of us at the Conéctate Project. This taxonomy, described in detail in chapter 6, assigns concept maps a topological level ranging from 0 to 6 according to the degree of topological complexity present in the map.

4.4.3 Concept map semantic content

The third and final dimension of concept mapping we considered deals with semantic content, that is, with what maps actually say and how they say it. As with structure, content might also be dependent to some extent upon teachers' command of the software. Difficulties inserting the cursor in a concept box, for instance, may dissuade a teacher from revising a concept he or she has struggled to write in the first place. Previous notions may also affect semantic content. For example, the idea that linking phrases must be ***pre***positions is a common misconception in Panama (see chapter 5), which often results in triads that, taken alone, do not form meaningful ***pro***positions: they constitute fragments of meaning, as opposed to complete units of meaning.

The quantity and quality of a map's content was ascertained via the semantic component of the taxonomy for concept maps developed in the course of this research. The specifics of this semantic instrument are discussed in chapter 6. Besides assessing the substance of the completed concept map, the semantic evaluation included an exploration of the process by which the concepts and linking phrases in the finished map came to be there: sequences of modifications to individual concepts and linking phrases were traced in an attempt to shed light on aspects of teachers' thinking during Cmap construction.

5 Teacher preconceptions regarding concept maps [32]

In this chapter we present the first of the three preliminary studies mentioned earlier. This study set the context for our main investigation by giving us a profile of the teachers attending the Conéctate workshops.

5.1 Motivation for studying teacher preconceptions

Concept maps have been known and used in Panama for many years. Several generations of educators have learned about them either formally, during their career training, or informally, on their own, once in-service. Shortly after the workshops began in 2005, it became apparent to us at Conéctate that prior notions about concept maps held by many teachers included a number of misconceptions and distortions which, we believed, might be interfering with their ability to effectively adopt concept mapping as a tool for meaningful learning.

This situation led us to conduct a simple survey in order to determine exactly what preconceptions teachers beginning their training at the Conéctate Project had about concept maps and their use. The study showed that although most teachers were familiar with concept maps, and a high percentage claimed to have used them in their classrooms, most of them had serious conceptual errors regarding this tool. Results of this investigation highlighted possible reasons why in the past concept maps seem not to have had the expected impact in Panama's schools. Results also suggested adjustments to the workshops that, if implemented, might improve their outcome.

5.2 Materials and methods

The data for this preliminary study was obtained through a questionnaire given to 6 training groups,[33] over the course of six consecutive workshops, beginning with workshop 5 in July, 2005, and ending with workshop 10 in September, of the same year. The full sample consisted of 115 schoolteachers.

Schools participating in the program were selected by the Project; as a matter of policy, schools from all over the country were chosen. Generally every school participating in a given workshop had representatives in each of the classrooms. The sample ended up including schools from eight of Panama's nine provinces,[34] and from the Comarca Kuna Yala,[35] one of Panama's three major Indian reservations (figure 4). It also happened that the places of birth of sampled teachers covered most of the Republic. Hence, although the

[32] This study was described in Miller, Cañas, & Novak, 2006.
[33] The author was the facilitator for each of these.
[34] At the time this study was conducted, no schools from Darién, Panama's most remote province, had yet participated.
[35] The word Spanish *comarca* translates as "reservation."

sample was neither random nor representative in a strict statistical sense, it was sufficiently diverse so as to provide a fairly good idea of what goes on nationwide.

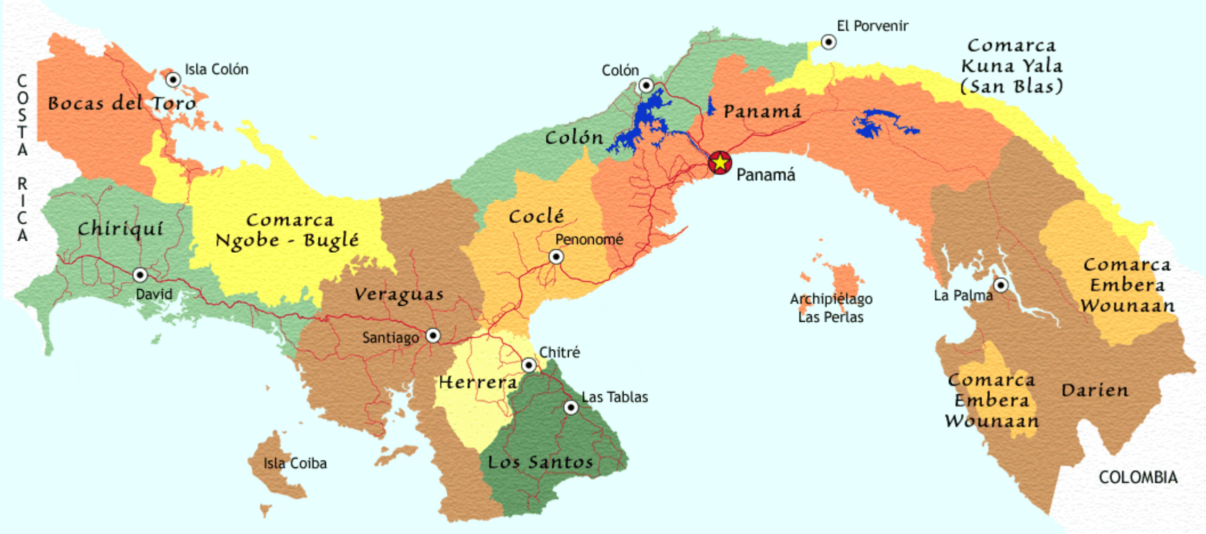


Figure 4. Map showing Panama's nine provinces and three major Indian reservations. (Source: http://www.worldheadquarters.com/Panama/map/province).

The instructions supplied to teachers along with the teacher questionnaire, included a brief explanation of the purpose of the study, and a confidentiality statement. Aside from the basic questions requesting demographic information, all other questions were multiple-choice; only one choice per question was allowed. It was emphasized that answers should reflect their personal experience as accurately as possible. Teachers were supervised at all times and, inasmuch as was possible, were kept from talking to each other. The questionnaire took about 20 minutes to complete, and was always given on the first day of workshop, as soon as the teachers had assembled in their assigned classrooms.

We should point out that the questionnaire given in each of the 6 workshops in this study were not entirely identical. Changes were made as the need to modify certain questions or add new ones became clear. Consequently, the sample size was somewhat different for different questions. In the next section, the value of *n* appearing next to each statistical result indicates the size of the sub-sample on which the calculation was based; if no number is given, the statistic was based on the full sample.

5.3 Results

Teachers in the sample were on average 40 years old, the range being 20 to 56 years. Approximately 70% of those surveyed completed their high school education at a Normal school[36] (as opposed to an ordinary high school), and 40% of these attended one particular Normal school, the *Escuela Normal Juan Demóstenes Arosemena*, in the province of Veraguas. As for higher education, 87% attended university. The detailed breakdown was as follows: 9% completed 1 to 2 years of university studies, 34% completed 3 to 5 years, 42%

[36] A high school level school designed to train teachers.

completed more than 5 years; only 15% said they had either not attended university or had not finished their first year. Regarding years of service, 15% of those surveyed had 1-5 years work experience, 23% had 6-10 years, 17% had 11-15 years, 15% had 16-20 years, and 30% had over 20 years work experience $(n = 94)$.

The sample included teachers with different levels of familiarity and comfort with technology. For instance, 46% $(n = 76)$ of the teachers worried they might damage a computer by touching it, 46% $(n = 74)$ indicated feeling self-conscious and uncomfortable about others knowing more about computers than them, and 26% $(n = 76)$ worried about appearing foolish while using a computer. Regarding frequency of use, 47% reported never having used a computer, 36% indicated using computers once in a while, 10% claimed to use computers often, and 8% to use them all the time $(n = 92)$. Finally, only 20% of teachers indicated possession of an e-mail account $(n = 35)$. There was a great deal of overlap between the group who had e-mail and those who used computers frequently or all the time.

Getting into the matter at hand, namely concept maps, our results revealed that practically all of those surveyed were familiar with concept maps, and a large percentage of them had used them in their classes (figure 5), though how frequently we do not know.[37]

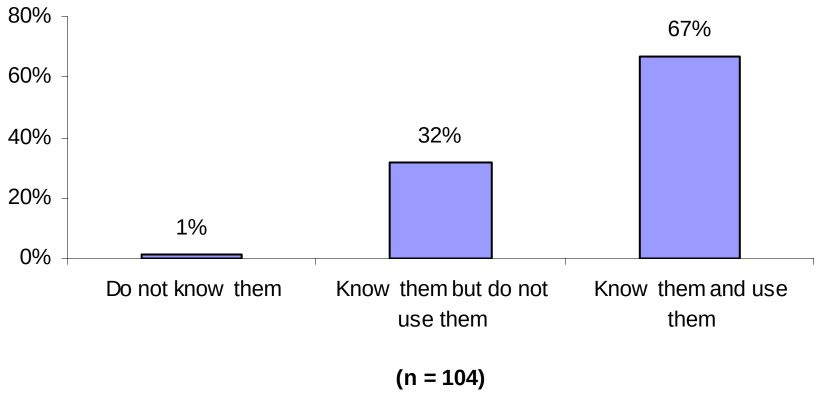


Figure 5. Use of concept maps by Panamanian teachers.

The teacher questionnaire also asked teachers to indicate the main source through which they had learned about concept maps. Figure 6 shows the results for this question. As can be seen, *universities*, particularly university professors, were the main conduit through which teachers in Panama come to know about this tool. *Seminars* were the second most common source. It is worth pointing out that although the questionnaire did not ask teachers to specify *who* was responsible for the particular seminar they attended, it is likely that it was either a university or the Ministry of Education, since in Panama it is generally these institutions who organize such events. *Colleagues* and *books* came in third and fourth, respectively. Regarding books, we must note that though this response option was first added to the questionnaire in workshop 7, it was not until workshop 9 that we realized teachers were not distinguishing between their students' *textbooks* and books about education (which is what we had in mind). Hence we were unable to obtain sufficient data to present reliable statistics on the two distinct book categories. Finally, only 5% of teachers reported learning about concept maps through a *high school teacher*. This seems somewhat surprising given that most educators in our

[37] This question was not asked.

sample attended Normal schools where, one would assume, pedagogical tools such as concept mapping are taught and/or used.

When asked about the benefits of concept maps for students, we found that practically all teachers in the sample (93%) agreed that the most important benefit for students is that they "help them organize and represent their ideas." The other two options suggested that their usefulness resides in that they "summarize material so that students can learn it faster" or that they "motivate students because they do not need to write so much."[38] The latter options were chosen by only 5% and 3% of teachers, respectively.

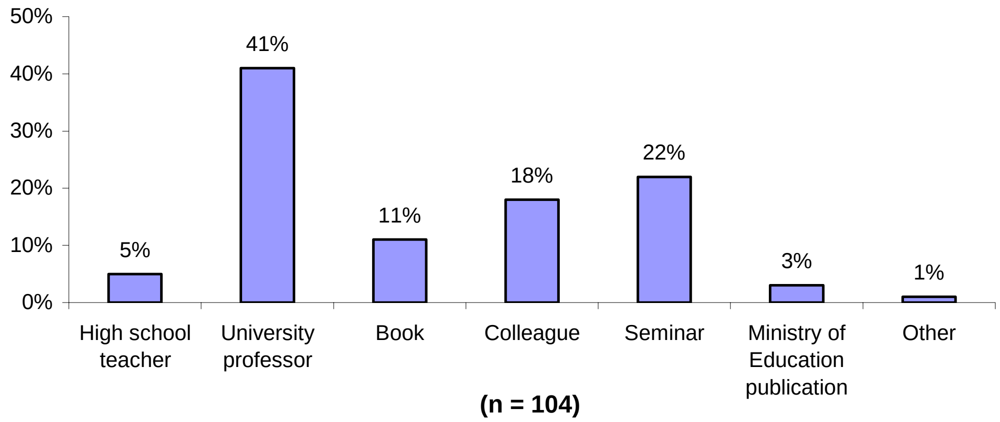


Figure 6. Primary source of teachers' information about concept maps.

These results stand in stark contrast to what teachers actually *do* with concept maps. Results on the didactic use (figure 7) show that the most common practice was for teachers to build a concept map in class for their students to memorize (51%). The second most common praxis was for teachers to provide students with an already-made concept map which they were to study from (32%). Fewer than 5% of educators asked students to construct their own concept maps.

[38] In Panamanian schools it is an old and widespread custom for teachers to write each day on the blackboard the *plan*, consisting of a summary of facts the teacher expects children to learn in each subject. The entire learning experience is often reduced to nothing more than copying these plans and memorizing them for a test.

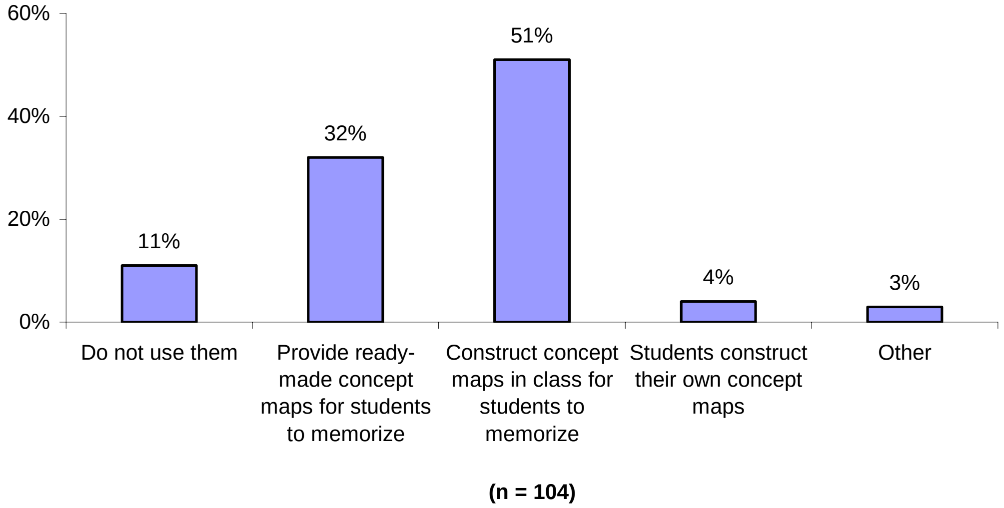


Figure 7. Main didactic use teachers make of concept maps.

As for the use of concept maps as an assessment tool, 39% of teachers never used them in this manner. Of those who did, 58% provided fill-in-the-blank structures, where students filled in concepts, linking phrases, or both. A mere 1% of teachers requested that students construct a complete map from scratch for evaluation purposes (figure 8).

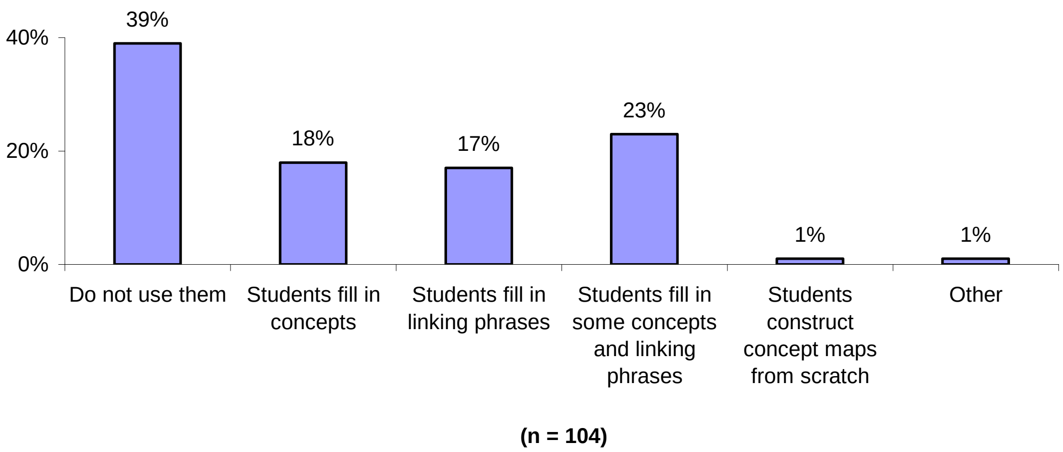


Figure 8. Main use teachers make of concept maps as an evaluation tool.

Figure 9 shows the preconceptions teachers hold regarding linking phrases. Though the vast majority (97%) concurred that linking words are necessary, 38% believed that only *pre*positions could be used, whereas 28% believed that any kind of word could be used, albeit only one word. The remaining third (32%) believed, correctly, that linking phrases could contain one or more words, of any kind.

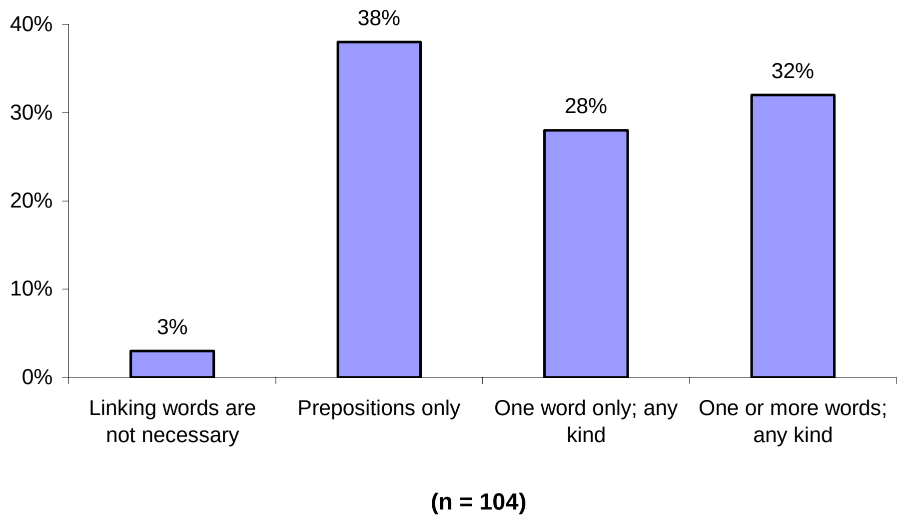


Figure 9. Preconceptions about the number and type of linking words.

An interesting result is that 51% $(n = 47)$ of teachers considered that connecting lines between concepts must not cross each other; and 50% considered that connecting lines must be straight lines $(n = 36)$. The intersection of these two subsets yielded that approximately one quarter of the teachers (27%) believed that lines could not cross each other *and* could not be curved $(n = 30)$.

The survey also inquired about stylistic aspects of concept maps, such as the shape of the boxes in which concepts are written, the use of upper and lower case letters in writing concepts and linking phrases, and the use of arrows on connecting lines. 83% responded that boxes could be of any shape, but 16% said boxes must be elliptical. More than half (53%) said concepts must be written in upper case, linking words in lower case; 11% said concepts must be in upper case, whereas linking words could be either upper or lower case; and 36% said it did not matter how concepts or linking words were written. The arrow at the tip of connecting lines is obligatory according to 32% of surveyed teachers, totally optional for 15%, and optional except in cases when it is unclear how to read the concept map for 48% of teachers.

Finally, teachers were asked about the direction in which concept maps should be read. Almost a third, 30%, of the educators responded that concept maps were always read in the downward direction, regardless; 22% said concept maps ought to be readable in both directions top-to-bottom and bottom-to-top; and 42% indicated, correctly, that they are read in the general downward direction unless arrows indicated otherwise.

5.4 Discussion of teacher preconceptions

In view of the high percentage of teachers (67%) who according to this study use concept maps and of the time concept maps have been in use in Panama,[39] and given the potentiality

[39] Concept maps of some form have been taught and used in Panama for at least 20 years.

of concept maps to facilitate meaningful learning, the obvious question that comes to mind is why have they apparently have had so little impact on the quality of Panamanian education? We believe the answer lies in what generations of schoolteachers know about and do with concept maps, as revealed by this survey.

This study showed that Panamanian elementary schoolteachers have many distorted notions about concept maps and their proper use. These distortions, far from propitiating meaningful learning, tend to perpetuate the traditional paradigm of rote learning.

One important distortion deals with linking phrases. Two thirds of teachers in our sample either believe linking phrases have to be a *pre*position or believe they have to consist of a single word. In propositional concept maps, where each triad *concept – linking phrase – concept* is supposed to constitute a meaningful statement, neither of these options is conducive to the construction of self-contained units of meaning. Two concepts joined by a preposition hardly amount to an affirmation of any kind. Restricting linking words to a single non-prepositional word is generally a better option, but still quite limiting. True, in a concept map one should strive for brevity; however, the overriding criterion should be whether the proposition expresses the desired relation between the concepts. This sometimes can be achieved with a single linking word, but more often than not, more than one word is necessary to accurately communicate the intended meaning.

Next we turn to cross-links, those propositions that connect concepts located in different regions or subdomains of a concept map. Their importance resides in the fact that relations established through cross-links tend not to be obvious and thus, require additional effort in terms of thought and creativity. Generally, in order to establish a cross-link connecting lines may have to go from one side of the concept map to the other, which often means crossing other connecting lines. However, as our results showed, half of the teachers (51%) believe lines in a concept map may not intersect each other. This suggests that in their minds, cross-links possibly are not considered as an option. Often intersections can be avoided by using curved lines. But then again, half the teacher would not allow curved lines either. Thus, if the 27% of teachers who admit neither intersections nor curved lines were to act according to their preconceptions, they would negate altogether the possibility of connecting different strings of thought in their concept maps.

The previous result is especially disturbing for it suggests two things: first, on a superficial level, a seriously misguided understanding of concept mapping; second, at deeper level, a tendency towards linear thinking, which we conjecture is almost certainly a consequence of rote thought patterns ingrained throughout elementary school and further reinforced at institutions of higher education. The above is an illustration of how what educators think about some particular pedagogical tool is often at great odds with the theoretical foundations on which that tool is based. For, if concept maps are a tool that promotes meaningful learning, and if learning meaningfully requires relating ideas, how can one hope to achieve this type of learning when one denies the very physical actions needed to establish good relationships between ideas?

Our results also show serious inconsistencies between what Panamanian educators *think* about concept maps and what they *do* with them. On the one hand, we found that when asked about the major benefit of concept mapping for students, 93% asserted that they help them "organize and represent *their* ideas." Nonetheless, when using them in the classroom as a tool for learning, fewer than 5% gave students the opportunity to construct their own concept maps on a given topic. The vast majority of teachers (over 95%) expected students to memorize concept maps they – the teachers – give them, or ones they construct together in class. The general notion seems to be that, on any given topic, there is one "correct" concept map, namely the teacher's map, and students must learn it. Needless to say, this entirely contradicts the theory on which concept maps are based. This equivocal notion is further reinforced by the fact that concept maps are frequently used to study eminently classificatory curricular content[40] (e.g., types of plants, types of animals, types of words), which does not lend itself to the construction of "personal" concept maps, concept maps that allow some degree of variation among one another as well as individual input. This is worrisome because as Moreira (1997) points out, "inasmuch as students use this technique to analyze articles, texts, chapters from books, novels, laboratory experiments and other educational materials pertaining to the curriculum, [in this measure] will they be using concept mapping as a resource for [meaningful] learning" (p. 3).[41] Hence, the picture that emerges reveals concept maps essentially being used to: 1) reinforce a monolithic view of knowledge and 2) encourage memorization rather than construction of meaning.

Something similar seems to be the case when concept maps are used as an evaluation tool. Of the 61% of educators in this study who used concept maps for evaluation purposes, only 1% of them asked their students to build a concept map from scratch. The general custom was to provide students with a concept map framework for them to fill in the missing concepts and/or linking phrases. Once again, this is a practice that fosters memorization over meaningful learning.

Teachers' preconceived ideas about the purely aesthetical elements of concept maps would be of much less consequence from the point of view of their impact on education, were it not for the importance that they themselves attach to these aspects. Throughout the six workshops during which the data for this preliminary study was collected, we had instances in which teachers strongly challenged facilitators on things such as the shape of concept boxes or the use of upper and lower case letters. Although many were receptive to the notion that these were subjective elements, others insisted on the need to establish "uniform criteria" for these purely stylistic matters. We found that often the reasons they gave to explain their insistence revealed that, at some point in their experience as students, a professor (usually a university professor) had penalized their work for not complying with his or her aesthetic criteria.

One last point is in order. As a result of both the interest awakened by our questionnaire and the workshops themselves, a number of teachers provided us with originals and photocopies of texts they had used whilst studying concept maps at the university. In all of them we discovered limitations, inconsistencies and conceptual errors similar to the ones maintained by the sampled teachers. We were surprised, moreover, that from one workshop to the next we always got the same two or three texts, even though some teachers had studied recently, and others many years before. Thus, it would seem that a rather small number of texts, used year after year, have contributed to the limited and distorted understanding of concept mapping of both university professors and elementary school teachers in Panama. The combination of distorted ideas with poor practices has transformed concept maps in Panama from a tool for meaningful learning into an instrument to perpetuate rote learning. To use Solomon's (2000) term, concept maps may have been "domesticated," that is, "allowed to do precisely that which fits into the prevailing educational philosophy of cultural transmission" (Disappointments and their reasons (I), ¶ 4).

---

[40] We base this statement on our experience with teachers in the workshops and during visits to schools.
[41] Translation by the author.

5.5 Conclusions

This preliminary study sought to explore the preconceptions regarding concept maps and their use held by Panamanian teachers who were beginning training at the Conéctate Project. Results reveal serious conceptual errors that not only limit but might even cancel any cognitive benefit resulting from this pedagogical tool. Outcomes also show that teachers' primary source of information on concept maps are university professors. Thus, it seems urgent to revise what is taught about concept maps at the university level. Additionally, it is imperative to improve the availability of good quality materials in Spanish, as part of the problem might be in the use, year after year, of the same conceptually limited or error-laden texts.

For Conéctate, knowing teachers' preconceptions about concept maps beforehand is important because it can help tailor the content, methodology and pacing of the workshops towards achieving the Project's ends. Knowledge about preconceived ideas also allows facilitators to better prepare to handle a variety of situations that might arise in the course of instruction. Some strategies we believe may be useful to help overcome these preconceptions are: 1) presentation throughout the workshop of concept maps made by both children (including Panamanian students) and experts, illustrating propositional structure, cross-links, and a range of different stylistic options; 2) use of devises such as "conceptual dice"[42] (Hughes et al., 2006) as a means to break away from standard textbook statements and help generate novel propositions; 3) group discussions of maps to provide feedback and stimulate search for unnoticed connections among concepts; 4) introduction to Internet early in the workshop (usually on day 3) as a source of information and resources to enrich maps; and 5) application of concept maps in a variety of situations to illustrate their versatility and many possible applications.

To conclude this chapter we return to the question with which we began the discussion section, namely, given the extended use of concept maps in Panama, why is it that they appear not to have had the expected positive impact on the quality of Panamanian education? It is our belief that at least part of the answer lies in the erroneous notions that Panamanian schoolteachers maintain regarding concept maps and their use, which this preliminary inquiry has made evident.

[42] The *conceptual dice*, developed by the Conéctate facilitator Adrian Chang, are a pair of dice on whose 12 faces have been written various related concepts (at Conéctate we use post-its so that they can be changed easily). The idea is to throw the dice and form a proposition relating the two concepts appearing on the upward faces of the dice.

6 A taxonomy for concept maps

6.1 Introduction

The massive scale on which concept mapping is being introduced by the Conéctate Project in Panama's public elementary schools, necessitated specialized instruments to measure the progress taking place in classrooms and in schools in using concept maps to foster meaningful learning.

On the one hand, learning to construct quality concept maps, maps that clearly and accurately reflect learners' understanding of the represented topic, is a process that generally begins with maps that are poor, both in structure and in meanings, and that improves over time, with practice, and with feedback from a teacher or other person with greater experience.

On the other hand, facilitator reports from workshops and follow-up visits, it was found, were neither sufficient nor adequate. One issue was that these reports tended to be highly subjective, dependent on each facilitator's interpretations of what constituted "good" concept maps and what constituted real progress toward better maps. A second matter was that these reports indicated a wide quality spectrum for the observed concept maps, making it difficult for the Project to know where it stood and how to proceed. Thus, it soon became clear there was a need for a "common language" that could help: 1) determine progress towards the goal of achieving significant learning through concept mapping, 2) determine the adequate level of support in concept mapping required by individual teachers and schools, and 3) conduct research that could provide further feedback regarding processes taking place and procedures being carried out at Conéctate.

Conéctate required a taxonomy for concept maps analogous to the Bloom's (1956) Taxonomy. Bloom, along with a group of researchers, developed a classification for levels of cognitive behaviors important for learning. In the cognitive domain, Bloom and his team classified thinking behaviors into six levels, from the simple recognition and memorization of data and information at the low end, passing through levels of increasing complexity and abstraction, all the way up to evaluation and synthesis at the high end. The concept map taxonomy developed at Conéctate was designed to provide a mechanism to determine the degree of progress in the representation of concept maps, beginning with simple maps, containing strings of concepts and texts, and without linking phrases, up to maps composed of clear propositions, good cross-links, relevant resources and links to other concept maps.

In developing our taxonomy for concept maps, the purpose was not to produce yet another grading scheme. Instead, the goal was to come up with a taxonomy that would allow the Project's personnel to gauge changes in concept maps deemed important for meaningful learning. This taxonomy was to provide a mechanism to determine advances in organization and representation of knowledge in concept maps, beginning with simple maps, typified by many nodes containing long portions of text, linear sequences of concepts, and absence of linking phrases, and culminating with complex maps, with well-defined, relevant concepts; well-structured and thoughtful propositions; good cross-links; relevant and quality resources; and links to other maps.

At the risk of being redundant, it is important to emphasize, once again, that this taxonomy was not conceived as a grading instrument for concept maps. Its features conform to a specific need of the Conéctate Project, a need for a more objective and reliable way to measure advances towards the goal of achieving knowledge representation forms that allow learners to faithfully express the complexity of their thinking. It is not our intention that this tool be used by teachers to grade their students, lest this give the impression that there exists a unique "best way" to evaluate concept maps. The taxonomy was developed to support clear-cut objectives of Conéctate and as a *research* tool. From this perspective, the tool will be used by a limited population of evaluators, namely, facilitators of the Conéctate Project, who share a common understanding of concept maps.

6.2 Conéctate's taxonomy for concept maps

Our experience observing the performance of both students and teachers early on in the construction of concept maps, and our knowledge of the preconceptions held by teachers regarding concept mapping, suggested that there was a need, initially, to separate structure and content. On the one hand, in learning to build concept maps it is common to introduce long pieces of text containing many concepts in lieu of individual concepts; to create long, strings of concepts with little or no branching; to leave out linking phrases; and to ignore or forget cross-links.[43] This results in maps that can not be read meaningfully, so that content analysis is out of the question. On the other hand, as facilitator reports made plain, upon returning to their schools after attending the workshops, some teachers reverted to the map structures they knew and were comfortable with before being trained at Conéctate, structures which tended to be linear and in which cross-links generally played no part.

For this reason, the taxonomy that our team developed consists of two parts, a *topological* component, which focuses on structural complexity, and a *semantic* component, which concentrates on quality of content. In the following sections we describe each of these parts in turn.

6.3 Topological taxonomy[44]

As noted above, at the outset the priority was to develop and validate a topological taxonomy. Thus, during the first half of 2006 we directed our efforts towards this goal. In going through the literature, we found that few schemes have been proposed to assess the topological structure of concept maps. Kinchin (2000) put forth a classification that included 3 topologies: radial, chain and network. Of the three, the network structure is the most elaborate and indicative of meaningful learning. Recently, within the context of a study comparing two evaluation techniques for concept maps Yin, Ruiz-Primo, Ayala, & Shavelson (2005) also examined map structural complexity. Though initially they based their work on Kinchin's classification, they found that this system did not allow them to characterize the totality of topologies observed in the course of their investigation; hence, two additional structures were incorporated. The new system consists of the following five topologies, ordered from the simplest to the most complex: linear, circular, radial, tree, and network.

[43] Pankratius (1990), in a completely different context, also observed and commented that "poor mappers with low achievement scores tend to construct linear maps with limited branching" (p. 325).
[44] This study was described in Cañas, Novak, et al., 2006.

Once again, neither of these classification systems provides a taxonomy with different levels, showing the *progression* in the ability to construct concept maps.

The purpose of the topological taxonomy (appendix B) developed by our team was to measure the structural complexity of concept maps in the specific context of the Conéctate Project. Though it bears some similarity with the classification systems described above, notably the one developed by Yin et al. (2005), ours is more comprehensive and detailed.

In defining the topological levels five criteria were considered: 1) *recognition and use of individual concepts* (as opposed to long texts), 2) *presence of linking phrases*, 3) *degree of ramification*, 4) *hierarchical depth*, and 5) *presence of cross-links*.[45] The taxonomy was developed based on our experience observing the maps in the schools and on direct participation from Joseph Novak on what he perceived was the 'natural progression' in map complexity as new concept mappers learned the use of the tool.

Obviously, the first criterion deals with content rather than structure. It was included as part of the topological taxonomy because, in our milieu, the presence of text in a concept map tends to be symptomatic of a misunderstanding of what a concept is. We believe that the ability to sort out texts into separate concepts is the starting point for establishing multiple, novel and flexible relations between these concepts, ultimately leading to complex and sophisticated knowledge constructs. As an illustration, we might consider the following text: *"The escapement passes energy to the pendulum to keep it swinging and also releases the gear train in a step-by-step manner."* This piece of text contains many individual concepts: *escapement*, *energy*, *pendulum*, and *gear train*. Each of these, represented separately, could lead to the establishment of a number of relations. We consider this criterion so important that a concept map in which texts predominate over individual concepts is classified as a level 0 concept map, regardless of the presence of any other structural element.

The second criterion, which deals with linking phrases, has a structural component and evidently also a semantic component. For the purposes at hand we consider only the structural dimension. In other words, in the topological taxonomy, the use of linking phrases refers only to the bridge that is established by their presence; their content is not important. Thus, any symbol used to join one concept to another is considered a linking phrase, regardless of the symbol used or whether it leads to a well-structured, meaningful proposition or not. This understanding applies equally to maps made by hand (using pencil and paper, or other materials) as to maps built using a computer program. When building a map with CmapTools, the program automatically places a linking phrase box with question marks in it when one concept is joined to another. Hence, these symbols cannot be interpreted as a linking phrase as they clearly do not constitute evidence that the author had the intention of setting up a specific relationship between the concepts.

The third criterion is associated to the occurrence of ramifications or branching at concepts or linking phrases (figure 10). The number of branches spreading out from any given node[46] is not relevant; the fact that there *is* branching is what counts. Thus, to determine the degree of ramification one counts the number of nodes at which branching takes place.

---

[45] In future versions of the taxonomy digital resources could be included among these criteria.

[46] The term *node*, taken from graph theory, refers to "points where lines come together or from which lines depart." In a concept map, both concepts and linking phrases can constitute nodes.

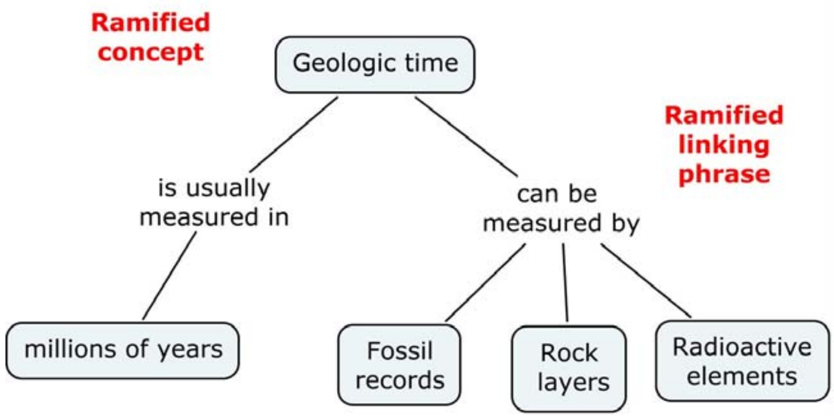


Figure 10. Illustration of branching points in a concept map.

Hierarchical depth is determined by counting the number of linking phrases between the root concept[47] and the concept most distant from it in the map.[48] Maps are considered "shallow" if the hierarchical depth is less than 3 and "deep" if it is 3 or more. Clearly this makes sense only for maps containing at least one root concept. In Conéctate this is generally not an issue, as teachers are taught to begin by posing a focus question which leads quite naturally to initiating their maps with a main concept relating to that question. In a cyclical map, any concept can serve as a root concept.

The final criterion involves cross-links. As noted earlier, Novak describes cross-links as "relationships or links between concepts in different segments or domains of the concept map" (Novak & Cañas, 2008, p. 2), and goes on to point out that "cross-links help us see how a concept in one domain of knowledge represented on the map is related to a concept in another domain shown on the map" (ibid.). For purposes of developing a reliable measurement instrument, we found it necessary to formalize this definition. In our topological taxonomy, a cross-link is defined as "a link joining two concepts, neither of which is the root concept, [49] in such a way as to form a closed loop or circuit."

The topological taxonomy was designed to be quick and easy to use, and sufficiently simple that its application would allow the person applying it, the evaluator,[50] to acquire the ability to recognize at a glance a map's topological level. It consists of 7 levels, ranging from 0 to 6. Concept maps comprised between levels 0-2 are considered maps with a "poor" topological structure due to the presence of long pieces of text, omission of linking phrases, and presence of linear sequences of concepts with very little ramification. Level 3 maps are considered "acceptable," since they contain no long pieces of text and are not missing linking phrases; however, there is only moderate ramification and depth, and no cross-links. Level 4 maps are essentially "good" maps; the main limitation is that they are missing cross-links. Finally, levels 5-6 are "very good" maps topologically speaking. To belong to a given topological

[47] The *root concept* refers to the most general or most inclusive concept in a concept map.
[48] Alternatively, one could count the number of concepts, and subtract 1 (for the root concept).
[49] The decision to exclude the root concept was somewhat arbitrary, based on our estimation that connections between the root concept and other concepts did not represent a significant relation between subdomains of the concept map. Undoubtedly, this is simply an opinion and one could easily consider modifying the definition to allow root concepts in cross-links.
[50] We will use this term for want of a better word.

level, a concept map must satisfy *all* conditions describing that level; a concept map that does not satisfy one or more conditions of a given level belongs to some lower level.

6.4 Reliability study for the topological taxonomy

The aim of the taxonomy we developed was to furnish facilitators with a common language in which to objectively express the progression in the quality of concept maps produced by students participating in the Conéctate Project, in order to support decision-making. Thus, it was critical to determine the consistency that could be expected in the application of this taxonomy by the group of facilitators. It is important to point out that consistency is an issue only when maps are being classified by different facilitators. The topological taxonomy, unlike its semantic counterpart discussed below, can be automated rather easily; in fact, colleagues at Conéctate are in process of doing so. Thus, in the near future, when students construct their maps with CmapTools and place them in public servers making them accessible remotely, Cmaps will be able to be classified automatically, and the reliability question will become mute. At present, though, both for purposes of Conéctate and of this dissertation, the reliability of the instrument needed to be considered.

6.4.1 Selection of concept maps

In order to guarantee that concept maps from each of the 7 topological levels would have the same chance of being selected into the sample, a group of facilitators put together a set of 210 maps, 30 from each of level. These maps, chosen from amongst those created by teachers in the course of their training, by students at participating schools and collected during follow-up visits, and other maps available on the network of CmapTools public servers, constituted the universe from which a sample of 50 concept maps was subsequently selected at random. Before proceeding to work with this sample, each map was touched up to cover any identification marks or other marks not pertaining to the map itself.[51]

It is worth noting that 24 of these maps were made by hand, while the remaining 26 were constructed with some software program. Also, 8 maps were in a language different from Spanish, and 5 did not show the classic hierarchical structure, with the root concept at the top of the map and more specific concepts below it.

6.4.2 Methods and experimental protocol

The reliability study was carried out in two phases: the first phase was a preliminary phase which provided feedback that allowed us to make adjustments to the instrument; the second phase was the actual validation study, whose results are reported below. Sixteen evaluators, chosen randomly from amongst the group of available Conéctate facilitators, participated in the first stage. None of them had had any previous experience with the topological taxonomy prior to this study. Evaluators worked individually, assigning to each of the 50 concept maps in the sample a unique topological level according to their understanding of the topological taxonomy.

[51] In the case of concept maps collected at schools, for instance, some of them had comments and/or corrections by teachers.

Prior to proceeding with the second stage, evaluators participated in a 2 hour training session during which the tool was formally presented to them, and did a brief practice session with 6 maps. After discussing the results of the practice session we proceeded to the second phase. All available facilitators (26 in total) participated, with the exception of those who were party to the instrument's design or the selection of the sample maps.

To guarantee complete independence on the part of the facilitators, all 26 evaluators worked simultaneously, and were supervised at all times. Evaluators had access to a description of the topological taxonomy.

6.4.3 Evaluator characteristics

All evaluators are part of the Conéctate Project. Their distribution by seniority is as follows: 10 belong to the first group of facilitators, recruited and trained in February, 2005; 3 come from the second group, enlisted and trained in July, 2005; and 13 are from the third group,[52] enlisted and trained in December, 2005. At the time this reliability study was conducted, facilitators from each of these three groups had taught 18, 12 and 5 workshops, respectively. Evaluators' professional fields were quite diverse, including physics, psychology, marketing, biology, agronomy, education, among other areas. As to gender, evaluators were rather evenly distributed, 58% women, 42% men.

6.4.4 Measures of agreement

The measure of agreement among evaluators was determined using two statistics: the *observed percent agreement* and the *kappa coefficient* both unweighted and weighted.[53] The kappa coefficient measures the level of agreement among evaluators above and beyond the agreement due purely to chance (Abraira, 1997). The number of evaluators was greater than 2, 16 and 26 for the refinement stage and the final validation, respectively. Hence, reliability statistics were calculated first for each possible evaluator pair, and then averaged in order to obtain the measure of agreement among all evaluators. The interpretation of the kappa coefficients was based on table 1, proposed by Landis & Koch (1977) and widely used in reliability studies.

---

[52] At the time the validation study was performed, this was the last group of recruits.

[53] We chose a *linearly* weighted kappa coefficient, with weights calculated by the following formula: $1-\left|\frac{i-j}{k-1}\right|$, where k is the total number of categories; and i and j represent the levels determined by the ith and jth evaluators, respectively. A weight of 1 means that the distance between the categories assigned by a pair of evaluators is 0, that is, there is full agreement; a weight of 0 means that the distance between the categories assigned by a pair of evaluators is the maximum possible, in this case 6.

Kappa coefficient	Agreement level
< 0	No agreement (beyond chance)
0 – 0.2	Poor
0.21 – 0.4	Fair
0.41 – 0.6	Moderate
0.61 – 0.8	Good
0.81 – 1	Very good

Table 1. Landis & Koch's table for interpreting the *kappa* coefficient.

6.4.5 Results

Preliminary phase results, along with comments from the participating evaluators, made evident the need to effect certain modifications to the taxonomy itself and the instructions for its use before proceeding to the second phase. The main modifications involved: 1) clarifying the criterion dealing with degree of ramification; 2) clarifying how to use the taxonomy, especially when a map did not fulfill exactly the conditions for a given topological level; 3) emphasizing that the tool deals with structure not content; 4) reducing the sample size to avoid fatigue;[54] excluding from the sample all maps in a language different from Spanish,[55] as well as those in which the root concept was not in the upper portion of the map.[56]

The sample used for the final validation was a sub-sample of 30 maps of the original set. Analysis of the data showed that the percent agreement was 55.7%, with a 95% confidence interval of (54.5%, 57.0%).[57] The unweighted *kappa* coefficient was 0.48, (0.46, 0.49), while the linearly weighted *kappa* was 0.72, (0.71, 0.73).

Searching for explanations for the observed discrepancies, we proceeded to look at how evaluators differed on a given concept map. Of the 30 maps, 8 showed an important level of variability in their classification. Variability was considered "important" if evaluations ranged over 4 or more levels, independently of whether the evaluations were concentrated around a particular level or not.

[54] Level of agreement in the preliminary phase dropped significantly during the last 25 maps as compared to the first 25. Given the size of the sample, we suspected that fatigue could have been a major factor. This suspicion was subsequently corroborated by several evaluators who, when interviewed indicated having felt quite drained after evaluating the first 25-30 concept maps, and not having adhered as strictly to the taxonomy or its instructions during the second half of the sample as during the first half.

[55] Our outcomes, corroborated by interviews, indicated that maps in foreign languages, particularly if the alphabet was not the Roman alphabet, made it more difficult for evaluators to distinguish between individual but lengthy concepts and actual pieces of text.

[56] Evaluators pointed out that it was harder to classify concept maps in which the root concept was in the center of the map or near the center. This may have been because this type of structure is much less familiar to them since at Conéctate concept maps typically have the root concept at the top of the map. In particular, they may have found it more difficult to correctly determine the maps' degree of ramification and hierarchical depth.

[57] From now on, for simplicity, 95% confidence intervals will be given as parentheses immediately following the statistic.

A careful inspection of these 8 concept maps revealed that the differences seemed to stem from evaluators not counting something correctly and/or not adhering to the instructions rigorously (table 2). In no case did we find evidence to suggest that the taxonomy itself (criteria or application instructions) was to blame for the discrepancies that occurred in the evaluation of these maps.

Additionally, we considered the distribution of all possible pairs of evaluations (table 3) to identify where the greatest dispersion occurred. As one can plainly see in the row below the main diagonal, the largest discrepancies correspond to differences of just one level. Among these, the most significant differences lie between levels 1 and 2 (9.9%), levels 5 and 6 (6.7%), and between levels 2 and 3 (6.0%).

Map number	Observations
4	Missing linking phrases counted incorrectly
10	Cross-links counted incorrectly
11	Cross-links counted incorrectly; hierarchical depth calculated incorrectly
14	Counting errors were found in the number of cross-links
16	Missing linking phrases counted incorrectly
17	No observations
24	Hierarchical depth calculated incorrectly
27	Long proper names possibly confused with pieces of text

Table 2. Observations about concept maps showing "important" variability in topological classification.

Evaluation by facilitator A	Evaluation by facilitator B						
	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Level 0	7.1%						
Level 1	5.5%	9.5%					
Level 2	2.1%	9.9%	11.2%				
Level 3	0.0%	0.4%	6.0%	7.2%			
Level 4	0.0%	0.2%	1.0%	2.6%	7.7%		
Level 5	0.1%	0.0%	2.2%	1.6%	3.4%	3.7%	
Level 6	0.1%	0.0%	1.1%	1.1%	0.7%	6.7%	9.0%
Subtotal	14.9%	19.9%	21.5%	12.5%	11.8%	10.4%	9.0%

Table 3. Distribution of 9,750 possible pairs of evaluations of 30 concept maps evaluated by 26 facilitators.

6.4.6 Discussion

Data analysis yielded an average pairwise percent agreement of 55.4%, (54.5%, 57.0%). The simple, unweighted *kappa* coefficient was 0.48, (0.46, 0.49), corresponding to *moderate* agreement on Landis & Koch's (1977) scale. The linear-weighted *kappa* coefficient was 0.72, (0.71, 0.73), equivalent to *good* agreement. Of the two *kappa* coefficients, the weighted would be considered more appropriate for a classification system such as ours, counting 7 levels, since the simple *kappa* penalizes too severely even the smallest difference between evaluators. The large improvement in agreement in the weighted *kappa* value relative to the unweighted value is in fact indicative of small differences between evaluators. Detailed analysis confirmed this inference: of a total of 9,750 pairs of evaluations of 30 maps by 26 evaluators, 34.1% resulted in disagreements by differences of *exactly* 1 level; 89.5% of these pairs resulted in disagreements by differences of *at most* 1 level.

Even so, the fact that there is a high percentage of variation between practically every pair of consecutive levels could be indicative of two things: 1) lack of clarity in the topological taxonomy (its description or its instructions), or 2) lack of practice and/or rigor in the application of the taxonomy by the facilitators. Based on the analysis of the 8 concept maps that showed greatest variability in their classification, though, we lean towards the second explanation. We also believe that evaluation reliability will increase considerably as facilitators become more familiar and experienced with this tool.

To recap, in light of the purpose for which the topological taxonomy was created, we consider the above results satisfactory. They demonstrate that the group of Conéctate facilitators, sharing a common view of concept mapping, *can* arrive at close agreement in their evaluation of arbitrary concept maps. We fully expect this agreement to increase as facilitators gain practice using the tool. Nevertheless, the high degree of reliability already attained will allow the Project to determine quite precisely the structural level of concept maps being produced in individual classrooms and schools in order to gauge the progress attained. This information will make it possible to customize the proper degree of support each classroom and school requires.

For the aims of this dissertation, the topological taxonomy provides us with a tool to determine the structural complexity of teachers' Cmaps at the beginning of their training and to measure its improvement after completion of the workshop.

6.5 Semantic taxonomy

In what remains of this chapter we consider the second part of the taxonomy for concept maps, namely the semantic component. The idea was to produce a semantic taxonomy that would serve as a tool to classify concept maps based on increasing complexity and quality content. Not surprisingly, developing a satisfactory tool to categorize maps' by semantic content proved to be considerably more challenging than designing one to classify them by structure. Unlike topology, where there is little room for interpretation, semantics entails dealing with meanings, and meanings are *always* personal and idiosyncratic. An additional complication was the "one-size-fits-all" design requirement we imposed on the tool, that is, it had to be applicable to all domains of knowledge and adaptable to many levels of expertise.

Thus, although our original intention was to produce a classification system by levels of increasing semantic complexity, similar to the one developed for structure, preliminary testing of the categorization we had come up with proved unsatisfactory. Given the particular semantic criteria we had selected and the levels we had defined based on these criteria, we found that semantic complexity did not necessarily progress in an even fashion across all criteria for all learners. Some semantic aspects might be quite advanced or well-developed, while others remained at a basic level. This finding is consistent with what is known to happen when acquiring cognitive skills that require learning multiple principles, as discussed in chapter 2.

We therefore opted for a point-based categorization system so as not to penalize learners for this asymmetric progression towards semantically more complex concept maps. A correspondence was then set up between score ranges and overall content quality. Nonetheless, we have not relinquished the idea of producing a reliable classification system based on increasingly complex semantic levels, akin to the topological taxonomy, and hope to continue work along these lines in the near future.

6.5.1 Semantic scoring rubric description

The semantic scoring rubric is meant to be applied only to concept maps containing sufficient structural and semantic elements to be read meaningfully. This essentially means that concepts predominate over texts, and that linking phrases are not missing. Roughly, concept maps with a topological level of 3 or greater meet these requirements. The scoring rubric draws heavily from ideas discussed by Novak & Gowin (1984), Derbentseva et al. (2004), Safayeni et al. (2005), and Cañas & Novak (2006), but also, as with the topological taxonomy, from our own experience with Panamanian teachers and students at the Conéctate Project.

Our rubric considers the following 6 semantic criteria: 1) *concept relevance and completeness*, 2) *correct propositional structure*, 3) *presence of erroneous propositions*, 4) *presence of dynamic propositions*, 5) *number and quality of cross-links*, and 6) *presence of cycles*. In what follows we discuss each of these.

Concept relevance and completeness is determined largely by "external" contextual factors. However, within the map itself various elements can guide the evaluator in assessing relevance and completeness. First and foremost, there is the root concept. This element is always available since at Conéctate teachers are taught to construct maps stemming from a given root concept; hence, it is never the case that a map contains no root concept. A second guiding element is the focus question. This element is less reliable, since sometimes the question is omitted, or ends up bearing no relation whatsoever to the map's root concept or the map's content. One may also consider the concepts nearest the root concept. This can be helpful if there is no focus question or the question is not related to the root concept. Though these elements certainly can help, there is no way around the fact that this criterion involves a great deal of subjectivity,[58] and hence one would expect it to contribute much of the variation among evaluators.

The second criterion involves recognition of propositions as independent semantic units. Propositions are characterized first, by their structure, generally triads of the form *concept – linking phrase – concept*; and second, by being meaningful and transmitting a complete idea. Not all triads constitute propositions. A triad fails to be a proposition if: 1) it lacks the proper structure; 2) it does not make logical sense; and 3) it is not autonomous, i.e., it is a fragment or continuation of a larger grammatical structure such as a sentence, and has no meaning independently of this greater structure.

[58] It is probably the most subjective of all 6 criteria.

This emphasis on correctly structured propositions is not simply a groundless whim. Propositional structure is essential to concept mapping. Requiring a person to make explicit relationships between concepts, be they previously known concepts, newly acquired, or a combination thereof, fosters a process of higher order thinking, essential to meaningful learning. Following the evolution of propositions over a given time span, furthermore, can help visualize the process of meaningful learning as revealed by subsumption, progressive differentiation and integrative reconciliation of concepts; link reworking; and overall map reorganization.

The third criterion deals with erroneous propositions, that is, propositions which make false assertions relative to some objective standard. In the present scheme, the occurrence of erroneous propositions is not penalized; their absence is rewarded. In applying this criterion, it is important to distinguish between relations that result in false statements due to misconceptions – true conceptual errors – and those that may arise from incorrect propositional structure. The tool is designed to give learners the benefit of the doubt by first requiring correct propositional format in order to assess truth value.

The next criterion concerns the static/dynamic nature of propositions. Our definitions for static and dynamic propositions were inspired by the corresponding notions of static and dynamic relationships defined by Safayeni et al. (2005), but we have made certain changes. For us a proposition is considered to be *dynamic* if "it involves physical movement, action, change of state, or it establishes some form of dependency relationship." We consider the presence of dynamic propositions very important since "the ability to represent both static and dynamic relationships in a single map may increase the power of the representational system (ibid, p. 2)."

Dynamic propositions may be *causative* or *non-causative*. In causative propositions one of the concepts must be associated to the "cause" or "probable cause" while the other must be associated to the "effect." Cause-effect propositions, in turn may be *quantified* or *non-quantified*. Quantified propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept. The following examples help clarify these distinctions:

- Examples of non-causative dynamic propositions:
  - *Roots absorb water*
  - *Herbivores eat plants*
  - *Living beings need oxygen*

- Examples of causative dynamic propositions:
  - *Cigarettes produce cancer*
  - *Rule of law attracts foreign investment*
  - *Heat melts ice*

- Examples of quantified causative dynamic propositions:
  - *Increased transparency in public affairs discourages corruption*
  - *Under-activity of the thyroid gland decreases body metabolism*
  - *Increased quality of education contributes to greater national development.*

Propositions which are not dynamic are *static*. Static propositions generally "help describe, define and organize knowledge for a given domain" (Safayeni et al., 2005, p. 10).

- Examples of static propositions:
    - *The sun is a star*
    - *Means of transportation include land transport*
    - *Panama is located in Central America*
    - *Animals may be vertebrates*.

Number and quality of cross-links is the next criterion. From a topological perspective, the interest was mainly on the *presence* of cross-links. Now, from the viewpoint of content, the emphasis is on whether these cross-links establish correct, suitable, and instructive relationships. The number of cross-links, however, is also important. In our view, a good map should have at least 3 cross-links, with physically distinct links. As for an upper bound, the guiding principle is whether no important and/or evident horizontal relationships have been left out.

The final criterion concerns the presence of cycles in the concept map. A *cycle* is a directed circuit in which the direction of the arrows allows traversing the entire closed path in a single direction. As Safayeni et al. (2005) observe, cycles enable the "representation of dynamic functional relationships among concepts. A cycle is built from a constellation of concepts, which represents a group of closely interconnected constructs. Cyclic Cmaps [or Cmaps that contain cycles] capture interdependencies or how a system of concepts works together" (p. 12). Though cycles constitute an important element of Cmaps, the presence of cycles does not necessarily imply a better map; moreover, acyclic maps may actually be very good. Thus, in our taxonomy, the distribution of points is such that acyclic maps can still belong to the highest semantic level, provided they attain a sufficiently high score in all other criteria.

Once points are assigned for each of these six criteria, they are added to obtain a raw numeric score, which is then translated into a 6-level scale with the following categories: *unevaluated*, *very low*, *low*, *intermediate*, *high*, and *very high*.

In applying the scoring rubric to a concept map, the evaluator must be aware of and strive to take into consideration a number of contextual aspects. First and foremost is the author's personal background, including age, education level and culture. A second aspect to consider is the source or sources of the map's content. A map may be based entirely on previous knowledge; or it may use a specific pedagogical experience, such as a reading, a film, an experiment, or a school visit, to build upon previous knowledge. Yet another factor to account for is the nature of a map's content: objective versus subjective. This consideration is essential, for instance, in determining whether a map contains errors or misconceptions, since subjective content maps usually can not be judged by objective standards. Factors pertaining to the evaluator also should be considered: variables such as education, personal preferences, knowledge of the map's topic, and attitude toward the evaluation task can bias his or her application of the tool.

For all these reasons, we expected rather low agreement amongst facilitators in our reliability study. To our surprise, the validation study (discussed below) showed an encouraging level of agreement, particularly in the linearly-weighted percent agreement.

6.6 Reliability study for the semantic scoring rubric

As with the topological taxonomy study, the reliability study for the semantic scoring rubric was carried out in two stages. The first stage provided valuable feedback that served to refine the instrument; the second stage yielded the reliability statistics we sought. Evaluator characteristics and measures of agreement were essentially the same as for the topological study, hence we omit these details.

6.6.1 Methods and procedures

Twelve facilitators volunteered to participate in the initial exploratory stage. Given the subjectivity and complexity of the scoring scheme, we discussed the tool with the evaluators prior to beginning; the discussion was followed by a brief practice session during which one map was analyzed semantically. The evaluators were then given 10 concept maps to evaluate. The reason for this small sample size was to avoid fatigue, which we knew had been a factor with the validation of the topological taxonomy, and was even more likely to play a role in this study, where the evaluation task demanded greater cognitive exertion. Results and evaluator feedback from this first trial indicated the need to clarify descriptions for some criteria and to completely revise others.

The revised taxonomy was used in the second phase of the study, which took place in December 2006 with the participation of all available Conéctate facilitators, a total of 33. A second, completely new set of 10 concept maps was used. This set was selected at random from a universe of 25 concept maps, 5 from each semantic level except the "unevaluated" level, that is, maps that do not meet the minimum criteria to be read meaningfully, or that score 0 points on the rubric. Once again, the tool was discussed with all participating evaluators prior to beginning the evaluation.

6.6.2 Results and discussion

The average percent agreement among evaluators was of 47.2%, (46.0%, 48.5%). The unweighted *kappa* coefficient was 0.29, (0.27, 0.30), and the linear-weighted *kappa* coefficient was 0.50, (0.49, 0.51), representing *fair* to *moderate* agreement, respectively.

As with the topological taxonomy reliability study, we considered the distribution of all possible pairs of evaluations (table 4) to identify where the greatest dispersion occurred. Once again we found that the largest differences happened between consecutive levels, especially between levels 1 and 2 (16%), between levels 3 and 4 (10%), and between levels 2 and 3 (9%). This explains the improvement in the linear weighted *kappa* statistic relative to the unweighted *kappa*. Nonetheless, compared to the topological taxonomy, the percentage of discrepancies by 2 levels was higher, which accounts for the overall lower *kappa* values.

Of a total of 5,280 pairs of evaluations of 10 concept maps by 33 evaluators, 39.5% resulted in disagreements by differences of *exactly* 1 level; while 86.7% of these pairs resulted in disagreements by differences of *at most* 1 level.

Evaluation by facilitator A	Evaluation by facilitator B							
		Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Level 0	**0.0%**						
	Level 1	**1.5%**	**30.0%**					
	Level 2	0.2%	**15.8%**	**5.9%**				
	Level 3	0.1%	3.6%	**9.4%**	**6.6%**			
	Level 4	0.0%	0.3%	4.7%	**9.9%**	**4.1%**		
	Level 5	0.0%	0.1%	1.2%	3.3%	**2.9%**	**0.6%**	
	Level 6	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**	**0.0%**
	Subtotal	**1.8%**	**49.7%**	**21.2%**	**19.8%**	**7.0%**	**0.6%**	**0.0%**

Table 4. Distribution of 5,280 possible pairs of evaluations of 10 concept maps evaluated by 33 facilitators.

A feedback session was conducted once the results were computed to inform facilitators of the study's outcome and to obtain their impressions regarding the tool. This session led to still further revisions of the scoring rubric. The version resulting from these additional refinements was the one used in for this dissertation (appendix C).

7 Main study results

7.1 Overall sample description

The data for the main study reported in this dissertation was collected from 18 Conéctate training groups, in which a total of 350 teachers and 25 facilitators participated.[59] Recordings of the first concept map were obtained for 342 teachers; for the final map, however, only 265 recordings were procured. The main reasons for the decrease in the number of recordings were: 1) teachers leaving their classrooms to participate in other workshop activities during map construction;[60] 2) teachers not attending the workshop on the days maps were recorded; 3) maps not being saved, or being saved locally in the computer's hard drive, instead of the in the CmapServer, and somehow getting lost or erased; 4) Recorder inadvertently being turned off; and in a couple of cases 5) Recorder failure, resulting in partial or total loss of the recorded file. The set of teachers for whom recordings of their first *and* final Cmaps were available was thus reduced to 258. This set constituted the sample for the principal study; all results presented below were based on the Cmaps constructed by this set of teachers.

Ages in the sample ranged from 19 to 66 years, the mean being 39.3 years. The sample consisted overwhelmingly of women (72.4%), a reflection of the national gender imbalance in the teaching profession.[61] Figure 11 shows the distribution of teachers in the sample by province of birth. As can be seen, the sample included teachers born in each of Panama's 9 provinces and in the Kuna Yala Reservation. Most teachers (25%) came from the province of Veraguas, approximately a 4-hour drive West of the nation's capital, Panama City. This is perhaps not surprising given that the country's most important Normal school, the *Escuela Normal Juan Demóstenes Arosemena* is in this province, and provides one of the best career opportunities for many youngsters of the area. The province of Panama was second with 22% of teachers and the province of Chiriquí, near the border with Costa Rica, a close third with 21%. The 3 small central provinces of Coclé, Herrera and Los Santos together accounted for 15% of teachers, while the Caribbean provinces of Colón and, the more distant, Bocas del Toro accounted for 8% and 6%, respectively. The most remote and underdeveloped of Panama's provinces, Darién, afforded only 2% of teachers, while the Kuna reservation contributed a mere 1%.

[59] 12 facilitators participated twice, in different workshops, over the 3-month period spanned by this study.
[60] Teachers designated as CAIs, "coordinators of the innovation classroom," for instance, were required to attend special sessions dealing with technological issues.
[61] Information obtained from SIE, Panama's new Education Information System, based on a total of 7,862 entered into the system by November 2007, reveals that 74% are women and 26% are men.

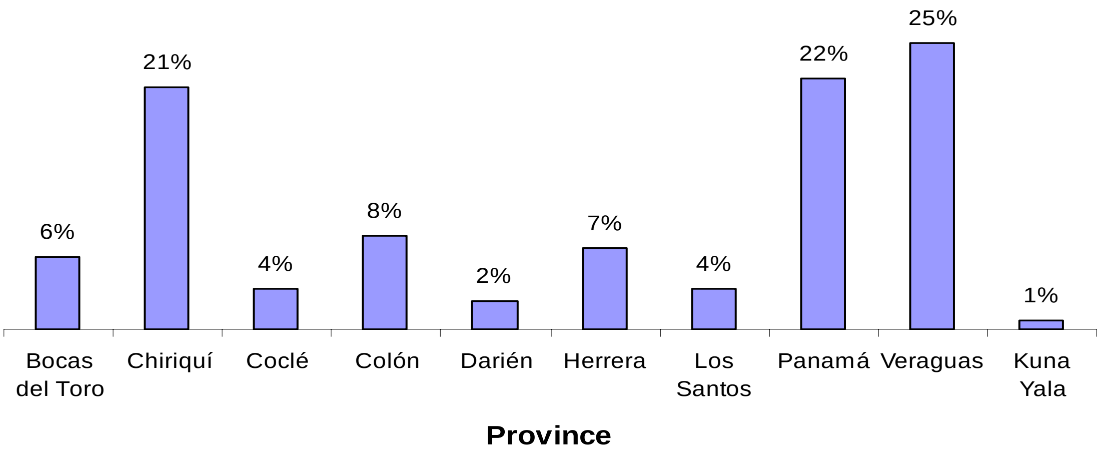


Figure 11. Distribution of teachers in the sample by province of birth.

The sample comprises 53 schools, of which exactly half were located in the province of Panama, 11 in Chiriquí, 5 in Bocas del Toro, 4 in Colón, and 6 in the central provinces of Coclé, Herrera and Los Santos. This particular sample included no schools from Veraguas or Kuna Yala, and only 1 from Darién. The uneven distribution of schools (figure 12) is a reflection first, of Panama's population distribution, heavily concentrated in the cities of Panama, Colón, and Chiriquí; and second (but related to the first), the physical accessibility of schools and ease of providing Internet access, hence their inclusion in the early stages of the Project.

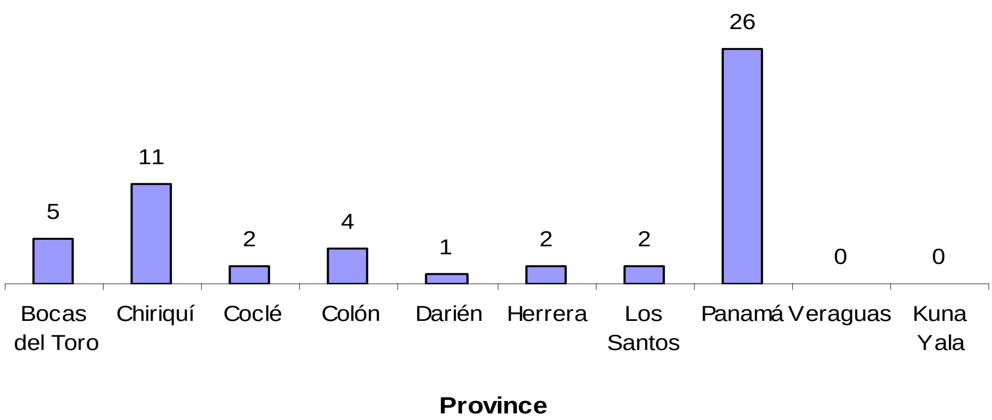


Figure 12. Distribution of the 53 schools in the sample by province.

Regarding education, 95% of teachers in our sample said they had attended university and completed at least one year of higher education. The breakdown is as follows: 9% finished

1-2 years, 31% completed 3-5 years, and 55% completed over 5 years of university education. The questionnaire also inquired about number of books read per year. Teachers in our sample read on average 2.3 books per year $(n = 210)$.[62]

Concerning awareness and prior use of concept maps, 2% indicated having had no knowledge of concept maps, about a third (34%) said they knew about them but did not use them, while approximately two thirds (63%) said they both knew about them and used them in their teaching $(n = 214)$.[63] As in the preliminary study, we found that teachers had important misconceptions about concept maps and their correct usage to foster meaningful learning. The most serious ones, in terms of their possible repercussions on map structure and/or content, were the belief that connecting lines can not cross over from one side of the map to the other, held by 52%[64] of teachers $(n = 125)$, and incorrect ideas as to the nature and number of linking words, maintained by 82%[65] $(n = 96)$. In subsequent sections, when examining the impact of previous notions about concept maps on our output variables, we will call upon these two misconceptions for our analyses.

Regarding their use, most teachers (72%) either gave students maps they themselves had made or made them in class, with some student input, and then asked students to memorize these "correct" maps. Only 5% reported having asked students to create their own individual concept maps to study from $(n = 219)$. Slightly more than half of the teachers (57%) had used concept maps to evaluate their students. Of these, 68% provided a partially filled in structure, and asked students to fill-in blanks with concepts, linking phrases or both; 24% provided lists of concepts, linking phrases or both, and asked students to use them to construct a map; only 1% asked learners to build a map entirely from scratch $(n = 215)$. Finally, the main source of information about concept maps for 45% of these teachers was an institution of higher education $(n = 222)$. This statistic, similar to the one previously obtained, confirms the urgency of addressing the teaching of concept mapping in Panama at the university level.

Previous experience with computers was an important variable to control. Assuming that greater experience corresponds to higher frequency of use, and considering the possession of an e-mail account as indicative of frequent use, teachers were classified as *experienced users* if they possessed an e-mail account and *inexperienced users* if they did not. With this characterization, only 23% of teachers turned out to be experienced users, a percentage similar to the 20% statistic obtained on the preliminary study.

The personal profile of experienced users, not surprisingly, was rather different from that of inexperienced users. For one, there is a gender factor, with women 3 times more likely to be inexperienced with computers than men $(P = 0.00)$. Also, experienced users were younger: average age, 34.9 versus 40.6 years $(P = 0.00)$. Accordingly, the average number of years of service was also lower; the mean for experienced users fell in the 6-10 year range, whereas the mean for inexperienced users fell in the 11-15 year range $(P = 0.00)$. The number of

[62] The statistics for the average person in Mexico, Argentina, Spain and Portugal are 2.5, 3.2, 7.7, and 8.5 books per year, respectively. Source: Centro Regional para el Fomento del Libro en América Latina y el Caribe, CERLAC, 2006.
[63] These percentages are similar to the ones reported in chapter 5.
[64] In the preliminary study the statistic was 51%.
[65] In the preliminary study the percentage was 68%.

years of university studies was not very different for either group; however, the number of books read per year was higher for the experienced group, 3.6 versus $1.9\,(P = 0.00)$.

The previous results were all obtained from part I of the teacher questionnaire. Part II tried to elucidate teachers' attitudes towards learning, in order to establish a preferred learning style somewhere along the continuum between rote and meaningful learning. Unfortunately, internal consistency checks, as well as random interviews conducted to verify information accuracy, revealed that the data was unreliable. The most evident reason involved misinterpretation of both questions and response options. A more subtle reason, however, may have been a desire (conscious or unconscious) to select the "right" answer (the answer they believed was "expected" of them), along with an aversion to identify themselves with attitudes generally assumed to be conducive to rote learning (and teaching).[66] The upshot was that the data we gathered was inaccurate and unreliable, and could not be used.

In spite our failure to obtain reliable and valid data concerning preferred learning style, we nevertheless suspected that most subjects in the sample would be strongly inclined towards the rote end of the learning spectrum. Our basis for this supposition was twofold: first, teachers' similar socio-economic and cultural backgrounds; and second, their almost identical schooling. In Panama, practically all public elementary schoolteachers fall within the *very low* to lower *middle* socio-economic brackets (CONACED, 2006). Consequently, most of them would have attended public elementary schools and a considerable fraction[67] would have gone on to do secondary work at the *Escuela Normal Juan Demóstenes Arosemena*. Of those who continued their education beyond the secondary level, the majority would have attended the University of Panama, Panama's largest public university. Though educational institutions in Panama, particularly at the higher levels, sometimes pay lip service to constructivist educational ideals, in practice they all share the same behaviorist methodologies and emphasis on rote learning. Moreover, since teachers' parents probably had little or no schooling, and since few teachers would have been able to afford traveling out of the country to further their education, there would have been scarce opportunity for them to experience, at home or abroad, different educational environments than the ones available through Panama's educational system.

We recently learned of a study carried out at the end of 2006 by Suárez & Barrios, two Conéctate colleagues, which unwittingly revealed what our questionnaire was unable to, and whose data seems to corroborate our hunch about teachers' preferred learning style. The study was concerned with measuring the impact of the workshop. Of particular interest was teachers' ability to help students improve their concept maps by posing "pedagogical questions," to use Chacón's (2006) term, questions that would invite students to reflect and build upon their ideas. To this end, a set of approximately 60 teachers (three training groups) was given the following assignment on the last day of their 2-week training period: provided with 4 rather poor concept maps created by students, they were asked to pose as many questions as they could to help the authors improve their maps. Teachers were given 20 minutes to carry out this task. Bloom's Taxonomy was then used to classify each question

[66] In Panama, as in many other countries, efforts have been made to implement constructivist teaching methods, and teachers have been sensitized to the fact that purely memoristic learning is detrimental to students' true intellectual growth and achievement.
[67] In the preliminary study the fraction was 40%.

according to the cognitive demands it posed. The outcome of this classification is shown in figure 13 below.[68]

The vast majority (96%) of the questions teachers formulated belong to the two lowest levels of the taxonomy: 85% of these questions would direct students to *remember* information, whereas 15% would ask them to *explain* information. Notoriously absent were questions that might lead to *applying*, *analyzing*, *synthesizing*, or *evaluating* information.

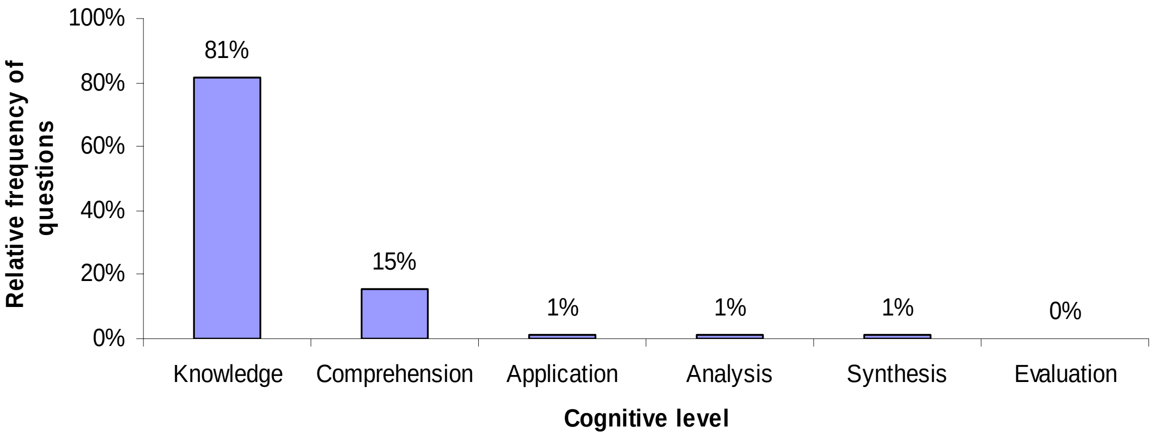


Figure 13. Classification according to Bloom's Taxonomy of questions posed by teachers to help improve student concept maps.

Although determining favoured learning style was not its original intent, we believe this exercise provides a viable alternative (at least within the context of the Conéctate Project) to investigate this question in a manner that largely avoids the pitfalls of attitude surveys. The fact that there are no obscure or indirect questions to misinterpret, no personal attitudes to unveil, and no "correct" answers to choose, all contribute to lower teacher defensiveness. At the same time, teachers must perform. They may try to do "their best," but since they do not know what is being looked at, this is not a problem. In our opinion, this strategy provides an honest portrayal of the kinds of knowledge teachers consider worthwhile, which in turn reveals much about the learning modes they are inclined to engage in.

For purposes of distinguishing teachers in our own sample on the basis of their learning styles, the Suárez & Barrios study came too late. Nevertheless, the portrait presented by the graph in figure 13 is unequivocal: by showing that teachers attending the Conéctate workshops appeal almost exclusively to memorization and comprehension skills, it eloquently supports our suspicion that they are inclined to learn and teach mainly by rote. Therefore, for the remainder of this study, whenever we find it necessary or useful, we will feel justified in referring to and invoking this result.

7.1.1 Characteristics of training groups

In order to better control for the facilitator factor, we looked at how the other independent factors varied across training groups. With respect to computer experience, proportions of experienced and inexperienced users tended to remain quite even across training groups

[68] At present, the analysis of the complete sample has not been completed. These results are based a subset of roughly a third of the teachers, corresponding to one training group.

(figure 14). A logistic regression was performed to test the variation among the means of the different groups. The result was not significant, implying that variations in the graph must be attributed to random variation, and that the 18 training groups should be considered statistically uniform in terms of the proportion of experienced to inexperienced users.

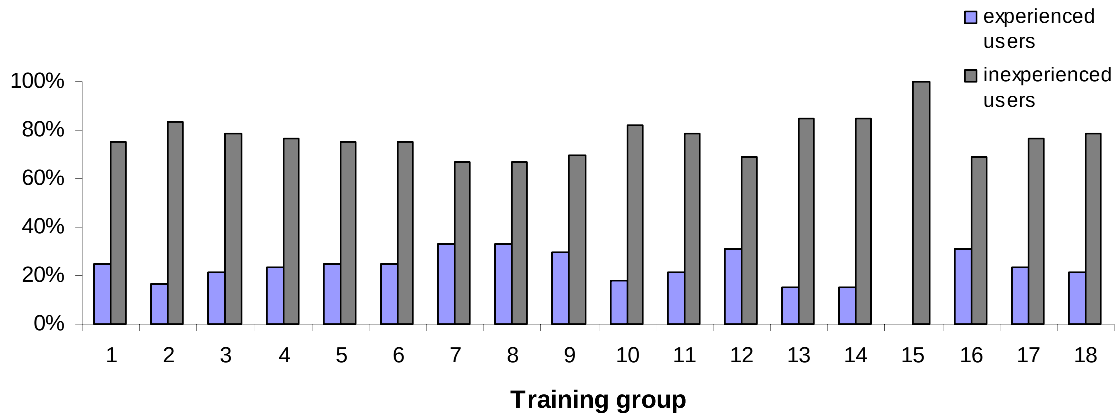


Figure 14. Distribution of experienced and inexperienced computer users by training group.

Likewise, additional tests showed that training groups did not differ significantly by: age, years of university studies, years of service, province of birth, school location, prior awareness and use of concept maps, or misconceptions about linking phrases.

The only significant differences we could find among training groups were by gender, where the percentage of females ranged from 55% in some groups to 93% in others; and with regard to misconceptions about connecting lines, where the percentage of teachers holding the misconception went from 22% in some groups to 67% in others.

7.2 Teacher interaction with CmapTools

As described in section 4.4, acquisition of skill in computer-mediated concept mapping was measured along three distinct but complementary dimensions. The first of these dimensions was the use of CmapTools, that is, the human interaction with the concept mapping program during the map construction process. This interaction was captured via the CmapTools Recorder. The resulting log files, containing over 250,000 lines of data, furnished information about every action performed along with the time at which it took place. This section reports on our findings.

Analysis of the logs revealed that the average construction time for the first Cmap was 1hr 32 min; construction time was significantly higher on the last Cmap, 1 hr 58 min. The total number of actions performed on the initial Cmap ranged from a minimum of 71 to maximum of 2,028, with an average of 483 actions per map; on the final Cmap the range went from 82 to 2,431, with a mean of 750. Regarding specific action types, figures 15 and 16 summarize our findings on both initial and final Cmaps for the nine basic categories considered in our action typology.

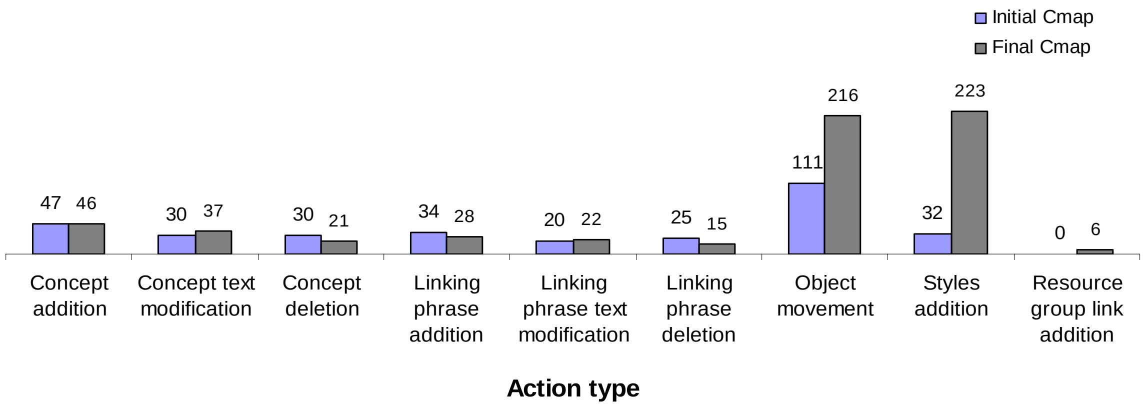


Figure 15. Distribution of action types (absolute numbers) on initial and final Cmaps.

Values in figure 15 represent *mean number of actions* performed in each category. It is clear from the chart that most of the increase in the total number of actions on the final Cmap went to object movement and especially to styles addition. The mean number of concept boxes added remained essentially the same on the first and last map; linking phrase addition, however, decreased significantly, as did concept box deletion and linking phrase box deletion. Concept text modification and linking phrase text modification increased slightly but significantly. Resource addition was initially 0, but this is not surprising since resources were not discussed until the third or fourth day of the workshop. Given that resource addition was an optional and less common action, though, it is important to complement the information in the table by the fraction of teachers who added resources. We found that on the final Cmap about half the teachers (51%) introduced at least one resource at some point during map construction.

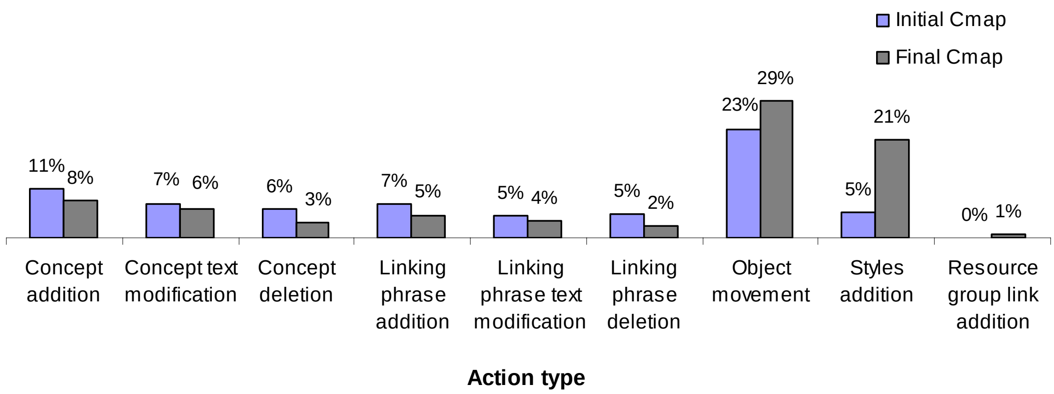


Figure 16. Distribution of action types (percentages) on initial and final Cmaps.

Since the total number of actions varied greatly for individual teachers, in order to compare action patterns we chose to look at *mean percentages relative to the total number of actions*. As the narrow confidence intervals in tables 5 and 6 suggest, percentages were rather uniform across the sample in both Cmaps. Inspection of the bar chart in figure 16 reveals several interesting things. First, we note the low percentages associated with the first 6 categories; of particular interest are the low percentages associated with adding and, especially, modifying text of concepts and linking phrases. Second, it is clear that the most frequent action performed by teachers during map construction was object movement. Third, the magnitude of the styles factor increased dramatically in the final map. And fourth, there is a great similarity in the patterns of the first and final Cmaps.

Comparison tests yielded statistically significant differences for all nine categories, including those where differences between initial and final maps were just a few percentage points. Specifically, adding, modifying and deleting concepts and linking phrases had higher percentages in the first map; moving objects, adding styles and adding resources, on the contrary, had higher percentages in the final map. We note as well the similarity between the patterns in figures 15 and 16, that is, between absolute numbers and percentages relative to total number of actions.

Action type	Mean percentage of total actions on initial Cmap	95% Confidence interval
Add concept box	10.6%	(10.3%, 11.0%)
Modify text concept	7.4%	(7.0%, 7.8%)
Eliminate concept box	6.0%	(5.7%, 6.3%)
Add linking phrase box	7.3%	(7.1%, 7.6%)
Modify text linking phrase	4.7%	(4.4%, 4.9%)
Eliminate linking phrase box	4.8%	(4.5%, 5.1%)
Move object	22.7%	(21.1%, 24.2%)
Add style	5.5%	(4.1%, 6.8%)
Add resource	0.0%	(0.0%, 0.0%)

Table 5. Confidence intervals for mean percentages in each action type category on initial Cmap.

Action type	Mean percentage of total actions on final Cmap	95% Confidence interval
Add concept box	7.8%	(7.3%, 8.3%)
Modify text concept	6.3%	(5.9%, 6.7%)
Eliminate concept box	3.3%	(3.0%, 3.6%)
Add linking phrase box	4.6%	(4.3%, 4.9%)
Modify text linking phrase	3.7%	(3.4%, 3.9%)
Eliminate linking phrase box	2.4%	(2.1%, 2.6%)
Move object	29.2%	(27.1%, 31.2%)
Add style	23.1%	(20.4%, 25.8%)
Add resource	0.9%	(0.7%, 1.1%)

Table 6. Confidence intervals for mean percentages in each action category on final Cmap.

7.2.1 Action typology vs. computer experience

It seems evident that the more experience one has had with computers, the easier it becomes to acquire the necessary skills to operate comfortably, at a mechanical level, with a new program. Thus, we expected to see somewhat different action type patterns for experienced and inexperienced users. In what follows we compare and contrast action type patterns for the two groups using mean percentages relative to the total number of actions.

ACTION TYPE	PERCENTAGE OF TOTAL NUMBER OF ACTIONS INITIAL MAP		
	Experienced users (n = 59)	Inexperienced users (n = 193)	Mean Comparison test
Concept addition	9%	11%	Significant (P = 0.00)
Concept text modification	8%	7%	Significant (P = 0.01)
Concept deletion	4%	7%	Significant (P = 0.00)
Linking phrase addition	6%	8%	Significant (P = 0.00)
Linking phrase text modification	5%	5%	**Non significant**
Linking phrase deletion	3%	5%	Significant (P = 0.00)
Object movement	27%	21%	Significant (P = 0.00)
Styles addition	10%	4%	Significant (P = 0.00)
Resource group link addition	0%	0%	**Non significant**

Table 7. Mean percentages for experienced and inexperienced users in each action type category on the initial Cmap.

On average, experienced users performed significantly more actions than their inexperienced counterparts: 513 and 978 on first and final Cmaps, for experienced users versus 474 and 686 for inexperienced users. Total map construction time, though, turned out not to be significantly different for the two groups on either map, and so was not considered.[69]

Table 7 gives mean percentages for the two groups for each of the 9 basic action types. Predictably, on the first map significant differences turned up in all categories except two, linking phrase text modification and resource group link addition. The percentages for addition and deletion of both concepts and linking phrases were significantly higher for the inexperienced group. The situation was reversed for concept text modification, object movement and style addition, where the inexperienced group had lower percentages.

[69] This is not totally surprising since facilitators more or less controlled the time. However, there was the possibility that teachers would decide they were done and stop working on their maps before the time was up.

ACTION TYPE	PERCENTAGE OF TOTAL NUMBER OF ACTIONS FINAL CMAP		
	Experienced users (n = 59)	**Inexperienced users (n = 193)**	**Mean Comparison test**
Concept addition	6%	8%	Significant (P = 0.00)
Concept text modification	6%	6%	**Non significant**
Concept deletion	2%	4%	Significant (P = 0.00)
Linking phrase addition	3%	5%	Significant (P = 0.00)
Linking phrase text modification	3%	4%	**Non significant**
Linking phrase deletion	1%	3%	Significant (P = 0.00)
Object movement	30%	29%	**Non significant**
Styles addition	31%	21%	Significant (P = 0.00)
Resource group link addition	1%	1%	**Non significant**

Table 8. Mean percentages for experienced and inexperienced users in each action type category on final Cmap.

In the final map (table 8), patterns for addition and deletion of both concepts and linking phrases remained unchanged relative to the first map, that is, higher percentages for inexperienced users, while styles addition continued to be higher for experienced users. Linking phrase text modification and resource group link addition remained equivalent for the two groups. Statistical differences in concept text modification, as well as in object movement, however, disappeared.

In general, lack of experience in computer use shows up as difficulties in the fine motor skills required to manipulate the mouse, specifically, the ability to *click, double click* and *drag-and-drop*. Such troubles could result in unintentionally creating unwanted concept and linking phrase boxes (see section 7.5 for further evidence supporting this conjecture). Though all users may at some point create boxes accidentally, one would expect this to be a more frequent occurrence with inexperienced users. Since unwanted boxes would have to be eliminated, one would also anticipate more of deletions. These expectations were indeed confirmed by the higher percentages for additions and deletions of concepts and linking phrases observed among inexperienced users.

It is important to call attention to the fact that percentages of text modification, of linking phrases in the initial Cmap, and concepts and linking phrases in the final Cmap, were equivalent and low in both groups, suggesting that neither experienced nor inexperienced users were particularly inclined to rewriting their concepts or linking phrases once they were put in the map. Two factors that might contribute to this lack of interest in modifying text are a rote style of learning and, related to that, an emphasis on form over content. Learners accustomed to learning by rote generally do not question, do not attempt to relate new information to previous knowledge; hence one would predict little or no modification of text once it has been written down. On the other hand, rote learners may prefer to deal with the way things *look* rather than with what they actually *say*. This would appear to be supported by the fact that the most common actions performed by all subjects, regardless of their experience with computers, were moving objects and adding styles.

Insofar as resources are concerned, similarities in percentages of resource addition can be explained quite easily by the fact that: 1) when constructing the first map neither group had been told that resources could be attached to maps, and 2) the numbers are very small compared to the total number of actions. In light of these small values, the percentages shown in tables 7 and 8 do not tell the whole story. A closer look shows that 69% of the experienced users included at least one resource in their final Cmap compared to 46% of the inexperienced users; this translates to a factor of 1.5 times as often. Moreover, the average number of resources added was significantly different for the two groups as well: 5 for the former and 3 for the latter, or 1.7 times as many resources for the experienced group.

Viewed from within, the group of inexperienced users showed significant changes between the first and last Cmap for every action type category: lower values for addition, modification and deletion of concepts and links, and higher values for movement, styles and resources. The pattern for the group of experienced users was identical, differing only in the movement category, where no difference was found between the two maps. Except for text modification, all other changes are in agreement with what one would anticipate as users become more adroit in utilizing the concept mapping program.

7.3 Topological evaluation of Cmaps

Structural complexity of completed concept maps, measured with the topological taxonomy, was the second axis along which we appraised skill acquisition in concept mapping. This section describes these results. It must be pointed out that the application of the topological taxonomy (as well as the semantic scoring rubric) to the 516 Cmaps in our sample was carried out by the researcher. However, results were validated by submitting approximately 10% of the sample, 50 randomly selected Cmaps[70] (25 initial maps and 25 final maps), to two independent evaluators,[71] who after discussing their differences arrived at a consensus evaluation. The percent agreement between our topological evaluation and that of the independent evaluators was 80%.

The topological level distribution for the first and last concept maps is shown in figure 17. One can appreciate from the graph that the initial map exhibits a fairly symmetric normal

[70] Given the context in which this study took place, it was not possible to find people who had the knowledge and the time to evaluate the entire sample set of 516 Cmaps.
[71] The two independent evaluators were a Conéctate facilitator and a consultant to the Project; both participated in the development of the taxonomy and hence were quite familiar with the instruments. In terms of actual experience using the tools, they were considerably more practiced with the topological taxonomy than with the scoring rubric, though.

distribution, with its peak around level 3. Indeed, the average topological level on the first Cmap was 2.9, (2.7, 3.1), corresponding roughly to maps with well-identified individual concepts as opposed to texts, lacking no linking phrases, but with low ramification, i.e., still mostly linear sequences of concepts, and rather shallow. A full third of the teachers' first maps fall within the region we have characterized as "poor" (levels 0-2), whereas barely over 10% may be considered "very good" (levels 5-6). In contrast, the distribution on the final map is skewed to the right and the proportions are reversed: fewer than 10% of the maps fall in the "poor" category, and well over a third are "very good" maps, topologically speaking.

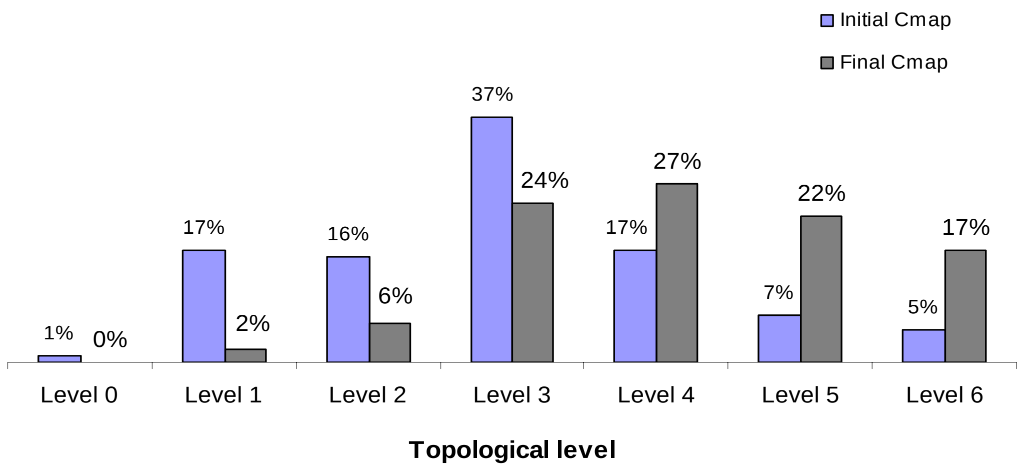


Figure 17. Topological level distribution on initial and final Cmaps.

This important shift to the right in the final map is captured by the mean topological level, which increased to 4.1 (4.0, 4.3). Level 4 maps contain no long pieces of text, omit no linking phrases, have high ramification (5-6 branching points), and have 3 or more hierarchy levels. Thus, as noted earlier, structurally speaking level 4 concept maps are "good" maps. However, they lack one major ingredient, cross-links. We have emphasized the importance of cross-links as a signal of integrative reconciliation, a key element of Ausubel's theory of meaningful learning. Without them concept maps tend to consist of separate strings of thought, unrelated to one another.

An interesting statistic to consider was the fraction of teachers whose concept maps increased in structural complexity. Computations show that 70% of teachers had final maps that were topologically more complex than their first maps. The average increase (rounded to the nearest integer) was 2 levels. The remaining 31% generated final maps that were equally or even less complex than their first maps. The average decrease (rounded to the nearest integer) was less, only 1 level. Although the positive results are good, one certainly wonders at the reasons why approximately a third of teachers would end up showing no improvement or building simpler maps at the end of the workshop.

Topological level did not differ significantly by *gender*, by *topic* (freely chosen, versus assigned reading), by *province of birth*, or by *school location*.[72] In contrast, a weak negative

[72] In all these computations, correlations and ANOVAS were used for continuous independent variables while logistic regressions were used for categorical independent variables.

correlation $(r = -0.28)$, which became negligible on the final Cmap $(r = -0.14)$, was found with *age*. Not surprisingly given its dependence on *age*, similar results were observed for *years of service*.[73] This pattern was to be expected, for as teachers acquire skill in building concept maps, the initial disadvantage due to age should decrease. Topological level also showed a weak positive correlation $(r = 0.22)$ with *map construction time* which became slightly stronger $(r = 0.28)$ on the final Cmap. This result makes sense because when there is little or no knowledge about a given task, additional time will generally not be helpful; when there *is* understanding, time will make a great difference in terms of doing a better job on the task. Though no association was found on the initial Cmap by *training group*, one did appear on the final map. Again this is consistent with the fact that any effect due to facilitators, if one was to exist, should become more noticeable over time. Astonishingly, there was no correlation with *years of university studies* on either Cmap. Relationships to computer experience and specific preconceptions about concept maps are discussed in the following two sections.

7.3.1 Topological level vs. computer experience

Experience with computers is expected to have some effect on the topological level of Cmaps. In particular one might anticipate greater structural complexity in maps of experienced users. Results confirmed this to be the case, but also showed that the advantage disappeared by the end of the workshop. The numbers were as follows: on the initial Cmap, the average topological level for the experienced user group was 3.5 (3.1, 3.9), whereas the average for the inexperienced user group was 2.7 (2.6, 2.9). This difference turned out to be statistically significant $(P = 0.00)$. On the final map the numbers were 4.3 (4.0, 4.6) and 4.1 (3.9, 4.2), for experienced and inexperienced users, respectively, no longer of statistical import.

7.3.2 Topological level vs. preconceptions about concept maps

Comparing topological levels of those teachers who used concept maps in their work (63% in our sample) and those who did not, we found significant differences on the first Cmap: 3.1 for the former group versus 2.7 for the latter (P = 0.01); by the final Cmap, though, the numbers were 4.2 versus 3.9, and were no longer significant at the 5% threshold. Our data also established that most teachers had serious misconceptions concerning certain aspects of concept maps. We were under the impression these incorrect notions might be partly to blame for the difficulties facilitators were encountering in getting teachers to correctly understand and apply the ideas presented in the workshops. Thus, we set out to look for indications that these ideas negatively impacted teachers' Cmaps. For reasons previously discussed, we focused our attention on the misconceptions about crossing connecting lines and about the nature of linking words. Of the two, only the former would be expected to have any impact upon Cmap structure. Nonetheless, we explored the influence of both on two notions related to structure: 1) topological level and 2) presence of cross-links.

Remarkably, calculations showed that the average topological level was not significantly different on either Cmap for those who would allow crossings than for those who would not. Similar calculations for cross-links also yielded no significant differences, that is,

[73] The logistic model with *age* and *years of service* as independent variables confirmed that indeed the effect was due only to the *age* variable.

preconceptions about line crossings were found to have no bearing on the presence (or absence) of cross-links in the maps. This result may be due to the fact that very few cross-links were included in the maps; further investigation into this question would seem necessary and worthwhile.

Misconceptions regarding the number and kind of words in linking phrases were found not to have any association with topological level or presence of cross-links, but this result was not surprising considering that neither the nature nor the number of words contained in linking phrases (as long as linking phrases are present) should affect the topology of concept maps.

7.3.3 Topological level vs. actions performed during Cmap construction

In this section we consider the relation between the structure of complete Cmaps and the actions performed during the construction process. To this end, we computed correlation coefficients between topological level and percentages of total number of actions dedicated to specific action types.[74] The results are shown in figure 18. In order to make patterns more plainly visible, we arranged the action type categories differently than in section 7.2: *addition* appears first, followed by *deletion*, *text modification*, *object movement* and *addition of styles*.

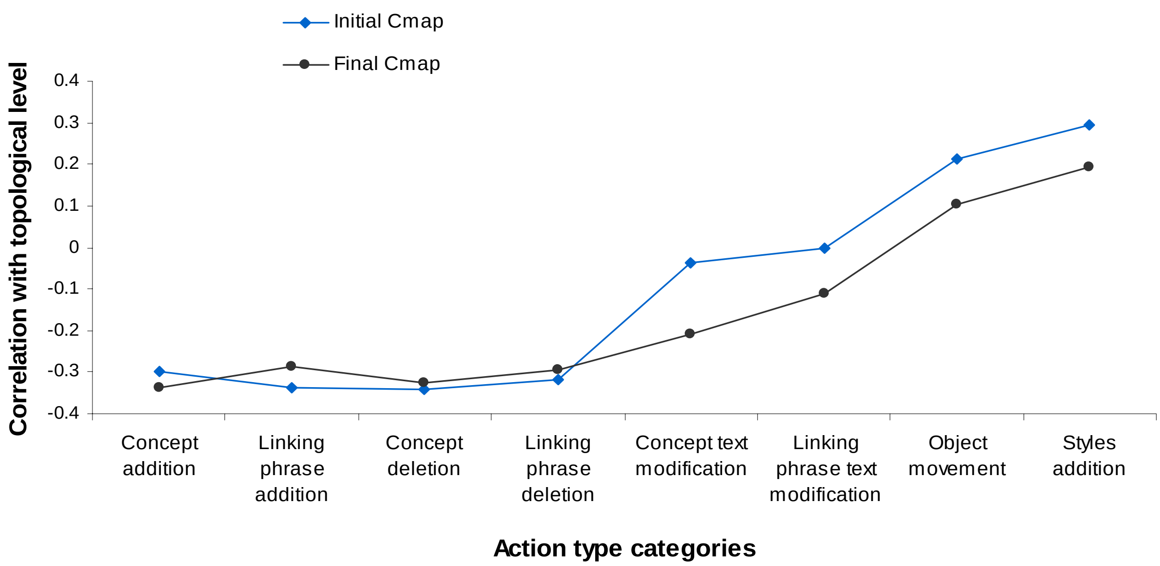


Figure 18. Correlations between topological level and actions performed during construction of initial and final Cmaps.

Two things strike our attention about the graphs in figure 18. The first is the similarity between the correlation patterns on the initial and final Cmaps. The second is that although the magnitudes of relationships are weak, there is nevertheless a very definite tendency. In the initial Cmap, additions and deletions of concepts as well as linking phrases showed negative correlations with respect to topological level; text modifications showed correlations close to 0; while object movement and style additions had positive correlations. Combined with results from 7.2.1 and 7.3.1, this pattern suggests the hypothesis that those who struggled the most with CmapTools (as manifested by adding and deleting more, probably unwanted,

[74] Resource addition was not included due to the very small values involved.

objects), were less able to improve their maps' structures; conversely, those who were more computer savvy, who struggled less (as attested by higher percentages for moving and styling), were in a better position to improve the topology of their Cmaps. Interestingly, what teachers did in terms of text modification contributed little to improve map topology. The main difference with the final Cmap is that text modification became negatively (albeit weakly) correlated to topological level. An explanation for this could be that the kinds of modifications being made to the text[75] did not lead to any significant restructuring of the Cmap. Finally, the fact that correlations with object movement and style addition remained positive but decreased to negligible in final Cmaps may be a reflection of the emphasis on form over content: the mechanical ability was present, but it was not applied to improving structure.

7.4 Semantic evaluation of Cmaps

The third and final dimension along which we considered skill acquisition in concept mapping dealt with semantic content. This was the most complex and subtle aspect to gauge, since, necessarily, there was a great deal more subjectivity involved in content assessment than in the assessment of structure or in the determination of actions performed during concept map construction. Content evaluation was carried out mainly using the semantic scoring rubric, but additional analyses were performed on the process data registered by the CmapTools Recorder. We looked specifically at evolution patterns or transformation sequences of concept boxes and linking phrase boxes from the moment they were first created to their final form in the completed concept map. We analyzed approximately 2,500 individual concepts and 1,500 individual linking phrases contained in the Cmaps of a sub-sample of 25 randomly selected teachers. This exploration led us, quite naturally, to formulate and apply to our sub-sample a classification system for the types of modifications generally performed on both concepts and linking phrases. Finally, a statistic we have called "concept permanence," which measures the likelihood that a given concept once created survives in the final map, was computed.

As previously explained, the semantic scoring rubric we developed was part of a larger undertaking, namely, an effort to create a taxonomy for concept maps that would equip the Conéctate Project with sorely needed instruments to gauge the Project's advancement towards its larger goals and to customize support to individual teachers and schools. This study constituted the first application and testing ground of this tool, and has led to additional refinements of the rubric.

We observed earlier that the *semantic score* is the total number of points obtained across all 6 criteria of the scoring rubric. The semantic score is converted into a 6-level ordinal scale ranging from *unevaluated* to *very high* (see appendix C for conversion key), which is what we refer to as *semantic level*. The concordance between our evaluation and the one performed by the independent evaluators was 69%. Clearly, agreement is not as good as for the topological taxonomy, which allows much less room for personal interpretation. Nonetheless, in comparing the independent evaluation with our own we note two things: 1) the differences were never more than one level and, 2) when different, our evaluations were always higher, indicating that independent evaluators were stricter in their application of the tool. If we allow discrepancies of *at most* 1 level, agreement goes up to 100%.

[75] These modifications will be discussed in detail in section 7.5.

The following section reports the results of applying this scoring scheme to the full sample of 516 Cmaps from the 258 teachers considered in this investigation.

7.4.1 Semantic level distribution

Figure 19 shows the semantic level distribution for the initial and final Cmaps. The average semantic score on the first map was 6.4 (6.1, 6.7), whereas the average score on the final map was 8.1 (7.8, 8.5). Although the difference was statistically significant, in both cases the content level, according to our rubric, was *low*.

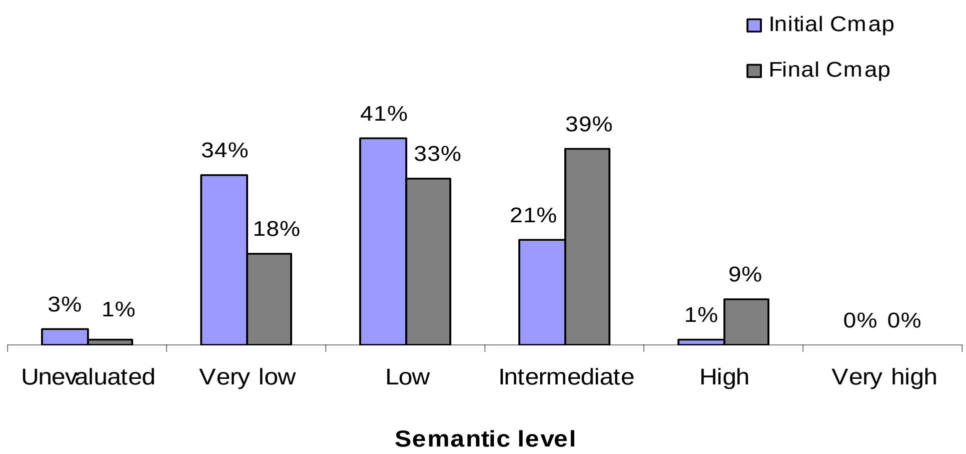


Figure 19. Semantic level distribution on initial and final Cmaps.

Computations indicate that while 64% of teachers improved their semantic score between the first and final map, this improvement did not always move them into a higher quality level. Of those whose score increased, 76% (48% of the total) advanced into a higher quality range. In the full sample, 52% remained at the same semantic level they started out at (either because their score did not increase or did not increase enough), or actually fell to a lower level. For the group whose level improved, average semantic score increase was 3.5 points, compared to a decrease of 1.5 points for the group whose semantic level remained unchanged or worsened. As with the topological level, the positive changes are encouraging. However, the magnitude of the change is barely one level. And there is still the 50% who changed in the wrong direction to be concerned about.

As with topological level, we examined the relationship between semantic score and other variables. Semantic score varied significantly by *gender* on the final Cmap, though not on the initial one: the average score for males was 9.0 versus 7.8 (P = 0.00) for females. No associations were found for *province of birth* or *school location*. Weak negative correlations turned up on both Cmaps relative to *age* ($r = -0.21$ and $r = -0.25$), whereas weak positive correlations showed up with respect to *construction time* ($r = 0.27$ and $r = 0.25$). Once again, there was no association with *years of university studies*: more years of higher education did not contribute to improve either structure or content. There appear to be differences by *training group*, more noticeable on the final Cmap than on the first, but since variances also fluctuated greatly from one group to another, the standard tests[76] are not reliable. Associations with *topic* and *computer experience* are considered below.

7.4.2 Analysis of specific semantic elements

In order to get a better sense of the semantic changes that took place, we looked in greater detail at three specific semantic elements: dynamic propositions, cross-links and focus questions. The first two are among the criteria included in the semantic scoring rubric; the third one is not, mainly because teachers may not write down an explicit focus question in their maps, but may simply have it in their minds.

We begin by examining the distribution of dynamic propositions, according to the categories put forth in the semantic scoring rubric (figure 20). We note a similar pattern for both the initial and final Cmap, characterized by a relatively uniform distribution across the first four categories, which contrasts with the absence of propositions in the fifth category, the class of quantified causative dynamic propositions. The main difference between the two maps was a general shift to the right. Nonetheless, almost a quarter of the final maps still contained only static propositions, and the fraction of maps containing more than 2 causative dynamic propositions, or 1 or more quantified causative propositions did not vary at all. It is important to point out that neither the notion of dynamic proposition nor this categorization were discussed in the workshops; indeed, these ideas were developed as part of the semantic scoring rubric and were not known to the majority of facilitators at the time the data was being collected. However, the ideas that motivated this particular classification, namely, the need to see more explanatory propositions in concept maps (as opposed to purely descriptive statements) were familiar to everyone at Conéctate, since they have been the subject of presentations and publications by Project's consultants (e.g., Cañas & Novak, 2006).

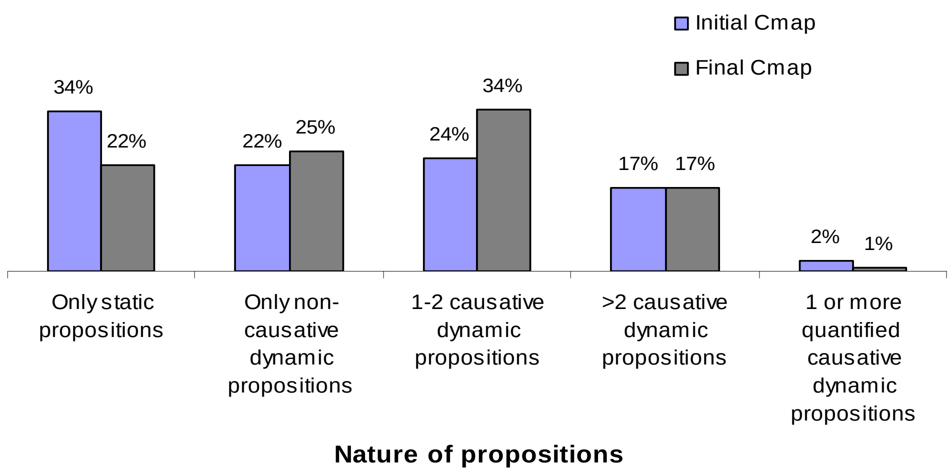


Figure 20. Nature of dynamic propositions present in initial and final Cmaps.

[76] Standard tests assume equal variances among groups. Tests that allow unequal variances, assume only two groups – we have 18.

The second semantic element we considered was the presence and nature of cross-links. From the graph in figure 21 it follows that 30% of the initial maps contained cross-links, and this percentage increased to 54% on the final map. This increase is important since as we have pointed out, cross-links are believed to be closely tied to creative and nonlinear thinking. However, it is important to keep in mind that the mere presence of cross-links does not guarantee this kind of thinking since cross-links may be meaningless, redundant, or irrelevant, or may even state erroneous ideas. In fact, of the cross-links on the first Cmap, 8% were meaningless, 4% erroneous and 3% redundant or irrelevant. On the last Cmap, the numbers were 12%, 2% and 9%, respectively.

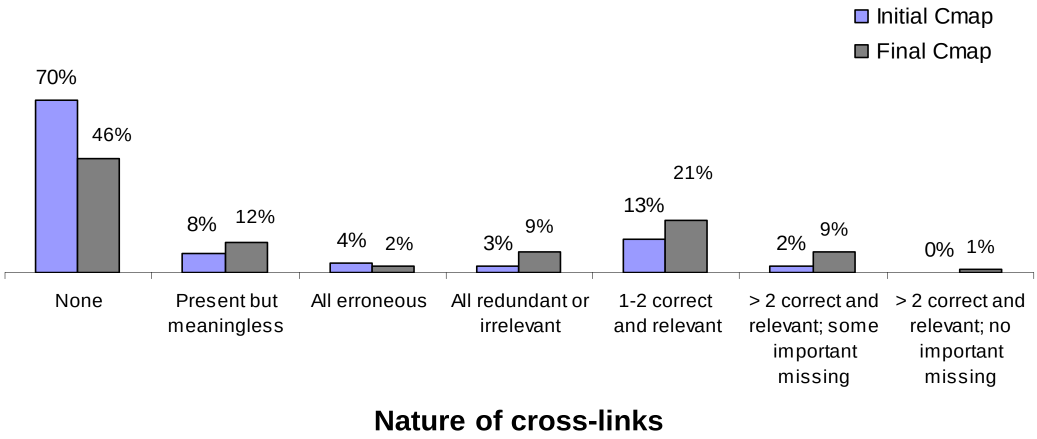


Figure 21. Nature of cross-links present in initial and final Cmaps.

An interesting result was the strong positive association between the presence of cross-links in the first and final Cmaps. As can be seen in the contingency table below (table 9), those teachers who included cross-links in their initial maps were almost twice as likely to include them in their final maps; on the other hand, those who did not have cross-links in their initial map, were just as likely to have them as not to have them in their final map. This result suggests that it is important to get the idea of cross-links across to teachers early in the workshop, and to reinforce it repeatedly throughout.

		CROSS-LINKS IN FINAL CMAP		
		Not present	**Present**	**Total**
CROSS-LINKS IN INITIAL CMAP	**Not present**	**92**	**88**	**180**
	Present	**27**	**51**	**78**
	Total	**119**	**139**	**258**

Table 9. Contingency table showing significant association ($P = 0.02$) between presence of cross-links on initial and final Cmaps.

Suspecting that certain facilitators might be more inclined to discuss cross-links early on in the workshop than others, we investigated differences in percentages of Cmaps containing cross-links across the 18 training groups. Analysis of variance exposed significant variations on both Cmaps. The range on the first map was 11% to 65%; the range on the final map was even greater, from 18% to 90%. Facilitator input (or lack thereof) is the most plausible explanation for this outcome. This kind of variability on something as crucial as cross-links draws attention to the need to work with facilitators regarding this issue.

Focus questions were the last of the three semantic elements we looked into. Figure 22 displays the distribution of focus questions on the initial and final Cmaps, according to the classification described in section 2.1.4. In both cases the distribution was centered on the open-static category; however, there was less dispersion in the final Cmap. As can be seen, the narrowing of the range in the final map resulted from a 20% decrease of maps with no focus question and a corresponding increase of maps with open-static focus questions; it is interesting to note, that the overall the percentages in the closed/classificatory and open-dynamic categories remained virtually unchanged. In a sense these findings were reflect the emphasis placed by facilitators on the importance of including focus questions in concept maps, and the encouragement given to considering topics outside the school curriculum, and closer to personal experience.

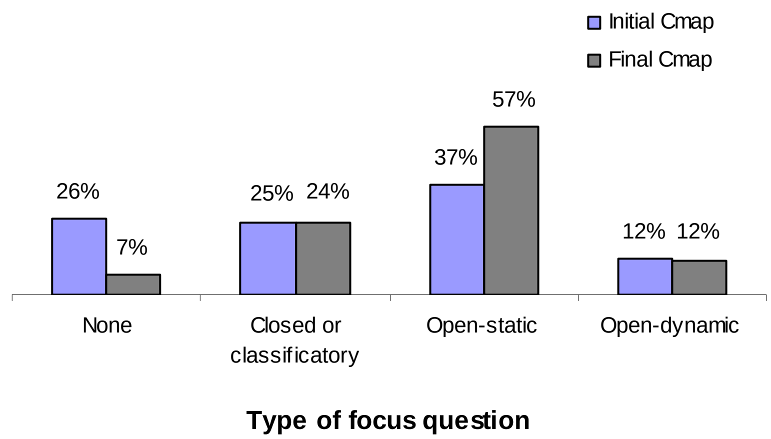


Figure 22. Distribution of focus questions in initial and final Cmaps.

Next we explore the relationship between the dynamic nature of the propositions present in a concept map and the type of focus question put forth. This was first done graphically (figures 23 and 24). Inspection of the graphs seems to indicate an association between these two variables, stronger in the final Cmap than in the initial one. If one were to envelope all four categories of focus question under a single bell-shaped curve, one would notice, in the first Cmap, that the center hovers somewhere between the closed/classificatory and the open-static category, and the distribution has a fairly high variance; in contrast, in the final map the mean lies farther to the right, above the open-static category, and there is much less variance in the distribution.

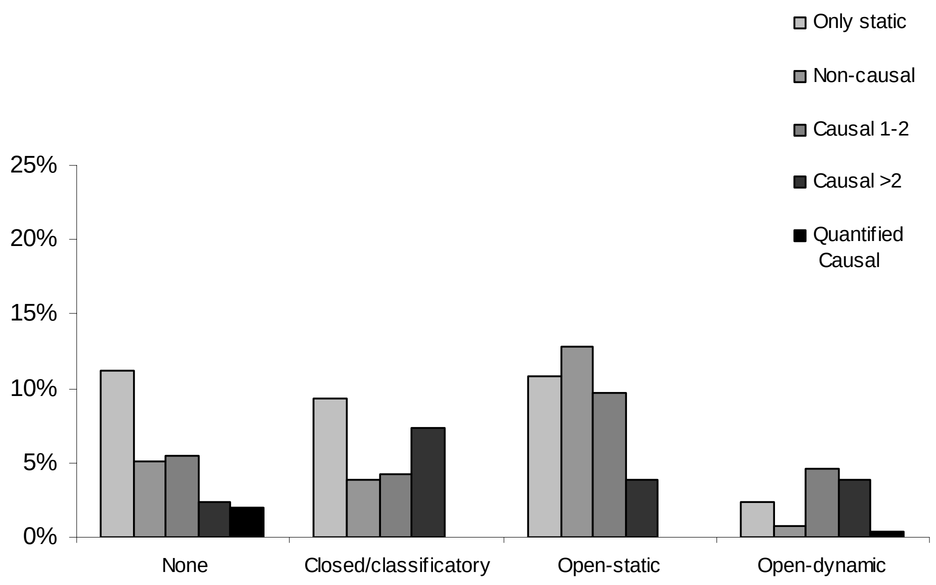


Figure 23. Relation between type of focus question and nature of propositions on initial Cmap.

If one looks across the different categories one also notes a certain pattern: the center of bell curves superimposed over each of the 4 categories moves farther to the right as the category moves to the right. This pattern is more pronounced and evident in the final map. What this suggests is that as the focus question becomes more open and requires more explanation to answer it, the propositions indeed become increasingly explicative.

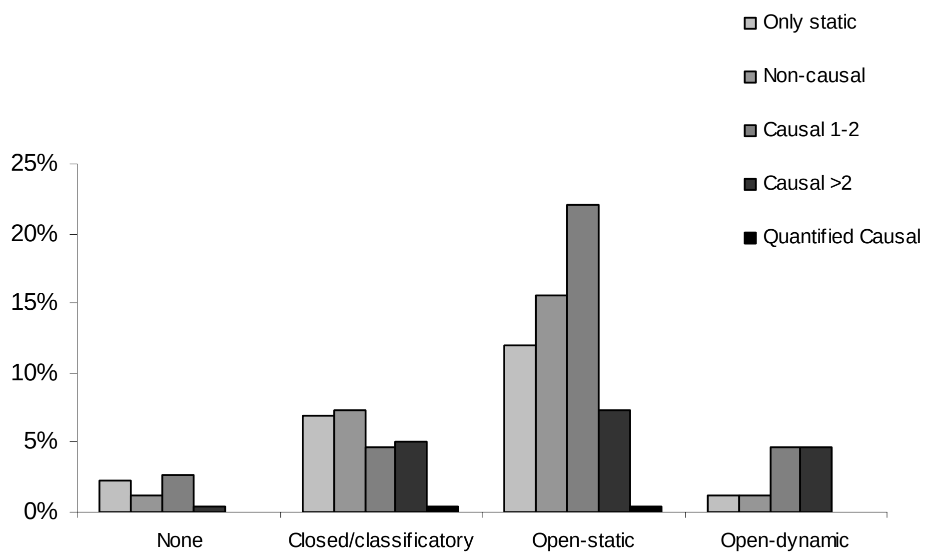


Figure 24. Relation between type of focus question and nature of propositions on final Cmap.

To investigate this relationship analytically we made use of ordered logit regression analysis, since the two categorical variables have a "natural" ordering. The "goodness of fit" probability was $P = 0.09$ on the initial Cmap and $P = 0.00$ on the final Cmap. Thus, the null hypothesis – that there is no relation between the type of focus question (independent variable) and presence of dynamic propositions (dependent variable) – is rejected in favor of an association between the two variables. Moreover, the probability values indicate a weaker association in the first Cmap and a much stronger relationship in the final one, in agreement with our interpretation of the graphs in figures 23 and 24.

7.4.3 Comparison between reading and non-reading-based Cmaps

In contrast to the final Cmap which was on a free topic, the first Cmap constructed on CmapTools could be based either on a topic freely chosen by teachers or on a reading provided by facilitators. As it turned out, 4 of the 18 training groups based their first map on an assigned reading. The text, which dealt with the benefits of regular physical activity, was explanatory in nature. It contained a great many cause-effect statements, and understanding the text required the reader to follow the sequences of causal relationships. Though written for the lay person, the text did contain technical terms such as "glycogen deposits," "resistance to the action of insulin," and "endorphins," which probably were not familiar to most teachers. In this section we compare teachers' performance on the reading-based and non reading-based (free topic) Cmaps.

The mean semantic score for the reading-based group was 6.9 points versus 6.3 for the non reading-based group. The difference turned out not to be statistically significant. Although the second map was free topic for everyone, we went ahead and computed the semantic score for each of the two groups on this map. The score for the reading-based group was 7.5, and for the non reading-based group, 8.3, and this difference did turn out to be significant. Intrigued by a significance which favored the *non* reading-based group, we compared and tested the *change in semantic score*, as opposed to the actual scores. The reading-based group increased by 0.8 points, while the non-reading based group increased by 2.1 points, almost three times as much $(P = 0.00)$.

TOPIC OF INITIAL CMAP

		Reading-based Cmap	Free topic Cmap	Total
SEMANTIC SCORE CHANGE	**Negative or no change**	**31**	**62**	**180**
	Positive change	**33**	**132**	**78**
	Total	**64**	**194**	**258**

Table 10. Contingency table showing significant association $(P = 0.00)$ between semantic score change and topic of initial Cmap.

The fact that the overall change for the non-reading group was higher than for the reading-based group was a somewhat surprising result that led us to delve deeper into each of the 6 criteria comprising the semantic scoring rubric, in the hopes of detecting the source (or sources) of the difference. What we found was that on the first map, the reading-based group had significantly more dynamic propositions and more conceptual errors. On the final map, no difference was observed between the two groups on either of these criteria; a significant difference was measured however in concept completeness and relevance, where the reading-based group came out lower.

The fact that the reading-based group produced more dynamic propositions on their very first map, but failed to maintain this advantage on the final map would suggest that the first measurement did not truly reflect that group's ability to compose dynamic statements. Rather, given that the text contained numerous dynamic relationships, and that the reading-based group was allowed to refer to the text while constructing their maps, the above result is consistent with what one would expect if propositions were being transferred directly from the text to the map. Further evidence for this is the great similarity among propositions from different teachers' maps, which in turn were quite similar to the original reading passage.

On the other hand, there is no reason to expect, a priori, significant differences in the number of conceptual errors between the two groups on either map. The increased presence of erroneous propositions in the reading-based maps appears to have been, at least in part, the result of reading comprehension and information processing difficulties, as the following examples illustrate.

Example 1:

Original text statement: *"stimulation of blood flow favors release of endorphins"*

Erroneous proposition in Cmap: *"blood flow favors release of endorphins."*

Example 2:

Original text statement: *"Physical exercise... facilitates control and reduction of risk of diabetes. Studies suggest that regular exercising can reduce the risk of developing diabetes. The reason is simple: it maintains a low body weight (obesity is a risk factor for this illness). Besides, it decreases resistance to insulin action, thereby controlling blood sugar levels."*

Erroneous proposition in Cmap: *"control and reduction of risk of diabetes decreases resistance to insulin action."*

The count of false propositions in the reading-based group may have been inadvertently increased by extraneous factors, such as lack of familiarity with the propositional nature of concept maps (recall this map was constructed on the second day of the workshop). The following example illustrates this point.

Example 3:

Original text statement: *"Keeping the body in motion diminishes premenstrual tension, by stimulating blood flow, thus sending oxygen to the muscles and liberating endorphins, a natural analgesic and mood-enhancer."*

The mapper may have intended to construct the propositions *"physical exercise diminishes premenstrual tension,"* and *"physical exercise stimulates blood flow,"* as shown in the map in figure 25.

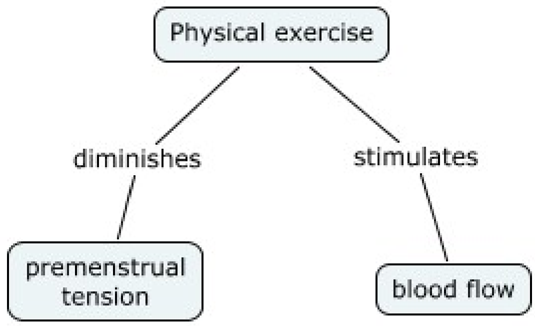


Figure 25. Correct representation of the propositions *"physical exercise diminishes premenstrual tension"* and *"physical exercise stimulates blood flow."*

However, being accustomed to the linear structure of text, as opposed to the non-linear structure of concept maps, the beginning mapper might place the two propositions head-to-tail, leading to the construct shown in figure 26, where the second proposition from the top, "premenstrual tension stimulates blood flow," is false. The idea in the mind of the mapper might have been correct, but its representation would not have.

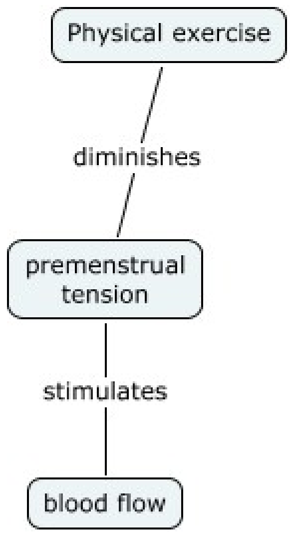


Figure 26. Incorrect representation of the propositions *"physical exercise diminishes premenstrual tension"* and *"physical exercise stimulates blood flow."*

We have found that it is rather common for beginning mappers to make the kind of mistake exemplified in figure 26, since they are still thinking in terms of the linear format of texts, rather than the nonlinear arrangements of concept maps. Unfortunately, there is no way for the evaluator to decide whether the proposition was an honest to God conceptual error or an inappropriate use of propositional structure, first, because the triad forms a valid proposition (according to criterion 2 in the scoring rubric), and second, because it is not uncommon for teachers to have misconceptions similar to this one. Thus, in situations like these propositions would have been counted, unjustly, as an erroneous.

Results from this section show that the non-reading based group clearly made greater progress, from a semantic point of view, than their reading-based counterpart. This outcome is interesting insofar as it intimates that the reading-based concept mapping assignment may have been somewhat detrimental to teachers' training. Two possible explanations, not necessarily independent, come to mind: 1) teachers from the non reading-based group had to struggle more, early on in their training, to construct their propositions – their learning was therefore more meaningful; 2) facilitators gauged incorrectly the understanding of teachers in the reading-based group, and thus provided less feedback. Further investigation would be needed to clarify this issue.

7.4.4 Semantic content vs. computer experience

The mean semantic score on the initial Cmap for experienced users was 7.3 (6.6, 7.9), versus 6.1 (5.8, 6.4) for inexperienced users. The difference, though small, was statistically significant (P = 0.00). We note that these scores both fall in the *low* quality level. On the final map once again, the difference was statistically significant (P = 0.00). The experienced group increased its average score to 9.1 (8.4, 9.8), while the inexperienced group increased to 7.8 (7.5, 8.2), which places them at the low end of the *intermediate* level and the high end of the *low* level, respectively.

Probing the semantic rubric item-by-item, we discovered that differences in quality between the two groups resulted mostly from a sole item, cross-links. On the initial Cmap, experienced users were 1.8 times as likely to construct cross-links (46% versus 25%); on the final map this factor decreased to 1.4 (68% versus 50%), but was still statistically significant. The quantity and quality of cross-links, as measured by the score on criterion 5 of the rubric, was also higher for experienced users on both Cmaps: 1.6 versus 1.2 on the first, 2.2 versus 1.7 on the last, significant in both cases.

7.4.5 Semantic content vs. preconceptions about concept maps

Significant differences in semantic score were found between teachers who used concept maps in their work and those who did not. On the first map the scores for the two groups were 6.8 and 6.1 (P = 0.06), respectively; on the final map, 8.5 and 7.7 (P = 0.03). As in section 7.3.2, we also explored the impact that the two major misconceptions (regarding crossing connecting lines and linking words), might have had on content, as reflected by the semantic score. No significances were found for either misconception.

7.4.6 Semantic score vs. actions performed during Cmap construction

In this section we examine the correlations between semantic score and the actions performed by the teachers while constructing their Cmaps. The graphs in figure 27 were obtained in a manner analogous to the one described earlier for figure 18 (section 7.3.3).

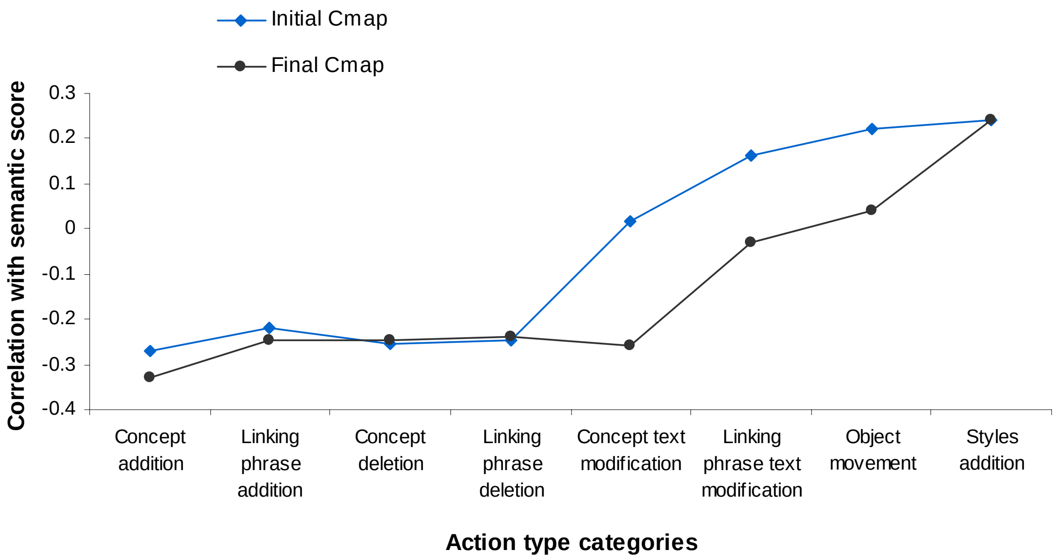


Figure 27. Correlations between semantic score and actions performed during construction of initial and final Cmaps.

The most conspicuous feature of figure 27 is perhaps its likeness to figure 18. As with topological level, correlations of action types with respect to semantic score are weak but show a clear pattern. Correlations for additions and deletions of concept and linking phrase boxes are negative, and essentially the same on the initial and final Cmaps. Correlations for object movement and styles addition, on the other hand, are positive, though the object movement relationship became nearly 0 on the final map. The greatest changes were with respect to text modification, where the correlation changed from null to negative, for concepts, and from positive to null, for linking phrases. These downward changes indicate that efforts invested in modifying text were at best irrelevant for, and at worst detrimental to, Cmap semantic quality.

These results, together with those from 7.2.1 and 7.4.4, suggest (as before for topological level) that those who were less adept in using CmapTools were less able to improve map content. Contrariwise, it appears that those who grappled less with the program were more successful in increasing content quality; nonetheless, that this was less true on the final Cmap may be a reflection of greater emphasis being placed on form rather than content. A similar argument may help understand the decrease in correlation coefficients for text modification. Additionally, the fact that these negative changes were greater in absolute value than in figure 18, might be a reflection of the greater relevance of text modification for content than for structure.

7.4.7 Semantic level vs. topological level of Cmaps

What relation if any exists between semantic level and topological level? In this section we investigate the association between structural and semantic complexity of the completed Cmaps.

Calculations yielded only 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 topological levels, we found (table 11) 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. On the other hand, those who had a positive change in topology had only a slightly greater chance to improve semantic level (1.1); while those who had a negative change in topology where about half as likely (0.6) to improve semantics. Overall, we see that changes in content have a greater effect on structure than vice versa. That is, improving content quality will tend to improve topology, not the other way around.

		SEMANTIC LEVEL CHANGE		
		Negative or no change	**Positive change**	**Total**
TOPOLOGICAL LEVEL CHANGE	**Negative or no change**	**48**	**29**	**77**
	Positive change	**85**	**96**	**181**
	Total	**133**	**125**	**258**

Table 11. Contingency table showing significant association $(P = 0.02)$ between changes in topological level and changes in semantic level.

7.5 Transformation sequences of concepts and linking phrases

In section 7.2 we analyzed the actions performed by teachers during construction of their concept maps. This analysis shed some light on what goes on in computer-mediated concept mapping when teachers are first acquiring the skill. For instance, we were able to obtain basic information regarding, among other things, the number of times concept and linking phrase boxes were added and deleted, and the number of times text was written inside concept and linking phrase boxes. However, the picture that emerges from that data is still rather vague. We may know, for instance, what fraction of a teacher's actions corresponds to writing text within a concept box, but we cannot distinguish between text that was written for the first time and modifications of previously written text. This is an important distinction if one is interested, as are we, in understanding thought processes occurring during concept map construction.

To better infer the cognitive processes taking place during the concept map creation process, one must follow the progression or evolution of each and every concept box and linking phrase box. The enormity of this task, compounded by real time constraints, forced us to limit our analysis to a subset of the full sample set. Thus, a sub-sample of 25 teachers was selected at random from the original pool, for a total of 50 Cmaps (25 initial maps and 25 final maps). Among the 25, 4 teachers were experienced computer users, that is, 16% of the sub-sample.[77]

Every concept box and linking phrase box created in each of these 50 maps was followed, from its initial appearance, through all text modifications, to its final form. Since we were interested mainly in following semantic transformations, we overlooked style and layout modifications. Altogether, 2,499 distinct concept boxes (1,334 in the initial map and 1,165 in the final map) and 1,533 distinct linking phrase boxes (893 in the initial map and 640 in the final map) were tracked, an average of approximately 50 concepts boxes and 30 linking phrase boxes per map.

Six different evolution patterns (for concept boxes as well as linking phrase boxes) were possible: 1) boxes might be created but never written in; 2) boxes might be written in and deleted without ever writing in them; 3) boxes might be written in once but never modified; 4) boxes might be written in and subsequently modified (once or more times); 5) boxes might be written in and subsequently deleted; and 6) boxes might be written in, modified (once or more times) but ultimately deleted from the concept map. Table 12 below shows the results of our analysis.[78]

TRANSFORMATION SEQUENCES	CONCEPT BOXES		LINKING PHRASE BOXES	
	Initial Cmap (n = 1,334)	Final Cmap (n = 1,165)	Initial Cmap (n = 893)	Final Cmap (n = 640)
Box created, left empty	1%	1%	1%	1%
Box created, deleted with no writing	54%	35%	54%	30%
Box created, text written, never modified	25%	43%	19%	40%
Box created, text written, text modified (once or more)	5%	10%	4%	7%
Box created, text written, box deleted	14%	9%	20%	19%
Box created, text written, text modified (once ore more), box deleted	2%	2%	2%	3%

Table 12. Percentages of concept boxes and linking phrase boxes following each of the 6 possible transformation sequences in initial and final Cmaps.

The numbers in table 12 are quite revealing. We note first the very high percentage of concept boxes created and deleted with no writing in them. In the first Cmap the value was 54%; by the final map it had decreased approximately 20 percentage points, but still remained quite high, at 35%. This suggests the possibility that many of these boxes may have been created unwittingly, perhaps due to lack of manual dexterity manipulating the mouse. Comparing experienced and inexperienced users, though, we found no significant differences between the

[77] The percentage in the full sample is 23%.
[78] Percentages represent averages per map.

two groups. Nonetheless, comparisons between the two groups should be interpreted with caution given the small numbers of experienced users in the sub-sample (4), and the very high standard deviations found in the data

Of course, it is also possible that some of these boxes were created purposefully, but were deleted for some other reason, such as, having a change of mind about wanting to write something; or wanting to move the concept box somewhere else and finding it easier to delete and start again, than to drag the already existing box. If so, experienced and inexperienced users might display similar action patterns.

Also worth noting are the percentages of concept boxes written in exactly once: 25% and 43%, in the first and final maps, respectively. Much more modest (in the order of 10%) are the numbers associated with boxes written in more than once, i.e., boxes in which original text was modified. Finally, we observe the nontrivial percentages of boxes written in (once or more) and subsequently deleted, 16% in the initial map, 11% in the final one. As with boxes added and deleted with no writing, none of these patterns were found to vary in a statistically significant manner between experienced and inexperienced users except for one: concept boxes in which text was written and subsequently modified were significantly higher in the final Cmap for the experienced group (24% versus 8%); as before, though, confidence intervals were very wide, and so these numbers need to be considered conservatively.

Percentages of transformation sequences for linking phrase boxes are quite similar. Linking phrase boxes created and deleted with no writing in them were 54% and 30% in the initial and final Cmaps, respectively. This similarity with concept box numbers is not surprising since linking phrase boxes are generally created and deleted along with concept boxes. Linking phrase boxes created and written in exactly once doubled from 19% in the initial Cmap to 40% in the final one. Links written in more than once were under 10% in both maps; those written in (once or more) and then deleted added up to 22% in both maps.

Comparison between experienced and inexperienced users produced only one significant difference at the 0.05 level, namely, boxes added with no writing and not deleted (2% for experienced, 0%, for experienced). However, there were three more at the 0.10 level or very close: boxes written in and modified (higher for experienced users in both Cmaps); boxes written in and deleted (higher for inexperienced users in the final map). Again, due to the small number of experienced users in the sub-sample, and the high variance of the data, these results need to be interpreted with caution.

7.5.1 Specific text modifications of concepts and linking phrases

Next we focused our attention on those boxes in which text was written and subsequently modified, but not deleted. Pooling together the maps in the sub-sample, we identified a total of 151 distinct sequences of text modification, 56 in the initial Cmap, and 95 in the final Cmap. Inspection of the text modifications we encountered suggested a classification scheme, ranging from trivial modifications of text format to deep alterations of content. The result of this classification is given in table 13. Those cases in which original text was modified more than once, the variation between the original and final form of the text determined the category into which the sequence was placed. Percentages in table 13 refer to the fraction of the total pool of sequences examined.

As the table makes clear, more than half of all changes (59% in the first Cmap, and 52% in the final Cmap) fell into the first 5 categories, corresponding to changes which essentially have no effect on a concept's meaning.[79] Substantial modifications involved greater concept specificity, which increased from 9% to 18%; a complete change of concept, which rose from 11% to 14%; and better concept definition, which decreased from 18% to 9%, presumably as a result of a better understanding of the notion of "concept."

CONCEPT MODIFICATION	Initial Cmap (n = 56)	Final Cmap (n = 95)
No change at all [80]; changes in text format (font type and size, upper and lower case, etc.)	21%	18%
Add or remove article	5%	17%
Spelling changes	16%	10%
Gender and/or number changes; changes between infinitive and conjugated form of verbs.	11%	6%
Concept rewording	5%	4%
Increase in concept specificity	9%	18%
Improved concept definition	18%	9%
Complete change in concept	11%	14%
Other (less specificity, worse definition, etc.)	4%	5%

Table 13. Nature of concept text modifications in initial and final Cmaps.

An analogous categorization was carried out for text modifications of linking phrases. In this case, 74 distinct text modification sequences were found in the pooled sub-sample, 33 in the first map and 41 in the final map. Classification categories were again suggested by our observations; they are similar, but not identical, to the categories for concept modifications.

[79] It might be argued that changes of format can impinge upon the intended meaning of a concept or linking phrase, as when italics or bold face or colors are used for emphasis. For this study, however, meaning has been considered as disjoint from format, since the meaning that could be implied by a given format has no objective reference for interpretation.

[80] Text was rewritten exactly as it was originally.

LINKING PHRASE MODIFICATION	Initial Cmap (n = 33)	Final Cmap (n = 41)
No change at all; changes in text format (font type and size, upper and lower case, etc.)	6%	12%
Improved reading of proposition	6%	12%
Spelling changes	12%	2%
Articles; gender and/or number changes	15%	10%
Linking phrase rewording	9%	7%
Removing concepts from linking phrase; introducing verbs	3%	10%
Greater detail added to linking phrase	26%	22%
Complete change in linking phrase	9%	12%
Other (linking phrase does not improve, may worsen)	15%	12%

Table 14. Nature of linking phrase text modifications in initial and final Cmaps.

Compared to concepts, modifications of linking phrases were somewhat more substantial. 59% of linking phrase modifications in the initial map, and 68% in the final map, actually modified semantic content. Furthermore, on the order of 10% of all modifications corresponded to a complete change of the linking phrase.

7.5.2 Concept permanence

An interesting question that emerged from analyzing concept modifications is how likely is it for a concept to remain or "survive" in a map after being created, and does this likelihood vary significantly between the first and final Cmaps? We will refer to this notion as "concept permanence."

In order to calculate this probability, we considered the complementary event, "concept removal." Once a concept has been placed in a map, there are two mutually exclusive events that result in a concept being permanently removed: 1) the concept box is deleted, and a new concept box with that same concept or its equivalent is never created again, E_1; and 2) the concept is modified so that its meaning is completely transformed, and a new concept box with the old concept or its equivalent is never created, E_2. The sum of the probabilities of these two events yields the probability that a concept is permanently removed; in symbols, $P(removal) = P(E_1) + P(E_2)$. The probability of a concept *remaining* or *surviving* in a map is the complementary probability, that is, $P(permanence) = 1 - P(removal)$.

Concept permanence was calculated separately for each of the 50 maps in the sub-sample; averages were subsequently computed to yield the mean concept permanence on the initial and final Cmaps. Results are reported in table 15.

CONCEPT PERMANENCE	Initial Cmap	Final Cmap
Average concept permanence	88%	95%
Standard deviation	12%	5%
95% Confidence interval	83% - 93%	93% - 97%
Average number of concepts per map	24.5	29.6

Table 15. Concept permanence in initial and final Cmaps.

As the table reveals, average concept permanence was quite high in the first map, 88%, and even higher in the final map, 95%. The standard deviation, furthermore, decreased in the last map relative to the first, with a corresponding narrowing of the confidence interval (but this is inevitable when 95% of concepts are not changed). These results strongly hint at a certain unwillingness to change ideas once they have been put down in writing. One might suppose that this reluctance is related to the amount of effort required to effectuate these changes for teachers with little or no computer expertise – typing difficulties and trouble manipulating the mouse, for instance, may dissuade teachers from changing their maps. However, the fact that concept permanence increased significantly on the final map to levels of almost 100%, and that it was observed for both experienced and inexperienced users, does not lend support to the latter hypothesis. On the other hand, this action pattern is consistent with what one would expect from people with a rote learning style: little questioning, thus little revising. These results contain an important warning: if concept maps are to become an instrument of meaningful learning, if they are not to be "domesticated" and lead us to do "more of the same," facilitators must find ways to motivate mappers to seriously and thoughtfully reconsider and revise their concept maps, which in turn will signify that they are revising and improving their mental structures.

8 Discussion

In this section we take up the discussion of the results reported in the previous chapter. In so doing, we look back to the original research questions[81] posed in Chapter 3 to put forth a series of claims that help provide answers to these queries. Each claim will be followed by those results that substantiate it and interpreted in the light of the theoretical framework guiding this study. In structuring the argument, claims will be divided into claims about the process of acquiring skill in concept mapping, claims about the taxonomy, and claims about the Conéctate workshop.

Supporting evidence for the claims comes either from comparing performance on the first and final concept maps, and/or from the final map alone. The former allows us to estimate skills acquired during the training; the latter, the level of expertise at the end of the training. In this regard, it is important to point out that although teachers' final maps were not necessarily their best maps,[82] they do provide a legitimate depiction of the level of skill attained by individual educators.

Claims about the process of skill acquisition

1. *During Cmap construction, teachers tend to emphasize form over content.*

This assertion is supported by results at two different levels: at a purely mechanical level, by results about actions types carried out during Cmap construction; at a semantic level, by results concerning the nature of text modifications.

With regard to action types, in the final map we found that form-related actions, like moving objects[83] and adding styles, accounted for half (50%) of all actions performed during construction; in contrast, actions related (or potentially related) to content, such as creating

---

[81] ***What*** *overall patterns of skill acquisition in computer-mediated concept-mapping are observed in Panamanian schoolteachers participating in the Conéctate Project?*

1. **What** actions, and changes in actions, are observed in teachers' interaction with the concept mapping program during the process of Cmap construction?
2. **What** changes are observed in the structure and content of completed concept maps?
3. **To what extent** are observed behaviours and results a function of previous experience with computers, prior experience with concept maps, and preferred learning style?

[82] During the workshop teachers generated concept maps based on challenging focus questions and collaborative work. They used information and resources available on the Web, and improved their maps through facilitator and peer feedback. Many of these concept maps reached high levels, both in structure and content. However, such maps can not be said to accurately reflect the skills individual teachers were able to gain from the workshop.

[83] Of course, moving an object may affect content, as when a concept is moved in such a way that hierarchical order is changed. However, we do not believe such cases were a common occurrence, and hence were not considered.

and deleting concept and linking phrase boxes, writing and rewriting text within those boxes, and adding resources, together represented less than a third (29%) of all actions. Moreover, approximately a third of concept and linking phrase boxes were added and deleted without ever writing any text in them (in the final map the percentages were 35% and 30%, respectively). Thus, a simple calculation[84] yields that the percentage of mechanical actions ultimately associated with content is actually closer to 23%, that is, in final map action types related to form were twice as common as action types related to content.

At the semantic level, and focusing on the 10% of concepts in the final map whose text was modified once or more and not subsequently deleted, we found that 55% of modifications included changes in text format; addition and deletion of articles; correction of spelling; changes in number/gender of nouns and tense of verbs; and rewording. These modifications had to do with form and had no bearing on the concept's intended meaning. On the other hand, greater concept specificity, separation of multiple concepts, total concept change, and other changes that *did* affect concept meaning, made up the remaining 45%. A similar analysis for the 7% of linking phrases whose text was rewritten once or more and not subsequently deleted, revealed that 43% of changes altered form without affecting meaning. Thus, for both concepts and linking phrases, the ratio of significant to trivial text modifications was approximately 1-1. These numbers clearly show an emphasis on form over content. This, in turn, suggests a reluctance to engage in deep, critical thinking, not unexpected amongst rote learners.

2. *The ability to produce structurally more complex Cmaps increased over the course of the workshop.*

The average topological level on the first Cmap was almost 3 and increased to just over 4 on the final map. Level 3 maps represent the first level at which concept maps are structurally correct. They do not contain long pieces of text in a single concept box, indicating an understanding of the notion of "concept"; and they do not omit any linking words, implying an awareness of propositional structure. However, at this level maps show only moderate ramification (3-4 branching points), and are still rather shallow (fewer than 3 hierarchy levels). Level 4 maps, on the other hand, are more ramified, 5-6 branching points, and deeper, 3 or more hierarchy levels. Hence, we see that as far as pure structure is concerned, teachers' concept maps increased both in breadth and depth.

3. *By the end of the workshop, computer experience no longer afforded an advantage for increased structural complexity.*

Evidence for this claim comes from comparing the topological level of Cmaps constructed by inexperienced computer users, on the one hand, and experienced users, on the other. As one might expect, on the first concept map the average topological level of inexperienced users was lower (2.7) than that of experienced users (3.5); and the difference was significant. However, on the final map the mean topological level of the former group (4.1) was no longer significantly different than that of latter group (4.3).

[84] $0.29 - (0.08+0.03)*0.35+(0.05+0.02)*0.30 \approx 0.23$

This, of course, does not imply that inexperienced users became equally skilled at using CmapTools as experienced users. Table 8 in section 7.2.1 clearly shows this is not the case. Significant differences in the interaction with the machine persisted between the two groups in the final map. For instance, inexperienced teachers still added and deleted more concept and linking phrase boxes than their experienced counterparts. What this result *does* show, however, is that in spite of these differences, inexperienced users were still able to produce concept maps equally complex, structurally speaking, to those generated by their experienced counterparts. For Conéctate's purposes, this is what matters.

4. Computer experience does afford a certain advantage for semantic content.

Unlike topological structure, certain semantic variables do appear to be related to computer expertise. The decision to incorporate additional content, for instance, by linking resources to a Cmap is one such variable. In general, only half the teachers (51%) linked resources, most often Web pages or images, to their maps. However, when computer expertise is taken into account, a significant difference appears: experienced users were 1.5 times more likely (P = 0.00) to link a resource to their Cmaps than inexperienced users (69% versus 46%). Moreover, among those who included resources, the number of links included was also significantly different. Experienced users linked on average 5 resources, inexperienced users under 3, approximately half as many (P = 0.00). These results are not really surprising. Although teachers with little or no computer experience did manage to produce, by the end of their training, Cmaps of equivalent topological level as computer savvy teachers, data from the recorder clearly shows that their interaction with the machine was still less fluid on the final Cmap: their total number of actions was significantly lower (686 compared to 978, P = 0.00); they added and deleted more, either because they unwittingly added boxes they did not want, or because it was physically easier to add and delete that to drag an object to a new location; and they experimented less with the styles palette. The outcomes about resources simply confirm that inexperienced users felt less comfortable with the machine, as manifested in searching the Web and linking resources into their Cmaps, than did experienced users. Given the relatively short duration of the workshops (two weeks), this is not surprising.

Overall map semantic quality, as measured by the semantic score, was higher for the group with computer experience as well. On the first map the experienced group scored in the *low* quality range, the inexperienced in the *very low* range (P = 0.00); on the last map, the experienced group scored in the *intermediate* range, the inexperienced in the *low* range (P = 0.00). In an attempt to explain these results, we examined the score components more closely; we discovered that differences were due mostly to a single criterion: cross-links. Presence of cross-links on the initial map was 46% versus 25% (P = 0.00), for experienced and inexperienced users, respectively; on the final map, 68% versus 50% (P = 0.01). Quality of the cross-links, as measured by the points on criterion 5 of the semantic rubric, was also slightly but significantly higher for experienced users: 1.3 times higher on both Cmaps. The question arises, why do teachers with computer experience perform better on cross-links than teachers with little or no computer experience? One might conjecture that the effort required on the part of inexperienced users to build a concept map is such that they are not looking to make any connections other than the most obvious ones, in other words, "horizontal" connecting lines require an additional effort that teachers are unwilling or unable to make. Or perhaps cross-links were included at some point during Cmap construction but were eliminated for some reason and thus did not appear in the completed Cmap. We also recall that teachers with computer experience read almost twice as many books per year than their colleagues with little or no computer experience (3.6 as compared to 1.8 books per year). Thus, this factor may also come into play. Evidently, a definitive answer will require further research. An interesting place to begin might be to compare hand-made to computer-made concept maps (at the beginning and end of the workshop) to test whether the difference in presence of cross-links still shows up, and thus is not due to the interaction with the machine.

5. *Regardless of preconceptions about concept maps, teachers achieved similar levels of proficiency in concept mapping.*

As shown in the preliminary study, almost all Panamanian schoolteachers are familiar with concept maps and a large fraction (63%) have used them at some point or other in their teaching; however, many have incorrect ideas about what they are and about their proper use as a tool to promote meaningful learning.

One important misconception, held by 52% of the sampled teachers (n = 125),[85] is the idea that connecting lines should not cross over each other. *A priori*, one would consider this notion worrisome because it would seem to diminish or rule out the possibility of relating ideas from different subdomains of a concept map via cross-links. Curiously, in our study this did not turn out to be the case: we found no significant effect of this misconception on the *presence* of cross-links in either the first or the final concept map. Moreover, there was no difference in the topological level on the first Cmap between the two groups; oddly, on the final map, the group *with* the misconception came out higher than the group without it (4.7 versus 4.2, P = 0.01).

On the other hand, teachers who included cross-links in their first Cmap were twice as likely to include them in their last one (P = 0.02). Combined with the previous results, this would seem to imply that what teachers *did* early on in the workshop had a greater impact than what they stated they *believed*. But if it was not prior knowledge about concept maps, what could have prompted some teachers to incorporate cross-links on their first Cmap? The answer appears to be: the facilitators. When we examined the effect of training group on the presence of cross-links, we found a significant association on the first Cmap (P = 0.05); not so on the final Cmap, where overwhelmingly the significance of the logistic regression model was due to cross-links on the first map.

Grave misconceptions also exist regarding the number and kind of words in linking phrases. Altogether, 82% of teachers (n = 96)[86] had some erroneous idea in this respect. These misconceptions were not found to have any association with topological level, not a surprising result considering that neither the nature nor the number of words contained in linking phrases (as long as linking phrases are present) are likely to affect the structural level of concept maps. The fact that no association was found on either Cmap with semantic score, however, *is* somewhat more surprising and harder to account for. Even limiting semantic consideration to the one criterion most likely to be influenced by misconceptions about linking words, namely, the ability to produce meaningful semantic units, we found no statistically detectable distinction between teachers who had erroneous ideas and those who did not. One explanation might be that overall semantic scores were so low that having wrong ideas about linking words hardly made any difference.

---

[85] In the preliminary study the statistic was 51%.
[86] In the preliminary study the percentage was 68%.

What these two illustrations suggest is that, regardless of previous notions held at the outset of the workshop, teachers ended up roughly at the same place. Sometimes, as in the case of including cross-links, they were able to move forward, probably due to a combination of their own ability and the help provided by their facilitators. Other times, as with creating units of meaning, not much progress was made. In this particular instance, what we found most striking was the fact that having the "correct idea" was not necessarily an asset, that is, it did not contribute significantly to teachers' ability to put together meaningful statements. This could be a reflection of a lack of understanding of the very concept of "proposition," as well as the result of a lifetime of meaningless, rote learning and teaching. Facilitators need to develop and implement more strategies to help teachers understand what propositions are and strengthen their ability to generate interesting and relevant relationships. Games such as like the conceptual dice may be able to help.

6. *During Cmap construction, thought processes are mostly linear; that is, there is little interconnecting of ideas from different subdomains of the map.*

Concept maps of level 4 (and lower) contain no cross-links. Without cross-links, maps tend to consist of separate strings of thought, unrelated to one another. The process of "interweaving" these strings through cross-links is precisely what may give rise, if done conscientiously and thoughtfully, to integrative reconciliation, a key element of Ausubel's meaningful learning theory. The absence of cross-links, therefore, may be a strong indication that teachers' thinking while building their concept map is mostly linear. Moreover, in concept maps cross-links can provide evidence of creative leaps on the part of the learner (Novak & Cañas, 2008). They require noticing and making explicit new or less obvious connections between different conceptual domains present in their maps.

In this study, 30% of teachers included cross-links in their initial concept map. The proportion increased significantly to 54% in the final map. However, on the first Cmap, 8% were contained only meaningless propositions (due to incorrect structure), 4% all erroneous and 3% all redundant or irrelevant propositions. On the last map, the percentages were 12%, 2%, and 9%, respectively. On the positive side, 30% of the final concept maps contained correct and relevant cross-links, which represents a significant improvement over the first map, where only 15% of teachers included correct and relevant cross-links.

Why is it that there is so little interconnecting of ideas from different subdomains of the concept maps? We de not know for certain. One possible explanation might be that teachers have certain preconceived notions about how concept maps should be structured and these preconceptions do not include links crossing over from one domain of the map to another (though, as pointed out in claim 5, we found no association between such preconceptions, as surmised from responses to questions in the teacher questionnaire, and the presence of cross-links in teachers' Cmaps).

Another possibility is that the absence of cross-links is related to a rote learning style. Based on the work of Suárez & Barrios (2006), it would seem that most teachers in our sample, regardless of whether their preconceived notions about concept maps were correct or not, were rote learners, and therefore disinclined to searching for and establishing connections between seemingly disconnected ideas.

An experiment presently being conducted at Conéctate by fellow facilitators using the "conceptual dice" provides an interesting clue. They have noticed that when asked to relate pairs of concepts appearing on the upper faces of the dice teachers are generally able to come up with propositions for any two concepts without much difficulty; however, when constructing their concept maps based on the propositions generated from throwing the dice, some of these, particularly those that correspond to cross-links, did not always appear in the completed map (Villareal, personal communication, June, 2007). Were the cross-links never included? If so, what holds them back? Could it be that the cross-links were included at some point and subsequently erased? A definitive answer clearly requires additional exploration.

7. *During Cmap construction, there is little rethinking of concepts and linking phrases, and hence of propositions, being put forth.*

This is a bold assertion to make, and all supportive evidence is necessarily indirect. Nonetheless, we believe a strong case can be made. The first data we call upon is from figure 16, which shows that writing (and rewriting) of text constituted a minimal fraction of the total actions performed during Cmap construction. Between concepts and linking phrases, text writing took up on average only 12% (7% concepts, 5% linking phrases) of the actions on the initial map and 10% (6% concepts, 4% linking phrases) on final map. One might have thought that computer experience would have some sort of influence on these percentages since, one would argue, inexperienced users might be more reluctant than experienced users to modify text, owing to lack of ease with the machine, typing difficulties, or both. However, with regard to writing, information distilled from the recorder logs yielded similar mean percentages for the two groups. The fact that users for whom computer skills are not a problem devote equivalent proportions of their actions to modifying text suggests that technological difficulties cannot be cited as responsible for the low percentages of text modification, and that something deeper must be at work.

The second data we cite is from tables 13 and 14 (discussed in claim 1), which reveal that approximately half the time text *re*writing, whether of concepts or linking phrases, involved trivial modifications with no substantial effect on meaning, such as correcting spelling, changing verb tenses or rewording using synonyms.

The third result we quote is concept permanence. The notion of *concept permanence* was introduced to measure how likely it was that once a concept was placed in a map it would persist, unchanged in its meaning, in the completed map. We found concept permanence in the first Cmap to be 88%, with a 95% confidence interval of (83%, 93%); concept permanence on the final Cmap increased to 95% with an even narrower 95% confidence interval of (93%, 97%). The unequivocal conclusion is that once a concept was put down in the concept map, as far as meaning is concerned, it became fixed.

These three facts by themselves, though highly suggestive, certainly do not prove that there is little going on in terms of rethinking ideas, and might not even be considered reason for concern. One could argue, for instance, that deep consideration was given to ideas *prior* to placing them in the concept map, so that there was little to do meaning-wise once they were in the map. The results take on a more disquieting character when one considers the actual quality of the completed maps. The average semantic score, the fourth data we summon, was 6.4 on the initial Cmap and 8.1 of the final one. These scores correspond, in our semantic taxonomy, to *very low* and *low* quality maps, respectively. The main reasons accounting for these poor results are: 1) incomplete concepts and/or excessive examples, 2) meaningless propositions, 3) dearth of dynamic propositions, and 4) erroneous, invalid, irrelevant or non existing cross-links. In view of these results, the counterargument that concepts and linking phrases were given significant previous consideration is considerably weakened.

Yet another blow to this hypothesis comes from comparing the 4 training groups which constructed their first concept map based on a specified reading, with the remaining 14 groups whose first map was on an individually chosen topic. Our results showed a significantly higher number of misconceptions and dynamic propositions for the reading-based group. Interestingly, both differences disappeared on the final concept map, suggesting they did not stem from something inherent to the group but rather were related to the specific concept mapping task. Noting the great similarity between the original text and the resulting Cmaps, especially in terms of dynamic propositions, our suspicion is that, in constructing the reading-based map, teachers essentially transferred the text into a map format.[87] In so doing, it appears that text was often transferred incorrectly, resulting in an increased number of erroneous statements or misconceptions. In view of the fact that teachers actually referred to the text during Cmap construction, the presence of incorrect propositions points not only to lack of consideration of the content, but to something even more serious: deficiencies in basic reading comprehension skills.

8. *An increase in semantic level tends to produce an increase in topological level; the converse is not necessarily the case.*

We discovered an interesting relationship (see section 7.4.7) between topological and semantic level: it appears that a positive change in the semantic level of a concept map tends to produce, simultaneously, a positive change in its topological level. That is to say, if the content of a map improves, its structure tends to improve as well. On the contrary, if a concept map shows topological improvement, semantics do not necessarily get better; while a decrease in topological level tends to be accompanied by a decrease in content quality. This suggests that the emphasis should be placed on improving map content, as this will pull the topology along with it. Nonetheless, topology should not be neglected, for if topological level decreases, semantic level tends to be lowered as a result.

9. *More dynamic focus questions lead to more dynamic propositions.*

This claim is based on results from section 7.4.2. There we showed, both graphically and numerically, that there is a clear positive association between the type of focus question and the nature of the propositions. In particular, the more open to personal experience and the more demanding of reasons and explanations a focus question is, the more explicative the propositions in the resulting concept map. In a sense this sort of connection was to be expected, for as Cañas and Novak (2006) have argued, dynamic thinking is required to build explanatory concept maps. Moreover, this finding confirms the result obtained previously by Derbentseva et al. (2006). However, it goes a bit beyond as well. Derbentseva et al.'s (2006) experiment compared two specific questions, a "what is..." question with a "how does..." question, which would be classified in the open-static and open-dynamic categories,

[87] Recall that teachers requested to be allowed to refer to the text whilst constructing their Cmaps. Facilitators complied in order to reduce the anxiety levels perceived amongst teachers regarding this concept mapping activity.

respectively. In our setting, 516 virtually different questions[88] posed by an equal number of teachers were considered. Thus, our data essentially generalizes the previous result, showing that it holds true, independently of any particular question.

What is essential to emphasize is that this association appeared in spite of the fact that *no overt effort was made to produce it.* We have already indicated that discussion of dynamic propositions is not part of the workshop content; moreover, most facilitators were not familiar with this notion, and so were not likely to have mentioned it on their own account during the workshops. Regarding focus questions, we can be sure that facilitators encouraged teachers to include them in their concept maps, and quite probably some facilitators (though we do not know how many) will have tried to get teachers to break away from the typical classificatory questions they generally would pose.[89] But certainly no mention of our classification of focus questions could have made for the simple reason that, like our definition of dynamic proposition, it was not known to the facilitators. Thus, we can be pretty certain that the association that has showed up reflects a real dependence between the variables. We believe that discussing the relevant ideas in the workshops would go a long way to strengthen this relationship and, consequently, the usefulness of concept mapping as a way to organize and understand the dynamic interdependencies of the world we live in.

Claims about the taxonomy

10. *The concept map taxonomy, topological and semantic, proved to be a reliable tool for assessing the progress in using concept maps as a tool for meaningful learning and knowledge construction.*

Designed to provide Conéctate Project facilitators with a common language to assess the progress in concept map quality, the concept map taxonomy is an important accomplishment. The topological taxonomy, in particular, has proved especially fruitful. Not only has it shown a high degree of reliability (in the study we conducted, 90% of the facilitators either agreed, or disagreed by just 1 level); it is also very straightforward to use, so much so, that once an observer becomes familiar with the tool, a simple glance at a concept map suffices to determine its topological level. Further evidence of its success is its routine use within Conéctate. For example, it is one of 9 criteria included in the "Reference Guide for Teacher Follow-up," an instrument used by facilitators during their follow-up visits to assess teacher progress towards the Project's goals, which in turn has served to redesign major strategies of the Project, including the workshop itself. The topological taxonomy is also being utilized as a measurement tool in research projects currently being carried out at Conéctate by others besides ourselves.

Considering the higher level of subjectivity implicit in the semantic scoring rubric, we were more concerned about the reliability of this tool. To our surprise, the second phase of the reliability study we conducted yielded only 19% pairwise disagreement by more than 1 level; in other words, in 87% of the cases evaluators either agreed, or disagreed by just one level. Nonetheless, feedback from participating facilitators did point to the need to further revise and clarify the instrument. The version of the scoring rubric used to assess the quality of

[88] It may have been that, coincidentally, some questions may have been repeated.
[89] This speculation applies to Cmaps other than the initial and final ones, where facilitators were asked not to intervene.

content of the concept maps considered in this dissertation has incorporated these revisions and clarifications. However, as it stands, the semantic tool is somewhat difficult to apply, and only a few facilitators are using it routinely; also, it may contain certain criteria that do not particularly contribute to a better appraisal of semantic quality and complexity, while others that may contribute more may have been left out. Hence, we plan to further refine this tool in the near future in order to make it into a easier to use and useful tool for the Conéctate Project.

Claims about the Conéctate workshop

11. *The decision to begin teacher training in concept mapping without a preliminary computer literacy module was a good decision; teachers acquired necessary computer skills "naturally," while engaged in meaningful concept mapping tasks*.

Though official statistics are not available, it is known that in Panama a large fraction of schoolteachers has little or no computer expertise (our data yielded values near 80% in both the preliminary and the main studies). Thus, an important question Conéctate had to face early on was whether to include a computer literacy module or not. After some debate, it was decided not to include such a module. The justification was three-fold. First, a computer literacy module would probably distract teachers' attention from the main objective of the workshop, namely, to acquaint them with pedagogical and technical tools designed to help learners learn meaningfully. Second, such a module would contravene the very spirit of meaningful learning, which requires a meaningful context; an independent computer literacy module, devoid of a significant framework, would thus contradict the essence of the workshop. And third, such a module would take valuable time away from the training; moreover, it would probably lead to redundancy, as material presented in the module might have to be discussed again in the workshop in the context of some concept mapping task being carried out with CmapTools. For the above reasons, it was decided that technological literacy in the Conéctate workshop would have to take place "naturally," that is, while using the computer for purposes that were real and meaningful for teachers.

Our results seem to confirm that on the whole this was a good decision. The strongest evidence comes from topology. Initially the topological level of the experienced group had been significantly higher; by the end of the two-week workshop there no longer was any difference in structural complexity between the maps produced by experienced and inexperienced users, implying that teachers were indeed able to pick up necessary computer skills along the way, and did not require a separate preliminary computer module to do so. Though admittedly less forcefully, semantic results tend to point in the same direction. Semantic scores for the two groups did not even out, as did topological level; however, they increased by equal amounts, so that the small difference present at the outset in favour of experienced users remained unchanged. Moreover, it appears that cross-links were the main source of disparity, and these, as we have seen in claim 5, can be encouraged successfully by facilitators. Thus, it is probable that with additional support, inexperienced users would be just as likely to include cross-links in their Cmaps and, thereby, attain equivalent semantic scores.

9 Conclusions

The research program we embarked on in the course of this dissertation sought to explore and characterize the patterns of skill acquisition in computer-mediated concept mapping, using as subjects Panamanian elementary schoolteachers being trained at the Conéctate Project. Given the untrod ground we were plodding over, at the start it was not at all clear *what* to look to for or *how* to measure it. Thus, carrying out this study necessitated: 1) deciding what aspects were worth observing in order to better understand the process of skill acquisition in concept mapping, and 2) developing and refining the instruments with which to carry out this prospecting. Both aspects of our research program took form and materialized over the course of the first two years of the Conéctate Project, a period during which the very needs of the Project suggested useful variables to observe and guided the development of tools with which to measure them. This itinerary led, on the one hand, to a description of the actions taking place during the process of concept map construction, and, on the other, to a characterization of structure and content of completed concept maps. Out of this there has emerged an understanding, albeit imperfect, of the changes undergone by our subjects in the process of acquiring skill in concept mapping.

Four tools provided the data for this study: the CmapTools Recorder, the topological taxonomy, the semantic scoring rubric, and the teacher questionnaire. The CmapTools Recorder, used for the first time as a research tool, gave us copious information on actions taken by map makers with which to explore the human-machine interaction taking place during Cmap construction. The topological taxonomy and semantic scoring rubric developed during the study allowed us to gauge structural and semantic quality of finished concept maps, respectively. Finally, the teacher survey supplied important background information about the population being studied. The fact that the data that emerged from the application of all these instruments has given rise to a fairly coherent image – much as the blue, green and red sensitive layers in color film give rise to a coherent photographic image – gives us confidence in the legitimacy of our measurement tools, and in the validity of our depiction of the concept mapping skill acquisition process.

The comparison of the two Cmaps, the “snapshots” taken at the beginning and at the end of the two-week workshop, showed that during their training teachers improved their concept mapping skills in all three of the dimensions considered by this study. Important progress was made in the physical interaction with the concept mapping program, as evidenced by the increase in the total number of actions performed, the inclusion of resources, and the “playing” with the styles palette, as well as the decrease in the percentages of additions and deletions, particularly of concept and linking phrase boxes deleted without any writing.

Significant advances in the topological complexity of completed Cmaps were also revealed, especially with regard to ramification and depth. Throughout the workshop teachers acquired sufficient computer and concept mapping skills to increase structural complexity by 2 full levels to produce on average Cmaps of level 4, on a scale from 0 to 6.

Worthy of special note is the fact that inexperienced computer users were able to achieve, during this short time, sufficient skill in concept mapping and in using the computer program to produce Cmaps of equivalent structural complexity to those produced by experienced computer users. Thus, computer expertise has been shown not to be a crucial factor for the acquisition of concept mapping abilities at the structural level. This achievement is quite remarkable considering that teachers not only lacked computer expertise, but in many instances had never touched a computer and actually dreaded the machine. Reasons for their fear and anxiety ranged from appearing foolish and ignorant using the computer to doing something that might damage it.

This particular finding is also important to the Project at a strategic level, as it furnishes evidence that the decision *not* to include a computer literacy module in the beginning of the workshop was in fact a good one. In addition to saving time and resources, not including a computer literacy module allowed teachers to focus more on the real objectives of the workshop, and to experience a situation of "just-in-time learning" and take cognizance of its benefits.

In spite of the achievements along the topological dimension, many teachers did not include cross-links in their Cmaps. These "horizontal" propositions, which relate concepts from different subdomains, capture to some extent the nonlinearity and interconnectedness of cognitive structure. We believe that the extra effort that establishing cross-links demands, contributes to a heightened awareness of these interconnections and can stimulate further knowledge integration. Such integration is a fundamental aspect of Ausubel's theory of meaningful learning. Thus, we consider the absence of cross-links an important shortcoming in the training process.

Semantic complexity, though it increased, showed much less of an improvement than the other two dimensions; moreover, Cmap content quality overall remained rather poor. One of the reasons for this may have been the tendency to emphasize *form over content*. Independently of subjects' computer expertise, percentages of boxes in which some text modification occurred were of the order of 10% for concepts and 5% for linking phrases; these low percentages are compounded by the fact that approximately half of the changes had no substantial effect on meaning. Thus, most of teachers' efforts during the early stages of training went into moving objects, experimenting with styles, and making relatively inconsequential alterations to text. Concept permanence levels of the order of 90% corroborate the latter statement, and suggest little rethinking of ideas once these were placed in the Cmap.

Preferred learning style was an important variable we had hoped to take into consideration. Regrettably, the data from this section of the teacher questionnaire failed to provide useful information and had to be discarded. Nevertheless, socio-cultural data, along with outcomes from the Suárez & Barrios (2006) study, support the conclusion that most subjects in our study were in fact rote learners. In light of this, the finding that our subjects emphasized form, or rather, deemphasized content it is not surprising: one would expect this behavior from rote learners.

Semantic score turned out to be more sensitive to computer expertise than topological level. The single factor found to account for the disparity in semantic scores between experienced and inexperienced computer users was cross-links. Not only were inexperienced users less likely to include cross-links, but cross-links produced by inexperienced users tended to be fewer and less relevant than those of generated by experienced users. Our guess is that this might be due to the additional exertion (physical and mental) required to construct these kinds of propositions. Reading habits may also play an important role: experienced users read twice as many books per year than did inexperienced users.

Lack of prior experience using concept maps did put teachers at a disadvantage in both topology and content; specific preconceptions apparently did not. Teachers who had erroneous ideas about connecting lines or about the nature of linking phrases, as revealed by their answers to survey questions, attained equivalent topological and semantic levels as those who did not have these misconceptions.

All in all, this dissertation has helped to paint a portrait of the early stages of the process of skill acquisition in concept mapping for a particular population of mappers. In view of the fact that learners are believed to generally require months to reach the point where they are able to accurately represent their knowledge and understanding of a topic in a concept map, the two-week period considered is this study corresponds to the very beginning of the training period, and hence our results tell only a small fraction of the story. This incomplete and necessarily imperfect tale is, nonetheless, a solid starting point. It helps us understand the difficulties that novice mappers confront, and explain the initial resistance they often display. This understanding, in turn, can assist in developing more effective concept mapping training programs, as well as in guiding trainers' expectations towards more realistic goals, as they work with apprentice mappers to achieve increasingly better representations of their knowledge structures, and to make better use of concept mapping to sustain meaningful learning processes.

9.1 Recommendations for the Conéctate workshop

Our research has allowed us to characterize the progress taking place in teachers in the process of acquiring skill in concept mapping. These advances constitute important achievements for the Conéctate Project. At the same time, our vantage point has enabled us to observe limitations of the workshop and allows us to make certain recommendations. In our opinion, modifications to the workshop should be devised and implemented in order to:

- *Get teachers to place at least equal, if not greater, emphasis on content as on form*
- *Increase the proportion of actions teachers dedicate to modifying text*
- *Increase the proportion of non-trivial or substantial text modifications*
- *Improve the overall semantic quality of teachers propositions*
- *Get teachers to include cross-links in their concept maps early on in the workshop*
- *Improve the quantity and quality (relevance and originality) of cross-links*
- *Increase the proportion of open-dynamic focus questions*
- *Increase concept map content dealing with events, as opposed to objects*

- *Promote the construction of dynamic propositions, including causal and quantified causal dynamic propositions*

- *Increase the time devoted to discussing and learning from erroneous propositions*

- *Increase efforts to help teachers understand the meaning of meaningful learning*

It goes without saying that in order to attain these objectives facilitators must be well acquainted with the topological taxonomy and the semantic scoring rubric, so that they may guide teachers (without making direct reference to these instruments) towards better representations of their knowledge structures through their concept maps. More effort is needed to help facilitators themselves understand the meaning of meaningful learning.

Devices such as the "conceptual dice" can prove helpful to move teachers away from standard, textbook statements, in the direction of establishing new relationships between concepts they never before considered related, or new relationships between concepts they always related in the same conventional ways.

The art of asking questions should be cultivated by facilitators, and used as a way to guide teachers to reflect upon the generalizations, omissions and distortions implicit within their propositions, and in the interrelationships among their propositions. These reflections should lead to more fine-grained, better qualified statements, which in turn should result in an improvement of the semantic quality of concept maps, and vicariously a topological improvement as well.

Greater emphasis should be placed metacognition, that is, on how concept map construction supports knowledge building and meaningful learning, in particular, the effect that making thoughtful modifications to concept maps has in enhancing personal knowledge structures.

Finally, though facilitators generally make the point that concept maps are never "finished," it is crucial to make sure this message gets across by revisiting and reworking concept maps constructed at earlier moments throughout the workshop. In this manner teachers experience and are sensitized to the endless possibilities for continuing growth (subsumption), refinement (differentiation) and interrelatedness (reconciliation) of and among concepts.

9.2 Topics for future work

Given what little was known about how people acquire skill in concept mapping, this study was necessarily exploratory in nature. It set out to discover variables that were worthwhile to observe, and to develop and refine tools with which to observe them, in order to provide a description of the changes that take place during the initial stages of training in concept mapping. In the course of this work, however, we have been able to glimpse new avenues of research we believe would be interesting to pursue.

To begin with, we had no external point of reference against which to compare the actions and achievements of the population in our study, namely, the population of Panamanian elementary schoolteachers. Thus, it would be interesting to contrast, using our tools, teacher performance with the performance of *expert* concept mappers, in order to get a better sense of how far away from "mastery" these beginning mappers are, and incidentally gain data on the robustness of the tools.

Originally, our intent had been to compare skill acquisition in concept mapping between rote and meaningful learners. Our fundamental hypothesis was to be that meaningful learners and rote learners present different patterns of skill acquisition. Our hope was that by understanding how different types of learners acquired skill in concept mapping, along with the factors that most influenced the process, we would be in a better position to assist them in their path towards meaningful learning with concept maps. Alas, this course of action had to be called off in view of the fact that we were not able to distinguish between learners with each of these learning styles. Subsequently, we came across a method we believe could provide an excellent way to differentiate between learners who are inclined towards the rote end of the learning continuum and those who are disposed towards the meaningful end. This method, described in section 7.1, involves asking learners to formulate questions to improve a series of concept maps. Questions are then classified according to Bloom's Taxonomy in terms of the cognitive demand each one poses. The outcome will be a function of the learner's cognitive processes and learning style. A first step, therefore, would be to validate this technique. If it turned out to be adequate, it could be used to distinguish between rote and meaningful learners and it would then be possible to pursue our original program to explore differences in concept mapping skill acquisition patterns between these two populations.

This study examined transformation sequences of concepts and linking phrases, but did not look at transformation sequences of propositions – mainly because the procedures we used to manipulate the log files were not automated[90] and therefore were extremely tedious and time-consuming. However, we feel the analysis of full propositions should be carried out, as this will almost certainly provide a more complete picture of the thinking taking place during concept map construction than the analysis of the two components taken separately can give.

We have pointed out that teachers with little or no computer experience were less likely to include cross-links than computer savvy teachers, and when they do include them, these tend to be fewer and less relevant. Additionally, certain facilitators remarked to us that occasionally they noted teachers who had included cross-links at some point during construction of their Cmaps, deleted them from the final version of the map. We feel this is something that should be looked into further in order to help clarify whether the low numbers of cross-links in general, even lower among inexperienced users, are related only to the extra effort these propositions demand, or whether some other issues (e.g., preferring not to risk appearing ignorant or preferring not to create a "complicated" looking map) are at play.

Finally, we would like to continue to work towards an accurate and reliable semantic taxonomy, similar to the topological taxonomy. The idea would be to use what we have learned about the semantic characteristics of teachers' concept maps to design a classification system based on increasingly complex content levels. We hope to be able to carry on with work in this direction.

[90] All the log data was processed in Excel using nothing more than filters.

Afterword

"Precisamente, son las instituciones relacionadas con educación las que menor esfuerzo han realizado para crear programas de gerencia de conocimiento y estructuras responsables por su mantenimiento y actualización."

Germán Escorcia

Learning beyond e-Learning, n.d.

In our opinion, this research project has set an important precedent in Panama. In our country, as in most other countries of Latin America, government sponsored projects like Conéctate are set forth to sail the seas of implementation, so to speak, with few navigational instruments to guide their journey. Thus, they often move off course and fail to reach their destinations.

From the beginning, the visionaries who designed the Conéctate ship knew that it had to include measurement instruments to provide information about its whereabouts so that, if need be, its course might be corrected along the way. In modern organizational theory parlance, Conéctate was to be a "learning organization," an organization capable of critical self-examination, which would allow it to learn from experience and respond in timely fashion to changes from the environment, in order to reach its objectives.

The present study, the most comprehensive one conducted so far at Conéctate, is one of many studies that attempt to critically examine the Project from within. We trust that the precedent this work has set will encourage more and better research in the future, and that the instruments and knowledge it has produced will help to steer this ship safely to port.

Bibliography

Abraira, V. J. (1997). *Precisión de las clasificaciones clínicas*. Doctoral dissertation. Universidad Complutense de Madrid, España. Retrieved March 14, 2008 from http://www.ucm.es/BUCM/tesis/19972000/X/3/X3044301.pdf

Anderson-Inman, L., & Ditson, L. (1999). Computer-based concept mapping: A tool for negotiating meaning [Electronic version]. *Learning & Leading with Technology, 26*(8), 6-13.

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York: Holt, Rinehart and Winston.

Ausubel, D. P. (1968). *Educational Psychology: A cognitive view*. New York: Holt, Rinehart and Winston.

Bloom, B., Englehart, M., Furst, E., Hill, W., & Krathwohl, D. (1956). *Taxonomy of Educational Objectives: Handbook I: Cognitive Domain*. New York: Longman, Green & Co.

Briggs, G., Shamma, D. A., Cañas, J. A., Carff, R., Scargle, J., & Novak, J. D. (2004). Concept maps applied to Mars exploration public outreach. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 159-166). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Cañas, A. J., Coffey, J. W., Reichherzer, T., Hill, G., Suri, N., Carff, R., Mitrovich, T., & Eberle, D. (1998). El-Tech: A performance support system with embedded training for electronics technicians. In *Proceedings of the Eleventh Florida AI Research Symposium, Sanibel Island, FL,* (pp. 79-83).

Cañas, A. J., Ford, K. M., Brennan, J., Reichherzer, T., & Hayes, P. (1995). Knowledge construction and sharing in Quorum. *Paper presented at the Seventh World Conference on Artificial Intelligence in Education, Washington, DC*, 218-225.

Cañas, A. J., Ford, K. M., Novak, J. D., Hayes, P., Reichherzer, T. R., & Suri, N. (2001). Using concept maps with technology to enhance collaborative learning in Latin America. *The Science Teacher, 68*, 49-51.

Cañas, A. J., Hill, G., Bunch, L., Carff, R., Eskridge, T., & Pérez, C. (2006). KEA: A knowledge exchange architecture based on web services, concept maps, and CmapTools. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 304-310). San José, Costa Rica: Universidad de Costa Rica.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A knowledge modeling and sharing environment. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 125-133). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Cañas, A. J., Hill, G., Granados, A., Pérez, C., & Pérez, J. D. (2003). *The network architecture of CmapTools.* (Technical Report No. IHMC CmapTools 2003-01). Pensacola, FL: Institute for Human and Machine Cognition.

Cañas, A. J., Leake, D., & Wilson, D. C. (1999). *Managing, mapping and manipulating conceptual knowledge: Exploring the synergies of knowledge management & case-based reasoning.* (AAAI Workshop Technical Report WS-99-10). AAAI Press.

Cañas, A. J., & Novak, J. D. (2006). Re-examining the foundations for effective use of concept maps. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 494-502). San José, Costa Rica: Universidad de Costa Rica.

Cañas, A. J., Novak, J. D., Miller, N. L., Collado, C., Rodríguez, M., Concepción, M., et al. (2006). Confiabilidad de una taxonomía topológica para mapas conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 153-161). San José, Costa Rica: Universidad de Costa Rica.

Castells, M. (2001). *The Internet galaxy: Reflections on the Internet, business, and society.* New York: Oxford University Press.

Centro Regional para el Fomento del Libro en América Latina y el Caribe (2006). *El espacio iberoamericano del libro*. Retrieved November 25, 2007, from: http://www.cerlalc.org/secciones/libro_desarrollo/Panorama.pdf

Chacón, S. (2006). La pregunta pedagógica como instrumento de medicación en la elaboración de mapas conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 327-334). San José, Costa Rica: Universidad de Costa Rica.

Chung, G. K. W. K., O'Neil, H. F., & Herl, H. E. (1999). The use of computer-based collaborative knowledge mapping to measure team processes and team outcomes. *Computers in Human Behavior, 15*, 463-493.

Clark, R. E. (2001). Media are "mere vehicles": The opening argument. In R. Clark (Ed.), *Learning from media: Arguments, analysis, and evidence: Perspectives in instructional technology and distance learning* (pp. 1-12). Connecticut: Information Age Publishing. (Original work published 1983)

Clark, R. E. (1991). When researchers swim upstream: reflections on an unpopular argument about learning from media. *Educational Technology, 31*(2), 34-40.

Coffey, J. W., & Cañas, A. J. (2003). LEO: A learning environment organizer to support computer-mediated instruction. *Journal of Educational Technology Systems, 31* (3), 275-290.

Coffey, J. W., Carnot, M. J., Feltovich, P., Feltovich, J., Hoffman, R. R., Cañas, A. J., & Novak, J. D. (2003). A summary of literature pertaining to the use of concept mapping techniques and technologies for education and performance support. The Institute for Human and Machine Cognition. Retrieved March17, 2006 from: http://www.ihmc.us/users/acanas/Publications/ConceptMapLitReview/IHMC%20Literature%20Review%20on%20Concept%20Mapping.pdf

Coffey, J. W., & Hoffman, R. R. (2003). A knowledge modeling approach to institutional memory preservation. *The Journal of Knowledge Management, 7*(3), 38-52.

Conlon, T. (2004). "But is our concept map any good?": Classroom experiences with the Reasonable Fallible Analyzer. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 159-166). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Consejo Nacional de Educación (2006). *Un documento para la acción en el sistema educativo Panameño*. (Primer informe al Señor Presidente de la República). Unpublished manuscript.

Daley, B. J., Cañas, A. J., & Stark-Schweitzer, T. (2007). CmapTools: Integrating teaching, learning and evaluation in online courses. In S. Conceição (Ed.), *New Perspective of Teaching Adults Online*, (pp. 37-47). Jossey-Bass.

Departamento de Estadística del Ministerio de Educación, República de Panamá (2005). *Estadísticas educativas – MEDUCA*. Retrieved March 13, 2008, from: http://www.contraloria.gob.pa/dec/Aplicaciones/EDUCACION

Derbentseva, N., Safayeni, F., & Cañas, A. J. (2004). Experiments on the effects of map structure and concept quantification during concept map construction. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 209-216). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Derbentseva, N., Safayeni, F., & Cañas, A. J. (2006). Two strategies for encouraging functional relationships in concept maps. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 582-589). San José, Costa Rica: Universidad de Costa Rica.

Dutra, I., Fagundes, L., & Cañas, A. J. (2004). Un enfoque constructivista para uso de mapas conceptuales en educación distancia de profesores. In A. J. Cañas, J. D. Novak, & F.

M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 217-226). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Dutra, I., Fagundes, L. Johann, S., & Piccinini, C. (2006). Logical systems and natural logic: concept mapping to follow up the conceptualization processes. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 359-366). San José, Costa Rica: Universidad de Costa Rica.

Escorcia, G. (n.d.). Learning beyond e-Learning. Retrieved March 25, 2008, from http://www.camposc.net/dm/Learningbeyondlearning.pdf

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction, 12*, 213-232.

Ford, K. M., & Bradshaw, J. M. (Eds.), (1993). *Knowledge acquisition as modeling*. New York: Wiley.

Ford, K. M., Cañas, A. J., Jones, J., Stahl, H., Novak, J. D., & Adams-Webber, J. (1991). ICONKAT: An integrated constructivist knowledge acquisition tool. *Knowledge Acquisition, 3*, 215-236.

Ford, K. M., Coffey, J. W., Cañas, A. J., Andrews, E. J., & Turner, C. W. (1996). Diagnosis and explanation by a nuclear cardiology expert system. *International Journal of Expert Systems, 9*, 499-506.

Gordon, S. E., Schmierer, K. A., & Gill, R. T. (1993). Conceptual graph analysis: Knowledge acquisition for instructional system design. *Human Factors, 35*, 459-481.

Greene, M. (1988). *The dialectic of freedom*. New York, NY: Teachers College Press.

Herl, H. E., Niemi, D., & Baker, E. L. (1996). Construct validation of an approach to modeling cognitive structure of U. S. history knowledge. *Journal of Educational Research, 89*(4), 206-218.

Herrera, L. (2003). *Regiones de desarrollo socioeconómico de Panamá: Transformaciones ocurridas en las últimas tres décadas 1970-2000.* Instituto de Estudios Nacionales, Universidad de Panamá.

Huff, A. S., & Jenkins, M. (2002). *Mapping strategic knowledge*. London: Sage Publications.

Hughes, G., Barrios, J. C., Bernal, D., & Chang, A. (2006). Los dados conceptuales: un juego para aprender a construir proposiciones. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. II, pp. 151-155). San José, Costa Rica: Universidad de Costa Rica.

IDC-EMC (2007). *The expanding digital universe: A forecast of worldwide information growth through 2010*. Retrieved November 3, 2007, from http://www.emc.com/leadership/digital-universe/expanding-digital-universe.htm

Ip, A., & Morrison, I. (2001). Learning objects in different pedagogical paradigms. In G. Kennedy, M. Keppell, C. McNaught & T. Petrovic (Eds.), *Meeting at the Crossroads. Proceedings of the 18th Annual Conference of the Australian Society for Computers in Learning in Tertiary Education,* (pp. 289-298). Melbourne: Biomedical Multimedia Unit, The University of Melbourne. Retrieved September 14, 2007, from: http://www.ascilite.org.au/conferences/melbourne01/pdf/papers/ipa.pdf

Johnson, P., & Johnson, G. (2002). Facilitating group mapping of core competencies. In A. S. Huff & M. Jenkins (Eds.), *Mapping strategic management*, (pp. 220-236). London: Sage Publications.

Jonassen, D. H., Beissner, K., & Yacci, M. (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Jonassen, D. H., & Carr, C. (2000). Mindtools: Affording multiple representations for Learning. In S. P. Lajoie (Ed.), *Computers as cognitive tools: No more walls*, (Vol. 2, pp. 165-196). Mahwah, NJ: Lawrence Erlbaum. Retrieved March 14, 2007, from: http://www.ed.psu.edu/insys/400/ssdb.htm

Jonassen, D. H., Peck, K. L., & Wilson, B. G. (1999). *Learning with technology: A constructivist perspective.* Upper Saddle River, NJ: Merrill/Prentice Hall.

Joy, E. H., & García, F. E. (2000). Measuring learning effectiveness: A new look at no-significant difference findings [Electronic version]. *Journal of Asynchronous Learning Networks, 4*(1), 33-39. Retrieved March 16, 2008, from http://www.sloan-c.org/publications/JALN/v4n1/pdf/v4n1_joygarcia.pdf

Khamesan, A., & Hammond, N. (2004). Synchronous collaborative concept mapping via ICT: Learning effectiveness and personal and interpersonal awareness. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 385-392). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Kinchin, I. M. (2000). Using concept maps to reveal understanding: A two-tier analysis. *School Science Review, 81*(296), 41-46. Retrieved March 14, 2008, from: http://nerds.unl.edu/pages/preser/sec/articles/conceptmaps.html

Kingston, J., & Macintosh, A. (2000). Knowledge management through multi-perspective modeling: Representing and distributing organizational memory. *Knowledge-based Systems, 13*, 121-131.

Kozma, R. B. (2001a). Kozma reframes and extends his counter argument. In R. Clark (Ed.), *Learning from media: Arguments, analysis, and evidence: Perspectives in* *instructional technology and distance learning* (pp. 179-198). Connecticut: Information Age Publishing. (Original work published 1994)

Kozma, R. B. (2001b). Robert Kozma's counterpoint theory of "learning with media." In R. Clark (Ed.), *Learning from media: Arguments, analysis, and evidence: Perspectives in instructional technology and distance learning* (pp. 137-178). Connecticut: Information Age Publishing. (Original work published 1991)

Labaree, D. F. (2007, November). *Limits on the impact of educational reform: The case of progressivism and U. S. schools, 1900-1950.* Revised version of paper presented at the conference The Century of the School: Continuity and Innovation during the First Half of the 20th Century. Monte Verità, Ascona, Switzerland. Retrieved January 16, 2008, from http://www.stanford.edu/~dlabaree/publications/Monte_Verita_Paper.pdf

Landis, J. R., & Koch, G. G. (1977). The measure of observer agreement for categorical data. *Biometrics, 33*, 159-174.

Lin, S-Y., Strickland, J., Ray, B., & Denner, P. (2004). Computer-based concept mapping as a prewriting strategy for middle school students. *Meridian, 7*(2). Retrieved May 22, 2007, from http://www.ncsu.edu/meridian/sum2004/cbconceptmapping/

Lyman, P., & and Varian, H. R. (2003). *How Much Information*. School of Information Management and Systems, University of California at Berkeley. Retrieved November 4, 2007, from http://www2.sims.berkeley.edu/research/projects/how-much-info-2003/

Markham, K. M., Mintzes, J. J., & Jones, M. G. (1994). The concept map as a research and evaluation tool: Further evidence of validity. *Journal Research in Science Teaching, 31*(1), 91-101.

McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept map assessment of classroom learning: reliability, validity and logistical practicality. *Journal of Research in Science Teaching, 36*(4), 475-492.

McNeese, M. D., Zaff, B. S., Peio, K. J., Snyder, D. E., Duncan, J. C., & McFarren, M. R. (1990). *An advanced knowledge and design acquisition methodology: Application for the Pilot's Associate*. (Report AAMRL-TR-90-060, Human Systems Division, Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson AFB, OH).

Miller, N. L., Cañas, A. J., & Novak, J. D. (2006). Preconceptions regarding concept maps held by Panamanian teachers. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. (Vol. 1, pp. 153-161). San José, Costa Rica: Universidad de Costa Rica.

Moreira, M. A. (1997*). Mapas conceptuales y aprendizaje significativo en ciencias.* Retrieved March 13, 2008 from http://www.if.ufrgs.br/~moreira/mapasesp.pdf

Moreira, M. A. (2000). *Aprendizaje significativo crítico*. Retrieved March 13, 2008 from http://www.if.ufrgs.br/~moreira/apsigcritesp.pdf

Morrison, G. R. (2001). An analysis of Kozma and Clark's arguments. In R. Clark (Ed.), *Learning from media: Arguments, analysis, and evidence: Perspectives in instructional technology and distance learning* (pp. 199-204). Connecticut: Information Age Publishing. (Original work published 1994).

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations*. Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Novak, J. D. (2003). The promise of new ideas and new technology for improving teaching and learning. *Cell Biology Education, 2*, 122-132.

Novak, J. D., & Cañas, A. J. (2008). *The theory underlying concept maps and how to construct them.* (Technical Report IHMC CmapTools 2006-01 Rev 01-2008). Florida Institute for Human and Machine Cognition. Available at: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm

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

Novak, J. D., Gowin, D. B., & Johansen, G. T. (1983). The use of concept mapping and knowledge Vee mapping with junior high school science students. *Science Education 67*(5), 625-645.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Education Research Journal, 28*(1), 117-153.

Pankratius, W. J. (1990). Building an organized knowledge base: Concept mapping and achievement in secondary school physics. *Journal of Research in Science Teaching, 27*(4), 315-333.

Papert, S. (1987, May). *A critique of technocentrism in thinking about the school of the future*. Paper presented at the conference Children in an Information Age: Opportunities for Creativity, Innovation, and New Activities. Sofia, Bulgaria. Retrieved January 27, 2008, from http://www.papert.org/articles/ACritiqueofTechnocentrism.html

Patry, J., & Bourgeoys, M. (2004). Effects of short term training in concept-mapping on the development of metacognition. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 503-510). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Pea, R. D. (1985). Beyond amplification: using the computer to reorganize mental functioning [Electronic version]. *Educational Psychologist, 20*(4), 167-182. Retrieved September 14, 2007, from http://www.stanford.edu/~roypea/RoyPDF%20folder/A26_Pea_85a.pdf

Pines, A. L., Novak J. D. Posner, G. J., & VanKirk, J. (1978). The clinical interview: A method of evaluating cognitive structure. (Research Report). Ithaca, NY, Cornell University.

Preece, P. F. W. (1976). Mapping cognitive structure: A comparison of methods [Electronic version]. *Journal of Educational Psychology, 68*(1), 1-8.

Programa de las Naciones Unidas para el Desarrollo (2002). *El compromiso con el desarrollo humano: Un reto nacional*. (Informe Nacional de Desarrollo Humano Panamá). Retrieved March 16, 2008, from http://www.undp.org.pa/_pnud/Documents/doc00-web.pdf

Regoczei, S., & Plantinga, E. P. O. (1987). Creating the domain of discourse: Ontology and inventory. *International Journal of Man-Machine Studies, 27*, 235-250.

Rice, D. C., Ryan, J. M., & Samson, S. M. (1998). Using concept maps to assess student learning in the science classroom: Must different methods compete? *Journal of Research in Science Teaching, 35*(10), 1103-1127.

Rodríguez, M. L. (2004). La teoría del aprendizaje significativo. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 535-544). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Ruiz- Primo, M. A. (2004). Examining concept maps as an assessment tool. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping,* (Vol. I, pp. 555-562). Pamplona, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Ruiz-Primo, M. A., Schultz, S. E., Li, M., & Shavelson, R. J. (2001). Comparison of the reliability and validity of scores from two concept-mapping techniques. *Journal of Research in Science Teaching, 38*(2), 260-278.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33*(6), 569-600. Retrieved January 27, 2008, from http://www.stanford.edu/dept/SUSE/SEAL/Reports_Papers/all.html#CM4

Ruiz-Primo, M. A., Shavelson, R. J., Li, M., & Schultz, S. E. (2001). On the validity of cognitive interpretations of scores from alternative concept-mapping techniques. *Educational Assessment, 7*(2), 99-141.

Rye, J., & Rubba, P. (2002). Scoring concept maps: an expert map-based scheme weighted for relationships. *School Science and Mathematics, 102*(1), 33-44.

Safayeni, F., Derbentseva, N., & Cañas, A. J. (2005). A theoretical note on concept maps and the need for cyclic concept maps. *Journal of Research in Science Teaching, 42*(7), 741-766.

Schrum, L. (1999). Technology professional development for teachers. *Educational Technology Research & Development, 47*(4), 83-90.

Slangen, L. A. M. P., & Sloep, P. B. (2005). Mindtools contributing to an ICT-rich learning environment for technology education in primary schools. *Int. J. Cont. Engineering Education and Lifelong Learning, 15*(3-6), 225-239.

Solomon, G. (2000, June). *It's not just the tool, but the educational rationale that counts.* Invited keynote address at the ED-MEDIA 2000 Conference, Montreal, Canada. Retrieved September 23, 2007 from http://www.aace.org/conf/edmedia/00/salomonkeynote.htm

Stoyanova, N., & Kommers, P. (2002). Concept mapping as a medium of shared cognition in computer-supported collaborative problem solving. *Journal of Interactive Learning Research, 13* (1/2), 111-133.

Suárez, L., & Barrios, J. C. (2006). *Estudio de impacto del taller Conéctate*. (Internal report). Panamá: Conéctate al Conocimiento.

Tarté, G. (2006). Conéctate al Conocimiento: Una estrategia nacional de Panamá basada en mapas conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping,* (Vol. I, pp. 144-152). San José, Costa Rica: Universidad de Costa Rica.

UNESCO (1996). *Learning: The treasure within*. (Report to UNESCO of the International Commission on Education for the Twenty-first Century). Paris: UNESCO Publishing. Retrieved January 7, 2008, from http://www.unesco.org/education/pdf/15_62.pdf

UNESCO (2007). *The state of education in Latin America and the Caribbean: Guaranteeing quality education for all*. (A regional report, reviewing and assessing the progress toward education for all within the framework of the Regional Education Project). Santiago: UNESCO Publishing. Retrieved January 7, 2008, from http://www.unesco.cl/medios/biblioteca/documentos/documento_monitoreo_situacion_educativa_america_latina_caribe_ept_prelac_ingles.pdf

VanLehn, K. (1996). Cognitive skill acquisition. *Annual Review of Psychology, 47*, 513-539.

Vigotsky, L. S. (1978). *Mind and society: The development of higher mental processes.* Cambridge, MA: Harvard University Press.

Wandersee (2001). Using concept mapping as a knowledge mapping tool. In K. M. Fisher, J. H. Wandersee, & D. E. Moody (Eds.), *Mapping biology knowledge* (pp. 127-142). Dordrecht: Kluwer Academic Publishers.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research, 72*(2), 131-175.

Yin, Y. Ruiz-Primo, M. A., Ayala, C. C., & Shavelson, R. J. (2005). A comparison of two concept-mapping techniques: Implications for scoring, interpretation, and use. *Journal of Research in Science Teaching, 42*(2), 166–184. Retrieved October 9, 2007, from http://depts.washington.edu/biology/hhmi/conceptmaps/Yin%20et.al.,%202005.pdf

Young, L. (2003). Bridging theory and practice: Developing guidelines to facilitate the design of computer-based learning environments. *Canadian Journal of Learning and Technology, 29*(3). Retrieved March 14, 2008, from http://www.cjlt.ca/content/vol29.3/cjlt29-3_art4.html

Appendices

APPENDIX A: Teacher questionnaire

TEACHER QUESTIONNAIRE

(Part I)

The following questionnaire is part of a study whose objective is to improve this workshop. The data will be completely confidential, for use only by the research team; under no circumstance will it be possible to identify any individual from the reports derived from this investigation. **It is very important that your responses reflect your own experience.**

1. Name ______________________________________ Age __________________

2. Where were you born?
   ____

3. What is the name of the elementary school were you work?
   ____

4. How many years of university studies have you completed?
   a. None
   b. 1 to 2 years
   c. 3 to 5 years
   d. More than 5 years

5. How many years of service have you completed?
   a. 1 to 5 years
   b. 6 to 10 years
   c. 11 to 15 years
   d. 16 to 20 years
   e. More than 20 years

6. Are you familiar with concept maps?
   a. No
   b. Yes, but I don't use them in my classes.
   c. Yes and I use them in my classes.

7. If you are familiar with concept maps, which of the following options was your **main** source of information about them?
   a. A high school teacher
   b. A university professor
   c. An elementary school textbook
   d. A book of some other kind
   e. A colleague

f. A seminar
g. A Ministry of Education leaflet
h. Other. Please specify: ___________________________________

8. If you are familiar with concept maps, what kinds of linking words do you think may be used in concept maps?
   a. Concept maps should not contain linking words; concepts are joined directly to each other.
   b. Linking words should be prepositions or articles, and only one word.
   c. Linking words should be prepositions or articles, one or more words.
   d. Linking words may be any kind of word, but only one.
   e. Linking words may be any kind of word, one or more words.

9. If you are familiar with concept maps, do you think linking lines may cross one another?
   a. No, linking lines must not cross one another.
   b. Yes, linking lines may cross one another.

10. If you are familiar with concept maps, what shapes may connecting lines have?
   a. Connecting lines must always be straight lines.
   b. Connecting lines may be straight or curved lines.

11. Indicate the main use you make of concept maps in teaching your courses.
   a. I don't use concept maps.
   b. I build a concept map on a certain topic and I give it to my students and ask them to learn it.
   c. Students and I construct a map together and then they learn it.
   d. Each student builds his/her own map, and uses it to study from.
   e. Other. Please describe: ________________________________

12. If you have used concept maps as an evaluation tool, indicate the manner in which you generally use them.
   a. I have never used concept maps as an evaluation tool.
   b. I provide students with a structure for them to fill in concepts only.
   c. I provide students with a structure for them to fill in linking phrases only.
   d. I provide students with a structure for them to fill in some concepts and linking phrases.
   e. I ask students to build a complete concept map from a list of concepts I have provided.
   f. I ask students to build a complete concept map from a list of concepts and linking phrases I have provided.
   g. I ask students to build a complete concept map from scratch.
   h. Other. Please describe _________________________________

13. How frequently do you use the computer?
   a. Never
   b. Once in a while
   c. Often
   d. Always

14. Do you have an email account?
   a. Yes
   b. No

15. How many books did you read last year? ____________

16. What is the title of the last book you read? ____________________________________

(Part II)

For each of the following statements, choose the option that best reflects your own experience.

1. As a student, the most important thing for me in a course was to get a good grade.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

2. I trust I will do better in a presentation if I memorize what I have to say.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

3. I generally do not doubt things I read about or hear in a class.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

4. I prefer clear and direct explanations of things, not complicated by different perspectives or points of view.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

5. For me, the best way to understand the meaning of concepts is to remember definitions that appear in textbooks or given by teachers.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

6. I learn most things by going over them again and again.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

7. As a student, I always asked when I did not understand something.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

8. As a student, I tended to lose my motivation in a course when I didn't understand something, even if the topic interested me.
   a) Agree strongly
   b) Agree
   c) Neither agree nor disagree
   d) Disagree
   e) Disagree strongly

9. I find it hard to keep up my interest when I have to learn things on my own.
   a) Agree strongly
   b) Agree
   d) Disagree
   e) Disagree strongly

c) Neither agree nor disagree

10. When I learn something new, I feel uncomfortable if I can not relate it to something I already know.
    a) Agree strongly
    b) Agree
    c) Neither agree nor disagree
    d) Disagree
    e) Disagree strongly

Thank you for your cooperation

APPENDIX B: Topological taxonomy

TOPOLOGICAL TAXONOMY FOR CONCEPT MAPS

The present topological taxonomy has been developed to classify concept maps by structure, not content. It has 7 levels (0 through 6), and takes into account 5 basic criteria:

a. Recognition and use of individual concepts

- This criterion is concerned with the way concepts are represented within a concept map. In particular, the learner must distinguish and use individual concepts as opposed pieces of text, sentences or other grammatical structures.

  TEXT: "The escapement passes energy to the pendulum to keep it swinging and also releases the gear train in a step-by-step manner."

  INDIVIDUAL CONCEPTS: "Escapement", "Energy", "Pendulum", and "Gear train."

b. Presence of linking phrases

- Considers whether learner uses symbols to establish a relationship between concepts.

- Symbols may be words, letters, numbers, images, or any other intentionally placed symbol that depicts the relationship between the concepts.

- Correctness or logical sense of the resulting triads is not considered.

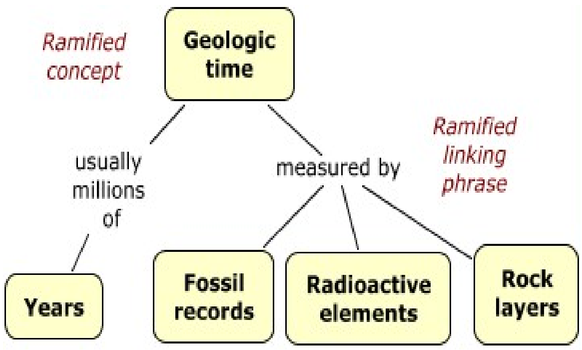
c. Degree of ramification

- Refers to the total number of branch points, that is, the points at which a concept map ramifies.

- Ramification points may occur at concepts or at linking phrases.

- The number of branches at a given ramification point is not considered.

- *Example*: A concept map with two ramification points, one at a concept and another at a linking phrase (see figure below).



d. Hierarchical depth

- This refers to the greatest number of linking phrases between the root concept and any given concept.

- Maps are considered "shallow" if depth is less than 3.

- Maps are considered "deep" if depth is 3 or more.

e. Presence of cross-links

- Number of cross-links present in the concept map is observed.

- A proposition is considered a cross-link if it joins two concepts, neither of which is the root concept, in such a way that a closed circuit is formed.

Rules for applying the topological taxonomy

- To belong to a given topological level, a concept map must satisfy all conditions describing that level.

- A concept map that does not satisfy one or more conditions of a given level belongs to some lower level.

- *Note*: It may happen that a map classified at a given level contains elements or satisfies conditions of higher levels. However, if it does not comply entirely with the requirements of that higher level, it does not belong there.

APPENDIX C: Semantic taxonomy

SEMANTIC SCORING RUBRIC FOR CONCEPT MAPS

This semantic scoring rubric is meant to be applied to concept maps that, for the most part, contain no texts nor lack linking phrases. When it is deemed that a map does not meet the requirements to be evaluated semantically, it is given a total score of 0 and assigned to the category of "unevaluated" concept maps.

In evaluating the semantic content of a given concept map, the following aspects must be taken into account:

- The author's personal context: age, educational level, cultural background, etc.
- The evaluator's personal context: educational level, cultural background, etc.
- If a concept map is based on specific learning experiences (e.g., readings, videos, plays, experiments, field trips) the instructional setting and content must be taken into consideration in applying the various criteria.

One word of caution is in order. This tool was designed to provide a reasonable guide to content evaluation in the context of Panama's Conéctate Project. Occasionally, strict adherence to the scoring rubric will not necessarily result in the fairest or wisest evaluation of a map's content. Thus, in applying this rubric it is important to keep in mind the 'spirit' of the various criteria, in addition to their exact wording.

CRITERION # 1: **Concept relevance[1] and completeness**
Note 1: *Relevance and completeness is determined, first, in relation to the* ***root concept****; second, the* ***focus question*** *(if there is one and the root concept corresponds to it); third, the* ***concepts closest to the root concept*** *(if there is no focus question or the root concept is not related to focus question).*
Note 2: *If several concepts appear within a single box, but clearly identified as individual concepts (for instance, separated by commas or marked by vignettes) they are counted as separate concepts.*

0 pts. The map contains very few concepts and/or most concepts are irrelevant, redundant or not well-defined (e.g., "characteristics" instead of "physical characteristics"); additionally, there is an excessive use of examples (one third or more of the map's concepts are examples).[2]

1 pts. One half or more of the map's concepts are relevant and well-defined, but many important concepts are missing; and/or there is an excessive use of examples (one third or more of the map's concepts are examples.

2 pts. Most concepts are relevant and well-defined, but some important concepts are missing. Appropriate use of examples (less than a third of the map's concepts are examples).

3 pts. All concepts are relevant and well-defined; no important concepts are missing. Appropriate use of examples (less than a third of the map's concepts are examples).

CRITERION # 2: **Propositions as "semantic units"**[3]

Note 1: *In the case of examples, it is permissible to use linking phrases such as: "like", "for example", "such as", etc.*

Note 2: *If the map contains a small number of propositions (excluding examples) or the map does not contain second level propositions,*[4] *this must be taken into account in the determining the score. The maximum number of points should only be given if the map provides* <u>*sufficient evidence*</u> *that its author truly understands the notion of proposition as a "semantic unit" in the sense previously defined.*

- 0 pts. The author does not understand how to construct propositions (very few propositions are well constructed).
- 1 pts. The author understands somewhat how to construct propositions (some propositions are well constructed).
- 2 pts. The author understands how to construct propositions (all or almost all propositions are well constructed).

CRITERION # 3: **Erroneous propositions**

Note 1: *Only propositions and examples validated under criterion # 2 are considered.*

Note 2: *Erroneous propositions resulting from incorrect use of the CmapTools software are not considered.*

- 0 pts. The map contains more than 2 erroneous propositions.
- 1 pts. The map contains 1-2 erroneous propositions.
- 2 pts. The map contains no erroneous propositions.

CRITERION # 4: **Dynamic propositions**[5]

Note 1: *Only propositions validated under criterion # 2 are considered.*

Note 2: *This criterion is independent of criterion # 3; that is, erroneous dynamic propositions are counted.*

- 0 pts. The map contains no dynamic propositions of any kind.
- 1 pts. The map contains only **non-causative** dynamic propositions.
- 2 pts. The map contains 1-2 **causative** dynamic propositions with **physically separate links**[6].
- 3 pts. The map contains more than 2 **causative** dynamic propositions with **physically separate links**.
- 4 pts. The map contains **quantified causative** dynamic propositions.

CRITERION # 5: **Quantity and quality of cross-links**

Note: *Only propositions validated under criterion # 2 are considered.*

- 0 pts. The map contains cross-links, but they are all erroneous (false).
- 1 pts. The map contains no cross-links.
- 2 pts. The map contains cross-links and these establish correct (true) relationships. However, they are redundant or not particularly relevant or adequate.
- 3 pts. The map contains 1-2 correct, relevant and adequate cross-links with **physically separate links**. However, based on the concepts present in the map, important and/or evident cross-links are missing.
- 4 pts. The map contains more than 2 correct, relevant and adequate cross-links with **physically separate links**. However, based on the concepts present in the map, important and/or evident cross-links are missing.

5 pts. The map contains more than 2 correct, relevant and adequate cross-links with **physically separate links**. Based on the concepts present in the map, no important or evident cross-links are missing.

CRITERION # 6: **Presence of cycles**[7]

0 pts. The map contains no cycles.

1 pts. The map contains at least 1 cycle, but **some propositions in the cycle do not satisfy criterion # 2**.

2 pts. The map contains at least 1 cycle and **all propositions in the cycle satisfy criterion # 2**.

Maximum score = 18 points

Levels:	Unevaluated	0
	Very low	1 – 5
	Low	6 – 8
	Intermediate	9 – 11
	High	12 – 14
	Very high	15 – 18

NOTES

[1] A concept is considered irrelevant if: 1) it is not related to the topic under consideration; or 2) it is related to the topic, but does not contribute substantially to it. One way to decide whether a concept is irrelevant is to think of removing it from the map and ask ourselves if this alters the map's content significantly (in relation to the root concept and the focus question). If our answer is "no," it is quite likely that this particular concept is not relevant to this map.

[2] Examples are specific instances or occurrences of concepts. For instance, "Chagres River" is an instance of the concept "river." Examples are usually joined to concepts by the following linking words: "for example," "like," "such as," among others.

[3] A triad is **not a proposition** if 1) it lacks the required structure CONCEPT + LINKING PHRASE + CONCEPT; 2) it does not make logical sense, either because its meaning depends on previous propositions, or due to grammatical mistakes, incorrect use of CmapTools, or some other reason; 3) it is not autonomous, i.e., it is clearly a fragment or continuation of a larger grammatical structure.

[4] A **second level proposition** involves the second linking phrase counted from the root concept.

[5] **Dynamic propositions** involve: 1) movement, 2) action, 3) change of state, or 4) dependency relationships. They are subdivided into **non-causative** and **causative** dynamic propositions. In causative propositions, one of the concepts must clearly correspond to the cause while the other one clearly corresponds to the effect. Causative propositions, in turn, may be **quantified**. Quantified propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept.

- Examples of non-causative dynamic propositions: *Roots absorb water*; *herbivores eat plants; living beings need oxygen*.

- Examples of causative dynamic propositions: *Electric charge generates electric fields*; *reproduction allows continuity of species*; *cigarettes produce cancer*; *independent journalism strengthens credibility*; *exercise decreases risk of developing diabetes*; *rule of law attracts foreign investment*.

- Examples of quantified causative dynamic propositions: ***Increased*** *transparency in public affairs* ***discourages*** *corruption*; ***under-activity*** *of the thyroid gland (hypothyroidism)* ***decreases*** *body metabolism*; ***increased*** *quality of education contributes to* ***greater*** *national development*.

Static propositions, on the other hand, serve only to describe characteristics, define properties and organize knowledge. They are generally associated to linking phrases such as: "is," "are," "have," "possess," "are made up of," "are classified into," "are divided into," "contain," "live," "are called," "is located in," "likes," etc.

- Examples of static propositions: *The sun is a star*; *means of transportation include land transport*; *Panama is located in Central America*; *animals may be vertebrates*.

[6] By propositions with "p**hysically separate links"** we mean propositions that use distinct linking entities (boxes) to join one concept to another. However, the linking words within these separate boxes may be repeated.

[7] A **cycle** is a directed circuit in which the direction of the arrows allows traversing the entire closed path in a single direction.