Chapter 2
Concept Mapping Using CmapTools to Enhance Meaningful Learning

Alberto J. Cañas and Joseph D. Novak

Abstract Concept maps are graphical tools that have been used in all facets of education and training for organizing and representing knowledge. When learners build concept maps, meaningful learning is facilitated. Computer-based concept mapping software such as CmapTools have further extended the use of concept mapping and greatly enhanced the potential of the tool, facilitating the implementation of a concept map-centered learning environment. In this chapter, we briefly present concept mapping and its theoretical foundation, and illustrate how it can lead to an improved learning environment when it is combined with CmapTools and the Internet. We present the nationwide "Proyecto Conéctate al Conocimiento" in Panama as an example of how concept mapping, together with technology, can be adopted by hundreds of schools as a means to enhance meaningful learning.

2.1 Introduction

Concept mapping has been shown to be an effective tool for learning at all levels, from preschool to graduate school and corporate training (Novak & Gowin 1984). Its use has extended across all continents as can be inferred by the diversity of participation and applications presented at the two International Conferences on Concept Mapping that have taken place (Cañas et al. 2004; Cañas & Novak 2006a).

In this chapter we demonstrate how, particularly when integrated with technology, concept mapping can be at the center of the learning process, and can function as an artifact through which the student demonstrates a growing understanding of a topic and its integration with other diverse topics, and through which collaborative knowledge building can take place. We then describe a nationwide effort by the Government of Panama to implement this concept map-based learning environment

A.J. Cañas (✉) • J.D. Novak
Florida Institute for Human and Machine Cognition (IHMC), Pensacola, FL, USA
e-mail: jnovak@ihmc.us; acanas@ihmc.us

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in hundreds of public elementary schools throughout the country. For the reader to understand the ideas presented, we begin the chapter with a summary of concept mapping, its underlying theory, and its integration with technology that allows the implementation of this concept map-based learning environment.

2.2 Concept Maps and Meaningful Learning

Various knowledge mapping techniques are covered throughout this book. Although superficially many of these techniques look alike, there are underlying differences that are key to understanding the potential uses of each. Therefore, we begin with a short summary of concept mapping and its underlying theory, in order to distinguish it from other mapping techniques.

2.2.1 Concept Maps

Novak's research group at Cornell University first developed concept maps in 1972 in a research project that sought to follow changes in children's understanding of basic science concepts after audio-tutorial instruction in Grades 1 and 2, and continuing through Grade 12 (Novak & Musonda 1991; Novak & Cañas 2006b). Concept maps proved to be an effective way to represent and contrast the students' understanding of various concepts throughout time. Since then, the ability to represent the knowledge structure held by an individual on any topic remains one of the most powerful aspects of this tool, and this has served many users for a wide range of applications. The tool also allows for collaborative sharing and building of knowledge, both to archive knowledge and to foster creative insights by individuals and groups (Novak 1998).

Concept maps, as we use the term, refers to a knowledge representation form that shows individual concepts at nodes with linking words that connect two concepts and indicate the relationship between them, thus forming a proposition. Usually, concepts are arranged hierarchically, from most inclusive, most general at the top to least inclusive, most specific at the bottom. We define a *concept* as a perceived regularity or pattern in events or objects, or records of events or objects, designated by a symbol, usually a word. Linking phrases are usually verbs which, when read together with the two concepts they join, form a simple phrase or proposition. Figure 2.1 shows a concept map that portrays key features of concept maps. Observe that for the most part, two concepts (which are depicted within rectangles) together with their linking phrase can be read as individual "sentences" that "make sense;" for example, "Concept maps *represent*Organized Knowledge," and "Concepts *are*Perceived Regularities or Patterns." In some cases, the proposition includes more than two concepts; for example, "Concepts *are*Labeled *with*Symbols." There is no restricted list of linking phrases – the map builder is free to use whatever phrase he/

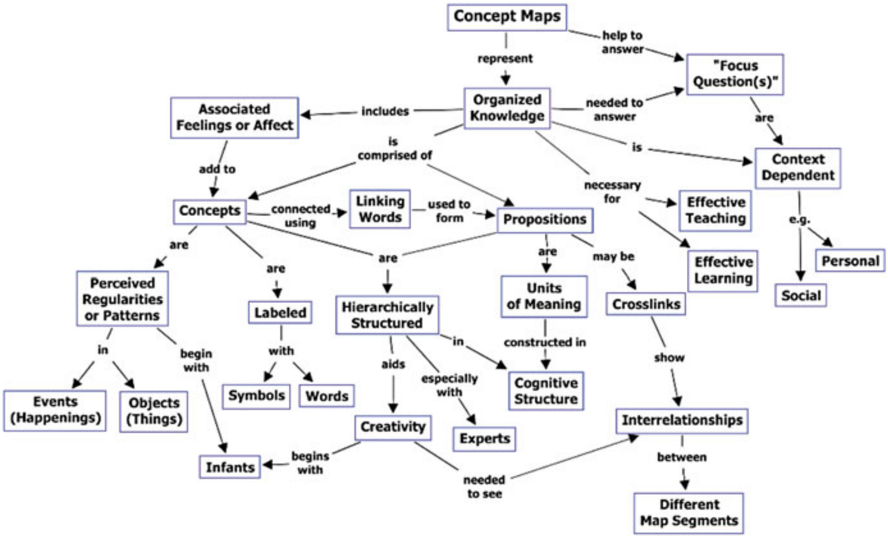

Fig. 2.1 A concept map that shows the key features of concept maps, as we define them

she prefers, as long as the concept-linking phrase-concept triad forms a sensible proposition. It is recommended that concepts and linking phrases be kept to as few words as possible. This propositional nature of the concept map, together with the freedom to select linking phrases, distinguishes concept maps from other types of graphical representations such as mind maps, argumentation maps, decision maps, and process maps.

2.2.2 Theory Underlying Concept Maps

Concept maps are also distinct from other mapping techniques in that they have a strong theoretical foundation. In 1963, David Ausubel published his theory of *cognitive*learning, and this became the psychological foundation for Novak and his research group's work on the concept map tool. Ausubel's theory puts forth several principles that explain how cognitive structure develops and elaborates. The most important principle is *meaningful learning*, a term that almost every researcher in education has used, but Ausubel (Ausubel 1963; Ausubel et al. 1978; Ausubel 2000) gives it explicit description. First, and in some ways most important, the *learner must choose*to seek ways to relate new concepts and propositions to existing relevant concepts and propositions she/he already knows. Second, the learner must *possess relevant concepts*and propositions with a sufficient degree of clarity and stability to anchor new, relevant concepts and propositions. Third, the material to be learned must be *potentially meaningful*; that is, it must be conceptually explicit and relatable to other ideas in this knowledge domain.

Meaningful learning represents one end of a continuum, with rote learning at the other end. Extreme rote learning occurs when the learner makes no attempt to integrate the new concepts and propositions to be learned into her/his cognitive structure and/or one or both of the two other conditions for meaningful learning are not met. Because motivation to integrate new knowledge with existing knowledge can vary and/or the learner may possess few or poorly organized relevant concepts and propositions, the same study materials may be learned by rote by one student and highly meaningfully by another. Several other principles of Ausubel's theory deal with processes involved in meaningful learning, and a discussion of these ideas can be found in Ausubel's writings or more succinctly in Novak & Gowin (1984), Novak (1998) and Novak & Cañas (2006b). Ausubel calls his cognitive learning theory *assimilation theory*, because new knowledge is assimilated into cognitive structure during meaningful learning, thereby modifying and enhancing the knowledge structure. *Constructivist*psychology and *constructivist teaching*are very popular terms in today's educational literature, recognizing that the learner must be actively engaged in the learning process. However, the literature on constructivist teaching often fails to recognize the subtle and important aspects of meaningful learning spelled out in Ausubel's psychology.

The theory of knowledge underlying concept mapping recognizes that knowledge is a human creation. We see knowledge creation primarily as the product of high levels of meaningful learning. Knowledge creation takes place by individuals embedded in a specific social milieu that changes over time. Consequently, knowledge evolves over time as the social milieu evolves. This *constructivist*view of knowledge stands in contrast to the *positivist*view of knowledge that dominated thinking during the first half of the twentieth century. Constructivist epistemology and constructivist psychology complement one another, and concept mapping serves to illustrate how this complementarity takes place.

2.2.3 Building Concept Maps

When learners build concept maps, meaningful learning is facilitated in several ways. The recommended procedure is to begin by first developing a good *focus question*that can be answered by understanding the knowledge that will be organized into the concept map. Focus questions that require explaining an event or the reasoning behind a procedure usually lead to better concept maps (Derbentseva et al. 2006), and concomitantly, better help to organize pertinent knowledge in cognitive structure (Cañas & Novak 2006b). A question such as, "How does DNA code genetic information?" is better than one that asks, "What is the structure of DNA?" The process of developing the focus question requires that the mapmaker think about what she/he knows about a given topic; identifying what a person already knows that is pertinent is essential to meaningful learning. Next, we recommend that the mapmaker identify 10–20 concepts that are pertinent to the focus question and list these in a "Parking Lot" at the side of the paper (or window when using a

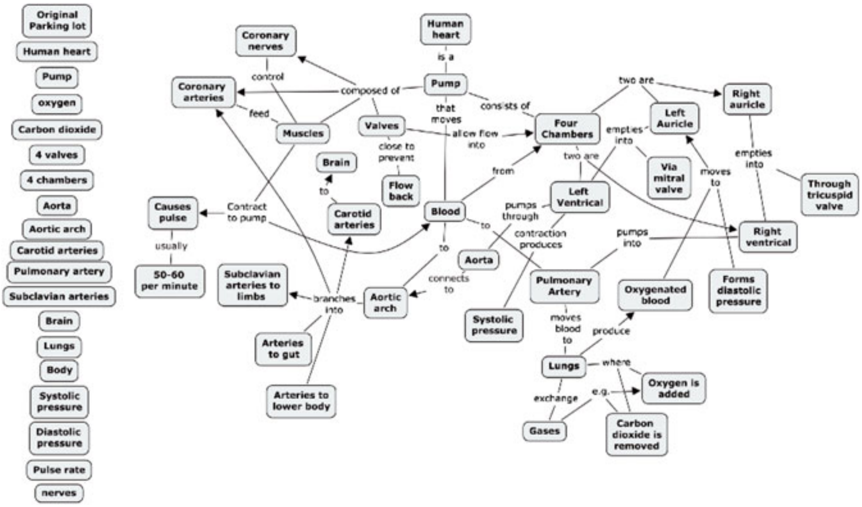

Fig. 2.2 Illustration of the end product in the construction of a concept map beginning with ordered concepts in a "parking lot." The map addresses the focus question: How does the normal heart function?

computer). Reordering the concepts in the parking lot according to the most general, most inclusive for the question under consideration is the next step, and this begins to move the learner toward synthesis and evaluation of what she/he knows; two activities that Bloom (1956) identified as the highest levels of cognitive thinking. Moving concepts from the now hierarchical parking lot into a concept map, and selecting the best linking words to connect the concepts, further induces synthesis and evaluation of relationships between concepts and construction of good propositions. As the concept map is elaborated, it is also helpful to look for *crosslinks*, or relationships between two concepts in different sections of the concept map. Such crosslinks sometimes lead to creative insights. One should plan on three or four revisions of a concept map before achieving a satisfying structure with clarity of ideas. This need for revisions is one reason the use of computer software is so helpful, as it highly facilitates the revision process. Figure 2.2 shows a concept map made by Joan Novak, starting with the list of pertinent concepts on the left side.

2.3 CmapTools: Integrating Concept Mapping with Technology

For many years, concept maps were drawn by hand. Iterating through revisions of a concept map was cumbersome and time consuming. Group concept mapping sessions were handled by using post-it notes. The introduction of personal computers enabled the development of software programs that facilitated the construction of concept maps. However, it was the marriage of the concept map and the Internet that launched a completely new world of applications and uses for concept mapping, as exemplified by the CmapTools (Cañas et al. 2004) software.[1] Based on this marriage of concept maps and technology, we propose the concept map-centered learning environment. To support this approach, CmapTools provides, among others, the following tools.

Network-based sharing and collaboration environment: Through a client-server architecture, students are given their own "space" where they can store their concept maps and associated resources. By providing this space long term, portfolios of each student's work can be collected and analyzed. Students control permissions over their space and they can create areas for group collaboration, publishing, and sharing. Alternatively, they can easily share concept maps by saving them in public shared servers. CmapTools was explicitly designed to support and facilitate collaboration. Students can collaborate with peers using a variety of collaboration features including (a) shared folders (Cañas et al. 2004) described above, (b) synchronous real-time collaboration whereby two or more students from the same or different schools can simultaneously modify the same concept map, with the changes displaying in each student's screen in real time, (c) annotations and discussion threads, which provide a rich mechanism for peer review where students (and teachers) with appropriate permissions can annotate, critique, question, provide feedback, and comment on each others' maps, providing an environment for argumentation, and (d) "knowledge soups" (Cañas et al. 1995; Cañas et al. 2001) whereby students share propositions (not concept maps) that can be commented on and argued over by other students through annotations and discussion threads, leading to collaboration at the "knowledge level." Together, these tools provide a rich and versatile environment for team-based learning, and/or for students to collaborate at the "knowledge level" while each student constructs his/her own map. The variety of collaboration tools provides educators with the option of selecting those tools most appropriate for the objectives pursued.

Construction of knowledge models: A student can easily construct multimedia systems using concept maps as a means to organize all resources (e.g., drawings, pictures, WWW pages, videos, spreadsheets, documents, other concept maps, etc.; (Cañas et al. 2003) involved in his learning process. Teachers often complain that students "cut and paste" from the WWW and submit reports and projects that they don't fully understand or – in the extreme case – have not even read. Because it is extremely difficult and unlikely to construct a concept map for a topic one does not understand, by requiring students to use a concept map as the means of organizing information, the student is forced to understand the topic. These knowledge models can be of any size and have been used to build complete WWW sites (Briggs et al. 2004). These resources can belong to other students, and can be stored in CmapServers in other schools or countries, or on any accessible location on the Internet. Figure 2.3 shows a student-constructed concept map about birds, as well as

[1] CmapTools can be downloaded from http://cmap.ihmc.us and is free for all to use.

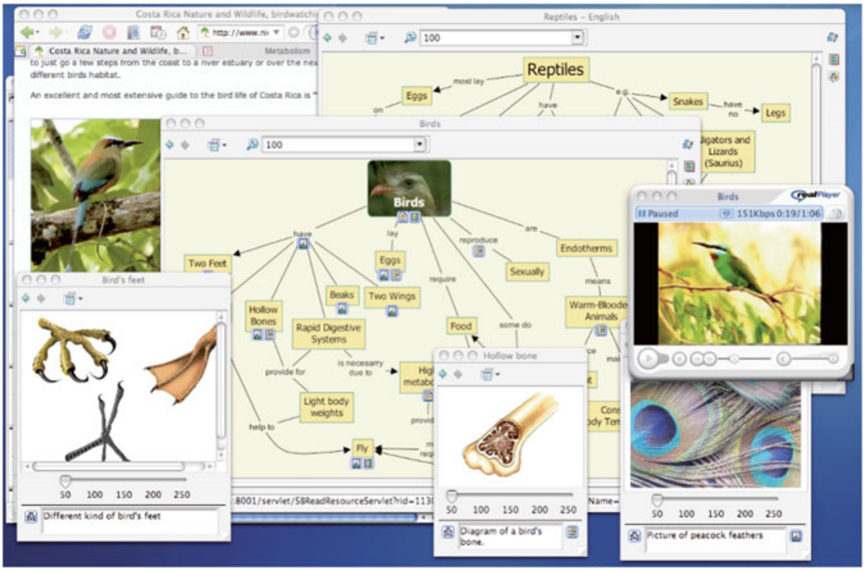

Fig. 2.3 Knowledge model about Birds constructed by a student. The various resources (images, videos, WWW pages, and other Cmaps) are linked to the Birds map and accessed through the icons underneath the concept. Notice that the student has integrated reptiles with birds, showing an understanding of the relationship between these. When saved on a CmapServer, this knowledge model automatically becomes a set of WWW pages browsable by others

associated resources that include images, videos, WWW pages, and a linked concept map about reptiles.

*Publishing and Internet presence:*Unfortunately, student-access to the Internet has become, in a large number of cases, an "objective" in itself. As with other technologies, the Internet, – or access to the WWW, which is usually what is meant by Internet access – by itself does not solve any of the problems we encounter in education. Although access to the information on the WWW is indeed valuable, as discussed below, we are concerned with the notion of students becoming "information pack rats" instead of "knowledge constructors." The CmapTools environment, therefore, supports easy "publishing" of knowledge models on the WWW. By storing a knowledge model in a CmapServer, it is automatically converted into a set of WWW pages, with links between resources including concept maps maintained through this conversion. If the CmapServer is accessible from Internet (that is, it can be accessed by users out on the Internet), and the appropriate permissions are set, the student's knowledge model is "published" out on the WWW. The CmapTools tools thus facilitate students (and teachers) selectively make their knowledge public and available to others.[2] We refer to the school as having a "presence" on the Internet, rather than being limited to just "access" to the Internet. For schools that

[2] Recently, other environments such as Wikis and Blogs have also made it possible to publish information on the WWW easily.

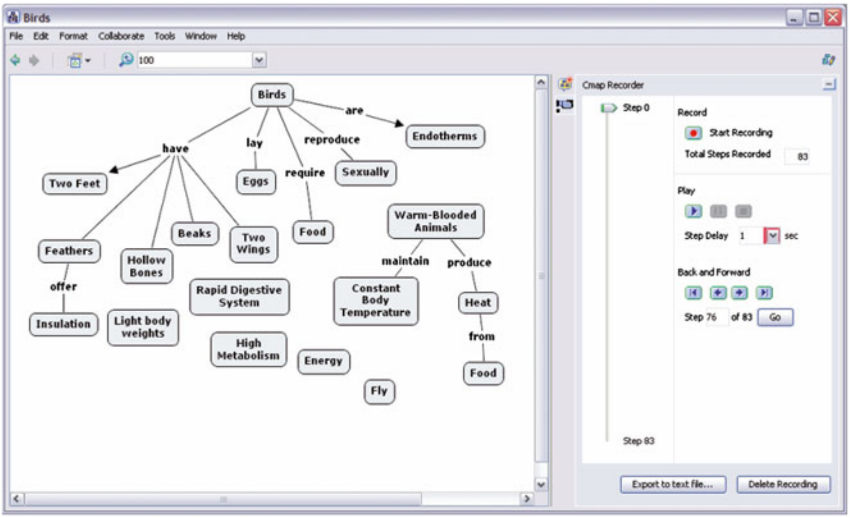

Fig. 2.4 An example of the recorder, which allows a step-by-step playback of the construction of a concept map

do not have a CmapServer, IHMC provides public servers where any person can publish his/her knowledge models.

Searching for information based on a Concept Map: By taking advantage of the topology and semantics of concept maps, CmapTools enables the user to perform intelligent searches on the WWW and CmapServers, for information that is relevant to the map he/she is constructing (Carvalho et al. 2001). By starting with a simple map – possibly the result of a pretest – the student can use the map to search the WWW for information related to the map. The student can then delve deeper into the topic, improve his/her understanding, link the studied resources to the map as a reference, and carry out other activities related to the topic under study. The student uses these resources to enhance the map periodically, demonstrating the learning that has taken place, possibly linking other maps he/she constructs or making links to previous maps, and iteratively proceeding on another search. This way the student's knowledge model grows, reflecting an improved understanding of the topic.

Recording the process of constructing a Concept Map: CmapTools provides the ability to record and play back sequentially, steps in the process of constructing a concept map (Dutra et al. 2004). This feature provides support to the teacher in what is a key aspect of concept mapping: the process of constructing a map. We are very often confronted with a finalized map without the opportunity to examine the process and steps by which the student constructed the map. Figure 2.4 shows, on the right, the controls to start, stop and step-wise move through the construction of a concept map. The section on the left displays graphically the changes in the map, including indications of who made each of the modifications to the map. The frequent problem of trying to determine which learner contributed what to a team project is obviated with the use of the "record" feature of CmapTools. This feature also provides a powerful tool for cognitive research studies seeking to understand how different learners construct their meanings in any discipline.

Presentations based on a Concept Map: CmapTools provides the ability to piecewise display a concept map and associated resources on a full screen. Having students present their results orally has become a common practice at all levels of education. Similar kinds of reports are common in business settings. CmapTools includes a module by which the concept map can be displayed full screen and piecewise, allowing links to other maps that have also been specified with presentation information. This breaks with the linearity of slide presentations, because links to other maps can be followed at any time during the presentation.

The features presented, together with a number of additional tools available in the software suite, provide the technology infrastructure within which we can build the concept map-centered learning environment.

2.4 A Concept Map-Centered Learning Environment

Educators have found a large variety of uses for concept mapping in terms of the types of use as well as the curriculum areas and age group of the learners. Coffey et al. (2003) reported on its use in a diversity of learning situations. Among these, we find lesson assignments, pretesting, readings, class discussions, practice or exercises, collaborative/cooperative work, comparing and contrasting views, research work, oral presentation, written reports, integration with other studies, post comprehensive test, and home/community presentations. In this chapter, we won't go into describing any of these uses, as they are well documented in the literature (Coffey et al. 2003). However, even though concept mapping is an effective tool that can be used in all the listed activities, in most cases it is used for only one of them. As an example, concept mapping has been shown to be very effective for pretesting of students; determining how much students know before the instruction begins. This use is particularly consistent with the main principle of the Ausubelian learning theory (Ausubel 1968, Epitaph):

> *If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him or her accordingly.*

In most cases, however, the concept maps that the student constructs as a pretest are seldom used throughout the rest of the activities that take place on that same learning unit. This was understandable when concept maps were made by hand, as it was tedious to refine and reconstruct the map. We propose using the concept map as the artifact around which the various activities of the learning process are centered, as shown in Fig. 2.5. Based on the features provided by CmapTools described in the previous section, the student can use the concept map prepared as a pretest as a launching point toward his/her learning experience. As the student progresses through the learning unit, the concept map is enhanced to show his/her increased understanding. If the student engages in other activities (e.g., fieldwork, interviews,

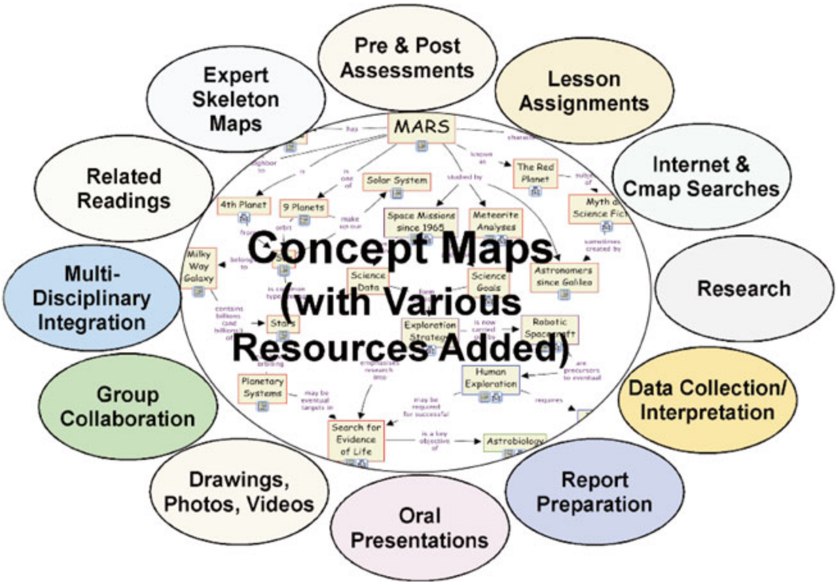

Fig. 2.5 This diagram illustrates how a concept map can be at the center of the various learning activities at school. As the student engages in the various activities shown, a concept map can show the student's increased understanding together with links to the resources involved in the activity

readings, writings, research, etc.), resources used and resources prepared by the student can be linked to the modified map. If the student is part of a team, concept maps can be built as a team or maps created by the various members can be linked together into a knowledge model. Unknown relationships between concepts generate questions for deliberation using annotations and discussion threads, and are a way to seed an issue-based IBIS discussion using Compendium, as described in chapters 7, 11 and 14 (Okada; Selvin; Sierhuis). Answers to unknown relationships can be researched using the search mechanism included in CmapTools, which takes advantage of the context provided by the concept map to generate smarter queries to Google and Yahoo, and to help locate other concept maps and attached resources that could be relevant to the concept map. Collaboration can take place among students within the class, within the school, or at other schools through the sharing mechanism provided by the CmapTools suite.

Throughout the learning activity, the student uses the concept map to reflect his/her increased understanding. Key in this learning environment is the fact that the process of constructing the concept map has more importance than the final map. Educators familiar with concept mapping understand that its power lies in the process of constructing the map, of reflecting on which concepts should be included and how they should be organized, and, more important, what the linking phrases should be. The key task is trying not only to express one's knowledge explicitly, but also to do so in a way that is clearly understood by others. The negotiation and argumentation that takes place between team members constructing a common map, whether working together on the same computer or collaborating using CmapTools, has more value than the final map. Throughout the whole process, the CmapTools Recorder is able to capture all the steps taken during the construction of the knowledge models, and provides the possibility of reproducing the complete sequence of steps graphically.

As the student completes a learning unit, the knowledge model constructed, together with attached resources and other tangible products resulting from the student's effort, should reflect the level of understanding and knowledge the student has achieved. We propose that these knowledge models be kept throughout the student's years in school, and that students be encouraged not only to link knowledge models from different learning units to demonstrate how they integrate knowledge that normally is fragmented, but also to go back and enhance knowledge models previously built. Knowledge models a student begins in elementary school can become highly elaborated by high school or college, providing a visible record of her/his intellectual growth.

Students are often asked to present their work to their peers, and often they do so through PowerPoint slides. Although we don't have anything against using PowerPoint, in the great majority of cases PowerPoint slides consist of bullets that don't make much sense unless somebody presents them to you. We feel that it's a pity when a student has a set of concept maps that are a concise and highly organized representation of his/her understanding that he/she be asked to convert them into a list of bullets in PowerPoint slides. As an alternative, as described earlier, CmapTools offers the user the capability of a full-screen presentation of concept maps that can be displayed piece-wise according to instructions set by the user. The user can make links to other concept maps with presentations and to resources of all types. This way, the knowledge model resulting from the student's efforts becomes in itself the presentation to his/her peers. By taking advantage of the links between concept maps and to resources, the presentation can show what the speaker feels is desirable without having to follow a linear sequence as in traditional PowerPoint presentations.

To complete their efforts, students can publish their knowledge models on the WWW. If their work was performed on a CmapServer that can be accessed from the Internet, then all that needs to be done is to make sure visitors have "read" access to the maps and resources. The students' work is published and accessible by others (e.g., family and friends) through any WWW browser, and with most CmapServers, is accessible through search engines such as Google after they re-index, usually within a few weeks.

2.5 Adopting the Concept Map-Centered Learning Environment

The concept map-centered learning environment is a moving target that has evolved as schools adopt the use of concept mapping as a process and take greater advantage of the capabilities offered by CmapTools and other new technologies. In fact, many

Fig. 2.6 On the left, high school students from the Instituto de Educatión Integral, in Costa Rica, are observing meteorological data on their laptop that they will compare with data from other countries using the WWW. Their work, including the data collected, is integrated through concept maps. The picture on the right shows Italian elementary school students conducting studies with plants to learn how plants grow and reproduce. Their school is part of a larger pilot effort that includes 150 teachers in Northeastern Italy

of the features that have been added to the software (e.g., the Presentation Module, the List View of propositions) are the result of schools providing us feedback for other uses of concept mapping that could be supported by technologies (e.g., student presentations).

The ideas that we have described in the previous sections have been implemented to varying degrees by schools in different countries. For example, the picture on the left of Fig. 2.6 shows high school students from Costa Rica at the Institute de Educación Integral analyzing meteorological data that will be compared with data from other countries. At this high school, students use laptops in their subjects to construct concept maps, which are the center of their learning experience, both individually and in groups (Alonso-Delgado & Silesky-Agüero 2004). Through the conceptual understanding derived from using concept mapping in their mathematics courses, students have been able to go beyond memorizing procedures and operations, and have significantly increased their grades in standardized national exams. The picture on the right of Fig. 2.6 shows elementary school children in Northeastern Italy, where a pilot project with 150 teachers is underway to improve science education in preschool, elementary, and high school under the leadership of Prof. G. Valitutti (2007) from the University of Urbino. These results have been reported in various publications (e.g., Berionni & Baldón 2006; Mancinelli 2006). Similarly, there are schools in other countries that are implementing or testing particular aspects of the concept map-centered learning environment. We prefer to concentrate on describing a large scale, nationwide effort that is taking place in Panama, where the concept map-centered learning environment is part of a project whose objective is to transform the public education system.

2.5.1 *Proyecto Conéctate al Conocimiento*[3]

In 2004, under the leadership of the then recently elected President Martín Torrijos, Panama adopted a national strategy based on meaningful learning for the public elementary school system through the project "Conéctate al Conocimiento" (Connect to Knowledge; Tarté 2006). With the aid of technology, the objective of Conéctate is to create a computer network that interconnects the schools, creating a space that allows the construction, sharing, and publishing of knowledge, development of new learning skills in individuals and groups, and preparation of the national capacity for the country's development as a knowledge-based society. This implies aiding in the transformation of elementary public education, from a traditional rote-learning system to one emphasizing knowledge construction and the development of skills according to the needs of the twenty-first century. The project's goal is to include teachers and students from 1,000 schools from all regions of the country over a 5-year period, with particular emphasis on reaching remote, rural schools. At the heart of the Conéctate project is the concept map-centered learning environment described earlier in this chapter. Thus, Conéctate provides a unique opportunity to observe and test on a national scale the ideas presented earlier.

2.5.1.1 Background Information

Before Conéctate, very few Panamanian public elementary schools had computers. Whereas in many other countries schools have had experience with technology for years or decades, and teachers have at least some familiarity with the use of computers, our studies showed that approximately 47 % of the Panamanian teachers had never used a computer before (Miller et al. 2006). In those cases where the schools had computers, a specialty teacher, usually with some computer technology degree, used them for a course on "Informatics" that is part of the elementary school curriculum. Miller (*Ibid*) reports that practically all teachers surveyed were familiar with concept maps, but that the most common practice was for teachers to construct a concept map in class for students to memorize. Fewer than 5 % allowed students to construct their own concept maps. Furthermore, there were a number of misconceptions among the teachers regarding concept mapping.

Even though Panama is a small country, rural villages are often very hard to reach, requiring many hours of travel over bad or nonexistent roads. In many cases, the schools that were to be included in the project did not have electricity, or the electricity distribution was such that installing computers in the school would leave the rest of the village without electricity. In many of the schools, both urban and

[3] Even though the authors, particularly Cañas, have been heavily involved with Proyecto Conéctate al Conocimiento, the views presented in this chapter should be interpreted as those of a third party. Credit for the success of the project belongs to the Facilitators, technical team and leaders of the project.

rural, a new classroom needed to be built to install the computers. As a result, there are schools in Conéctate with electricity from a local power plant, a satellite connection to the Internet, and computers in a new classroom.

Rote learning and students copying from the blackboard characterized the Panamanian classroom before Conéctate, as is the case in many Latin American countries. For the most part, the teacher does not have many resources to use in the classroom, and libraries are lacking or poorly stocked. However, teachers, particularly in rural areas, are highly motivated and committed to their students, and embrace new opportunities like those offered by Conéctate.

2.5.1.2 The Project

Housing the Project

Conéctate presents challenges both in the technological arena – given the location and infrastructure of many schools – as well as in the methodological aspects of how to transform the way learning takes place in the classroom. The main challenge, however, is scalability. Building a new classroom to install computers and training the teachers for one, two, or a few schools is a very different proposition than doing so for hundreds of schools involving thousands of teachers.

Transformations such as those sought by Conéctate are difficult to implement within the bureaucracy of a Ministry of Education. These large government organizations have so many issues to resolve just in terms of personnel (e.g. dealing with teachers' salaries), that there is little room for innovation, let alone at the speed and scale that Conéctate required. For this reason, Conéctate was temporarily situated under a newly created Secretariat for Governmental Innovation, whose objective is to modernize the Panamanian government through technology. For the long run, a not-for-profit organization is being created that will house the Project. Meanwhile, the agility of the newly created Secretariat enabled Conéctate to get going in a much shorter time period than would have been possible otherwise. Financial resources, however, still come from the Ministry of Education, and a very close coordination is maintained with education authorities.

The Technology

Given the physical infrastructure of schools and the scale of the Project, it was determined that it would be impossible to install computers (i.e., desktops) in each of the classrooms. The high temperatures throughout most of the country year round make it necessary to install air conditioning units wherever desktops are installed, which, combined with the need for electrical infrastructure in the schools, would make the cost of this alternative prohibitive. Therefore, computers are installed in a special room that is referred to as the Innovation Classroom. However, our experience has taught us that in most technology-in-education projects that have a computer lab, what takes place in the lab is usually not reflected in what takes place in the classroom. That is, training teachers on how to use new technologies, particularly if the computers are not in the classroom, does not achieve changing the way learning takes place in the classroom. In other words, training teachers on how to construct concept maps using CmapTools would not lead to the concept map-centered learning environment where the various activities that occur in the classroom take advantage of concept mapping. Furthermore, given the rote-learning environment we found in most classrooms, training teachers on the use of the technology would most likely have no effect on the way they manage their classroom. In each of the Innovation Classrooms there would be a computer aid (formerly the Informatics teacher), a specially trained teacher that would help the classroom teachers take advantage of the technology. However, we knew that we couldn't rely on training these aids and having them train the teachers – cascade training gets watered-down pretty fast. Thus, it was decided that to the extent possible, all classroom teachers would be trained not only in new methodologies needed to implement a meaningful learning environment in the classroom, but also in the use of technology.

Conéctate was designed to be a network of schools that facilitates collaboration, publishing, and sharing. To achieve this goal, the whole set of participating schools is seen as being part of the same community, as a single organization, with all schools interconnected and connected to the Internet. Within each school, a CmapServer is installed with a public IP address, which means that the server can be reached from other schools and from anywhere on the Internet. This leads, of course, to the school having a "presence" on the Web, not only access to it. Students and teachers can share and collaborate, and students can access their concept maps and resources from home or through an Internet Cafe (CmapServers in the Conéctate schools can be reached through the Places View in CmapTools or through a WWW browser). Within the CmapServer, each student and teacher has his/her own area for files, maps, and resources. The Project is in the process of implementing Nicho, a piece of software designed at IHMC that facilitates assigning each student an email address (managed by Google, teachers already have their email address) and implements a chat service. Nicho enables the use of the same userid for email, chat, CmapTools, and Web browsing, and additionally provides space in the school's file server. Through Nicho, students can use any of the computers in the school to access their resources and tailored environment. They are assigned a unique userid for their years at a school, and the "space" with its resources will migrate with her/him if she/he switches schools. The goal is for the technology to fully support and facilitate the sharing and collaborating environment needed to implement the concept map-centered learning environment described in this chapter.

Teacher Training

The scale of teacher training, together with the need to make personal visits to follow up on the teachers after the training, required the creation of a group of full-time Facilitators: professionals from a wide variety of disciplines that were trained

Fig. 2.7 Pictures showing teachers during workshops learning to use concept maps without a computer, as would take place in the classroom

to take on the tasks of training teachers, visiting schools, and preparing resources needed (e.g., documentation, videos, etc.), and in some cases carrying on research. The selection of the group was exhaustive, with more than 1,000 resumes reviewed to come up with a group currently of just over 30 Facilitators.

The teacher training workshops consist of 2 weeks of full time, intensive work. Training is also provided to the school principal (a principal that supports and understands the Project is one of the key factors needed for success) and Ministry of Education supervisors. Conéctate has the facilities to carry on 10 of these workshops concurrently, with 20 teachers in each group, for a total capacity to train 200 teachers every 2 weeks. Part-time substitute teachers teach in the classroom of participating teachers for the duration of the workshops. As was indicated earlier, most teachers have never used a computer before attending the workshop, and many have never used a keyboard. The decision was made, however, to have the teachers learn to use the computer through CmapTools as opposed to using Windows and/or Office as is often done. Within a few minutes, teachers are constructing their own concept maps, maybe with some difficulty in manipulating the mouse, but are engaged in representing their understanding, an effort that they can immediately identify with and that they perceive will be useful with their students. Suárez & Villareal-Bermúdez (2006) report that after a few days into the workshop, there is no distinction in the quality of the concept maps constructed by teachers who had or had not used a computer previously. That is, the use of the computer has become, to a certain extent, transparent. The workshops are completely construetivist in nature. In addition to concept mapping and meaningful learning, the workshop covers additional topics such as project based learning and collaborative projects, emphasizing the use of concept maps both as a way to integrate the projects' activities and to integrate diverse disciplines. Given that the teachers will not have computers in their classrooms, it is important that they feel comfortable with the idea of working with concept maps, both with and without computers. Figure 2.7 shows two examples of teachers using other materials to construct their concept maps. This experience carries on in the classroom as can be seen in Fig. 2.8, where the picture on the left shows students collaborating on the construction of a concept map with cardboard,

Fig. 2.8 The picture above shows students collaborating on the construction of concept maps in the classroom. On the right is a partial display of the material developed by students as part of a project

and the display in the picture on the right shows some of the end products of a project, with a couple of concept maps on the wall. Overall, the objective of the workshop is to provide a basic understanding of constructivist environments, meaningful learning, concept mapping, and proper use of the technology so that teachers further along can take advantage of any resource, whether it is technology based (software, sensors, etc.) or not, in a constructivist way.

Among the activities that take place during the workshop, there is one in particular that demonstrates how different aspects of the Project fit together, and how the work from the workshop continues when the teachers return to their schools. One of the first concept maps that teachers construct is themed "Who Am I?" – a concept map about themselves. Further along during the workshop, teachers from the same school together with their Principal prepare a "Who Am I?" concept map for the school. Along the way, teachers bring in pictures (family pictures, for example) that they wish to scan and link to the map, or borrow a digital camera to take pictures of their school when they go back for the weekend between the two weeks of training. The resulting concept maps are quite interesting, as teachers get quite personal in both their concept maps and their school's map, particularly when trying to describe what is to them important in their school (e.g., those from a remote rural school may emphasize that they have a boat with a motor, others emphasize that children receive free lunch, or list the names of the employees that clean the school). The teacher's maps are linked to the school's map, and when they are saved on the school's CmapServer, become the "web page" for the school. The school's map is then linked to a geographical map of Panama. Figure 2.9 shows a Web browser with three windows. The top left window is the main concept map for the Project, its WWW page (www.conectate.gob.pa). This map has a link to a geographical map of Panama, shown in the lower left window. For each province, there are links to each of the schools' "Who Am I?" maps, as is shown in the partial display of the schools of the province of Chiriquí. In the top right window is displayed the concept map for the school "El Limó"which describes details about this school. This school consists of only a computer aid and two teachers, one covering first, third and fifth grade, and

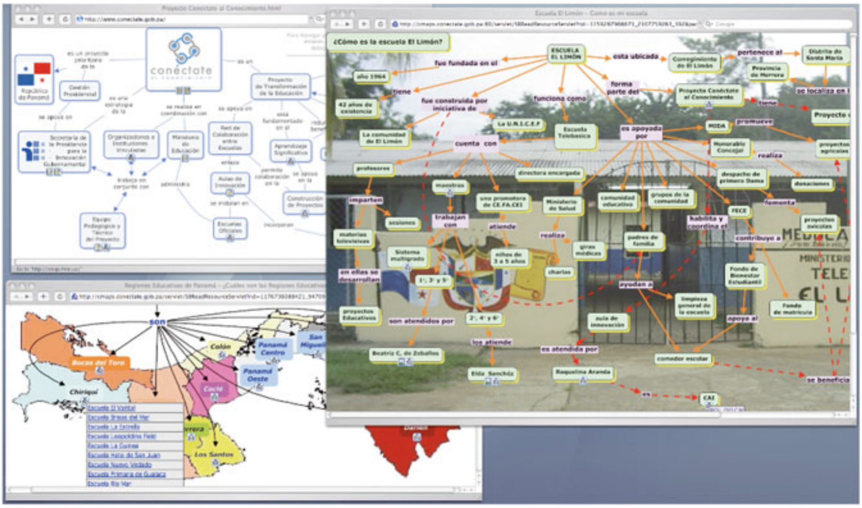

Fig. 2.9 These three browser windows show the linkage from Conéctate's Web page map (*top left*) to the geographical map of Panama (*lower left*) where there are links to each of the school's "Who Am I?," as shown in the right for the school El Limón From the school's map, links can be followed to teachers' maps, student's maps, etc

the second covering second, fourth and sixth (these are referred to as multigrade schools, and are very common in rural areas where the student population is low). There are links to the teachers "Who Am I?" map, from which there are links to the different grade's "Who Am I?"map. The intention is that from each of the grade's maps there will be links to each student's "Who Am I?"map, and links to projects the grade is engaged in. Each student can have links from his/her map to knowledge models that he/she wants to publish and share with others. As the Project progresses, students will be able to navigate to the concept maps of any other student in the Project, creating a sense of community. When students start collaborating with other students, they can easily search for their peer's concept maps and learn who they are, what their interests are, and so forth. This work is still in progress, of course, but the schools are moving toward this goal. The web pages for the school also provide a sense of pride and belongingness to the Project. Remember that most teachers had never used a computer. They return from the workshop with their school'ge as well as their own personal web page, and with their school having a "presence" on the Internet. They now have pages that they constructed by themselves, and more important, that they can modify at any time without the need of any webmaster or technician. This is a source of pride. As Google indexes the html versions of the concept maps, it is very common to see in the logs searches by teacher name –most likely teachers searching for themselves (or for a colleague). They also feel that having their maps linked to the main Project' map provides a sense of belonging –their school is now *part* of conéctate

Follow-Up Visits and Support

Nobody expects teachers to "change" during a 2-week workshop. It is clear that for many of them, the workshop opens up many opportunities and provides a multitude of ideas, but reality sets in when they return to their classroom. That is why the Facilitators periodically visit each of the teachers to provide support, help, and advice. The visits are conceived of as a continuation of the workshop, a means by which the learning process can continue. These visits, together with the workshops, consume a large portion of the Facilitators' time. However, it is clear that their visits make a huge difference in whether the teachers take the initial steps necessary to change the way learning takes place in their classrooms. With the Facilitators' support, many teachers that were afraid to move ahead have been able to rise to the challenge. As a support within the schools, the Facilitators rely on the computer aid to provide daily help to teachers when using the technology.

Given the scale of the Project, as the number of schools increases it becomes physically impossible to continue to visit each of the teachers personally. Furthermore, it is also impossible to bring all the teachers back for follow-up workshops. To continue providing training and support to the teachers long term, Conéctate is currently moving quickly toward an online support and training platform. Once a school has reached a certain level of performance, online support will help reduce the frequency of personal visits. The Project has developed a set of tools, including a topological taxonomy (Cañas et al. 2006) and a semantic rubric for concept maps, to determine the level of advancement of the schools.

Current Status

Conéctate now includes more than 300 schools installed with computers and Internet connection. By the end of 2007, 500 elementary schools will be part of the Project. As discussed earlier, this has meant, depending on the school's setting, construction of new classrooms, electrical infrastructure, local electrical power plants, satellite Internet connections, and all kinds of problems that are encountered when dealing with a large number of schools in remote and difficult access areas. More impressive, over 5,000 fourth-, fifth-, and sixth-grade teachers have been trained in the 2-week workshops, reaching approximately 100,000 students. The Project intended to train only the upper grade level teachers initially, but in a large number of schools, these teachers have already involved and trained the first- and second- and third-grade teachers on their own initiative.

It is illusory to expect that all 5,000 teachers will adopt the concept map-based learning environment in their classrooms. We understand that it is a long-term process, and that it will be years before the real effects of the Project can be determined. However, in the large number of cases where the teachers have adopted the proposed model, the changes are clear and measurable in terms of the environment in the classroom, the students' participation, interests and questions, and in the students' grades (cf. Rodríguez & Coloma 2006).

President Torrijos has announced Panama's participation in the One Laptop Per Child (OLPC) initiative, with an initial purchase of 100,000 laptops. Thus, the Project may soon be moving toward a model where the students will have their own laptop in the classroom.

Some Lessons Learned

Lessons are learned daily in such a large Project. In this section, we try to summarize some key observations. Readers will find some of them to be confirmations of results seen in other projects:

- Even in a Project that is conceived of initially as a technology-in-education effort, it is possible to transform the way learning takes place in the classroom, even when technology is not involved. (There were cases where, for various reasons, the installation of the computers was delayed way beyond the training of the teachers. However, there were teachers in this situation who, even without the technology, transformed their classroom based on the methodologies learned during the workshop).
- The school's Principal is a key player in the Project. If the Principal believes in the Project and supports it, the chance for success is much higher. Including the Principal in the training workshops was, therefore, an important decision, even though it is difficult to implement as most Principals firmly believe their school will collapse if they go away for 2 weeks.
- It is important to synchronize the arrival of technology with the teacher training; otherwise retraining may be needed.
- Teachers do not need to have previous training in the use of computers to be introduced to programs with a low threshold such as CmapTools.
- A sense of belonging and a sense of pride (e.g., the "Who Am I?" maps) can go a long way toward getting principals and teachers involved in the effort.
- Follow-up visits to the teachers, particularly shortly after they return from the workshop to the classroom, increase the chances of the teacher succeeding with the Project.
- Not all teachers are willing to change, thus one must accept that one may have to give up on trying to change many of them.
- In order to change the educational system permanently, the change needs to take place at the source: that is, the universities and institutes teachers graduate from need to change.

2.6 Conclusion

We have presented a concept map-based learning environment, where the concept map becomes an artifact through which the students demonstrate changes in their understanding of a topic. With the use of technology such as CmapTools, the concept map becomes a way to integrate various learning resources, and can be used as an artifact through which students can collaborate both locally and remotely. By organizing the knowledge models resulting from concept maps and attached resources, digital portfolios can be built that show the students' changes in cognitive structure throughout the years. Schools throughout various countries have reported successes with implementing some of these ideas. The large scale, countrywide implementation of this environment in Panama provides the opportunity to examine and test these ideas. The initial results are encouraging, as Conéctate al Conocimiento will have grown to 500 schools by the end of 2007. The experience being generated in Panama will undoubtedly help other countries in their efforts to adopt the concept map-based learning environment.

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