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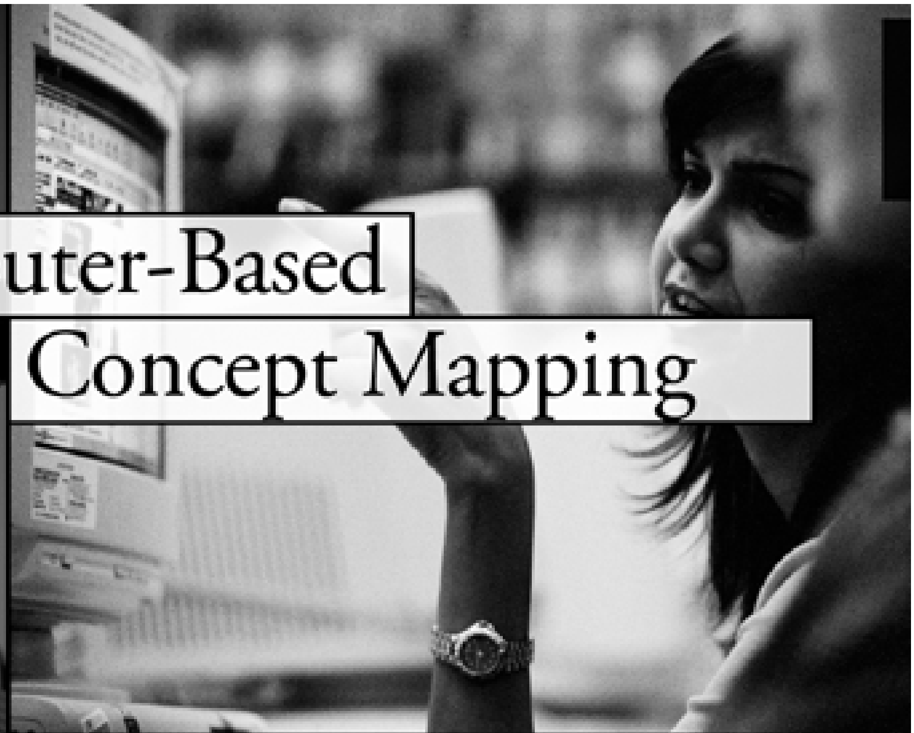


Computer-Based Concept Mapping

A TOOL FOR NEGOTIATING MEANING

In this feature article, the authors describe strategies for using computers to enhance teaching and learning through the process of electronic concept mapping. Each strategy provides teachers with step-by-step guidelines for integrating computer-based concept mapping into the curriculum and documents how research on the strategy is yielding promising results.

By Lynne Anderson-Inman and Leslie Ditson

Subject: Concept Mapping

Grade Level: All

Technology: Inspiration® (Inspiration Software Inc.)

Concept mapping is a process for representing concepts and their relationships in graphical form, providing teachers and students with a visually rich way to organize and communicate what they know. In the broadest sense, concept maps can be associated with other ways to represent information graphically, such as mind maps, semantic webs, storyboards, flowcharts, and other diagramming techniques. In the strictest sense, however, concept maps are hierarchical representations of concepts and propositions that reflect both the *content* and the *structure* of a person's knowledge in a given domain. Because knowledge content and structure may be different for different people (or change over time for the same person), concept maps help us communicate with each other about what we know or think we know. As such, concept maps can be used as "tools for negotiating meaning" (Novak & Gowin, 1984, p. 20).

Knowledge representation tools such as concept maps can help teachers and students externalize (or make visible) their understanding of a concept and its relationship to other concepts. In the accompanying example (Figure 1), a teacher demonstrates the relationships among three major concepts (sea animals, swimming, and not swimming) using two propositions: "Sea animals [are] designed for swimming" and "Sea animals [are] adapted for not swimming." Concept mapping by *teachers* helps students understand what is being taught, whereas concept mapping by *students* helps teachers understand what is being learned. By externalizing what is being taught or learned, teachers and students can clarify their understandings and clear up misconceptions. When concept maps are approached as "explicit, overt representation[s] of the concepts and propositions a person holds, they allow teachers and learners to exchange views on why a particular propositional linkage is good or valid, or to recognize missing linkages between concepts that suggest a need for new learning" (Novak & Gowin, 1984, p. 19).

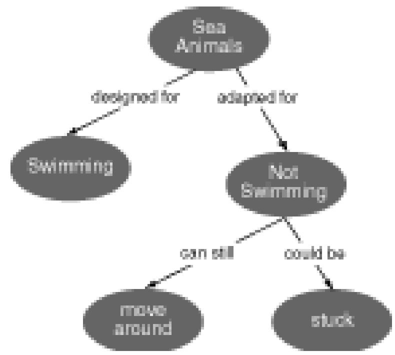


Figure 1. A simple computer-based concept map showing concepts and propositions.

If they are to be effective as tools for negotiating meaning, however, the concept maps created by teachers and students should be easy to modify. For example, teachers should be able to quickly add or rearrange information in their concept maps if it becomes clear that students find the maps confusing. And students should be able to modify or restructure their concept maps to reflect instruction and improved understanding over time. Unfortunately, concept maps created by hand with pen or pencil on paper are not easily modifiable. Editing a traditional concept map can be frustrating: Even a small change might require the map to be completely redrawn. If the person who has created the concept map has put effort into communicating concepts and processes with images or other graphic features (see Figure 2), then the task of modifying a map is even more daunting.

Computer-Based Concept Mapping

Over the past several years, the Center for Electronic Studying at the University of Oregon has been investigating the use of computers to facilitate concept mapping. Such computer-based concept mapping enables teachers and students to draw and redraw their concept maps in an electronic environment, thus making changes to a map's content and structure relatively easy. Concept mapping with a computer has greatly enhanced teachers' and students' willingness to use concept mapping for instructional purposes, because electronic maps transcend page size, are easy to create, and are dramatically faster to revise than their paper-and-pencil counterparts.

Much of our work has focused on the use of computer-based concept mapping as a tool for studying (Anderson-Inman & Zeitz, 1993), with particular emphasis on computer-based study strategies that foster information manipulation and knowledge representation (Anderson-Inman & Horney, 1997; Anderson-Inman & Zeitz, 1994). Through these efforts, we have developed and evaluated strategies that support the use of computer-based concept mapping by students when they take notes in class, record information from their textbooks, study for tests, brainstorm ideas for a paper or report, or synthesize information from multiple sources (Anderson-Inman, Horney, Knox-Quinn, Ditson, & Ditson, 1997). Over the years, we have become increasingly convinced that computer-based information manipulation strategies such as concept mapping enhance students' abilities to understand complex material (Zeitz & Anderson-Inman, 1992). This is especially true for students with learning disabilities who are often struggling in schools because of difficulties in reading and processing text-based materials (Anderson-Inman, Ditson, & Ditson, 1998; Anderson-Inman, Knox-Quinn, & Horney, 1996).

Because of its high visual potential and diagrammatic structure, concept mapping is an excellent alternative for students who are uncomfortable with more verbal approaches to sharing their knowledge. In our work we found that students who are good at concept mapping often excel on tests of spatial skills (Zeitz & Anderson-Inman, 1993) and might be classified as visual learners.

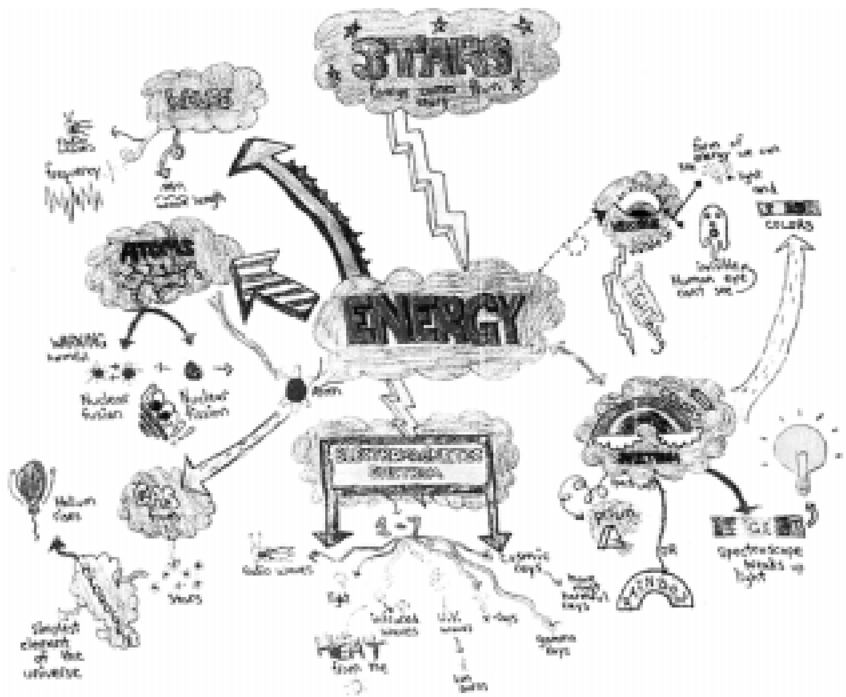


Figure 2. A hand-drawn student-generated mind map.

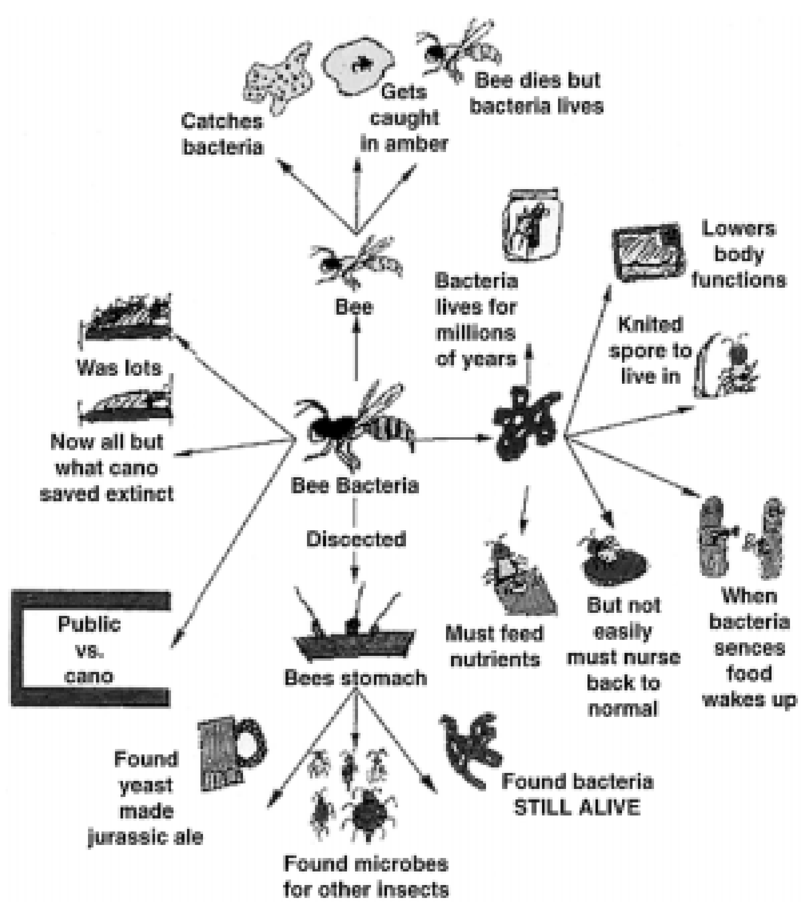


Figure 3. A symbol-rich concept map, created on the computer.

Olsen (1992) observed that "children who are visual learners . . . are simply different from verbal learners. Teachers need to understand and incorporate visual thinking and visual learning strategies into conventional teaching methods . . . to make it possible for both types of learners to reach their full language potential." (p. 6) Concept mapping is an excellent way of "negotiating meaning" with students who think well in graphical representations of their knowledge.

We have also learned that images can play an important role in students' construction of concept maps. They minimize the need for text and help students personalize their maps in ways that promote long-term retention of information. To encourage the inclusion of images and other graphics when concept mapping in a computer environment, we developed a strategy for creating "symbol-rich maps" (Center for Electronic Studying, 1998; Kessler, Ditson, Anderson-Inman, & Windham, 1996). This use of digitized graphics (generated on the computer or by hand and then scanned) fosters the student's unique, personal expression while still offering the benefits of working in an electronic environment. Figure 3 presents a symbol-rich map created by a middle school student who had read an article on bees.

Most of our published work has examined student use of computer-based concept mapping for studying and learning. In the remainder of this article, we focus on teachers' use of this mapping as a tool for planning, presenting, and evaluating student learning. The ideas, strategies, and illustrations resulted from three years of work with teachers on Project COMPASS (COncept Mapping Power for Academic Success in Science), a research and materials development project that was funded by the U.S. Department of Education.

Strategies for Computer-Based Concept Mapping

The following sections—brainstorming, curriculum planning, and concept formation tracking—show three ways in which teachers can integrate computer-based concept mapping into their curricula. Each method is more carefully elaborated and illustrated in our recently published *Concept-Mapping Companion* (Center for Electronic Studying, 1998).

To implement these strategies, teachers should have access to software that makes it easy to create concept maps or other types of diagrams. In most of our work, we have used the software program Inspiration® (1988–1997), a flexible and user-friendly program that supports the production of electronic outlines as well as electronic diagrams, maps, and flowcharts. Although our *Concept-Mapping Companion* is illustrated with screen shots from Inspiration® and capitalizes on some of the software's unique features, the instructional strategies described below can be implemented with any relatively similar graphics program.

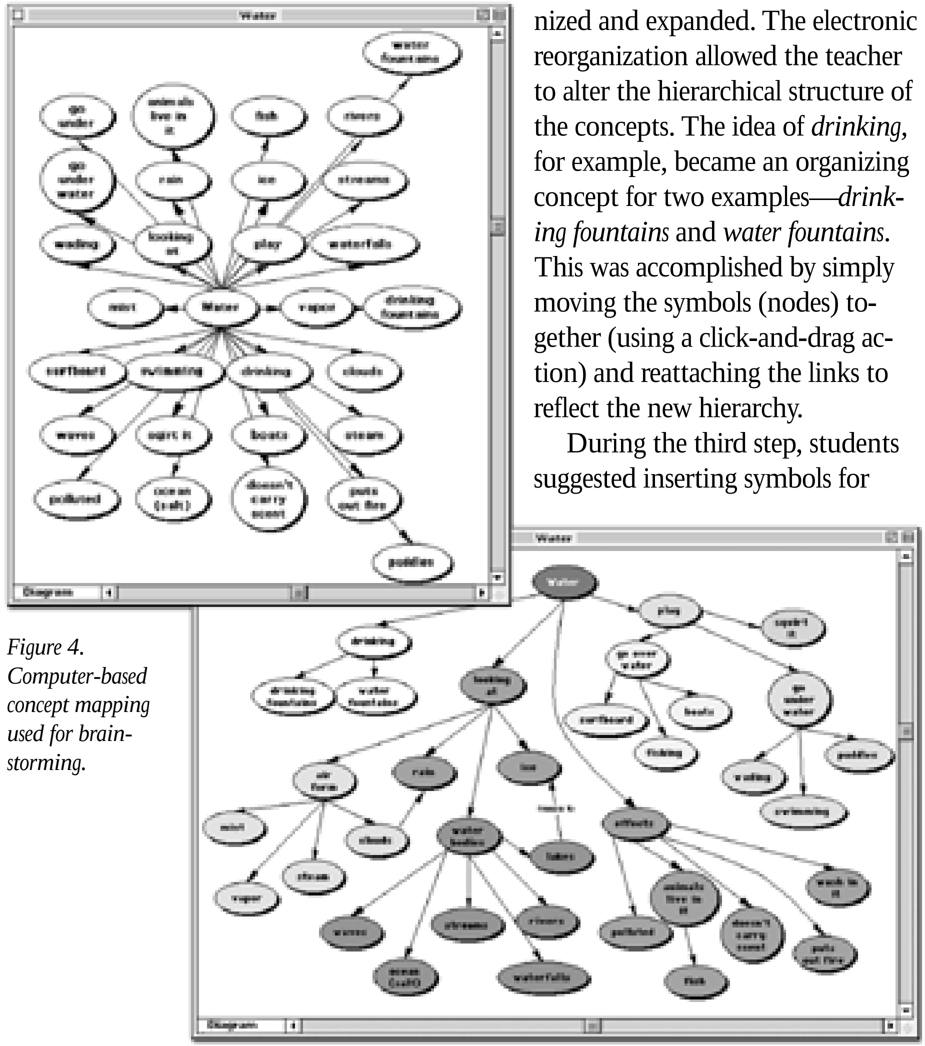


Figure 4. Computer-based concept mapping used for brainstorming.

Brainstorming. Computer-based concept mapping is an ideal tool for brainstorming. When directed by a teacher, the activity is effective for generating interest in a subject and helping students make their existing level of knowledge visible to themselves and others. Brainstorming also can help students organize or reorganize their perceptions and understanding before they get further instruction. If used before writing, brainstorming can help students generate ideas to explore as they write or identify sources of information about an assigned topic (Anderson-Inman & Horney, 1997).

Brainstorming *can* be done without a computer (and even without concept mapping), but recording the brainstorming process electronically has many advantages. First, typing is faster than writing by hand on chart paper or chalkboard; this encourages a freer flow of ideas and a more accurate recording of the information that emerges. Second, the generated ideas can be more easily organized into categories or themes without the need to erase and rewrite. Third, ideas can be expanded or elaborated more easily through additions and modifications. Fourth, the results of the brainstorming activity can be shared with all of the participants by printing paper copies.

The brainstorming strategy that emerged from our work on Project COMPASS has three steps:

1. Gather ideas.
2. Reorganize results.
3. Explore and expand the concepts.

Figure 4 shows two class concept maps on "water": one that emerged after the first step of gathering ideas and one after the results had been reorganized and expanded. The electronic reorganization allowed the teacher to alter the hierarchical structure of the concepts. The idea of *drinking*, for example, became an organizing concept for two examples—*drinking fountains* and *water fountains*. This was accomplished by simply moving the symbols (nodes) together (using a click-and-drag action) and reattaching the links to reflect the new hierarchy.

During the third step, students suggested inserting symbols for new categories (e.g., *air form* and *water bodies*) and began to clarify conceptual relationships by labeling links (e.g., *freeze to*). Because concepts and links can be easily added to an electronic concept map, the teacher was able to respond to these suggested changes immediately and thus support the students' efforts to help construct a map that reflects their existing knowledge of the topic.

Curriculum Planning. Through the years, teachers have used a variety of tools for curriculum planning. Concept mapping has recently emerged to help teachers clarify important conceptual relationships in the content they teach, as well as help them organize their instructional lessons or units in ways that are conceptually meaningful to students. Starr and Krajcik (1990), for example, found that constructing concept maps during curriculum planning helped teachers develop curricula that were more cohesively integrated. In work with preservice teachers, Martin (1994) found that concept mapping as part of the curriculum-planning process made the material more meaningful for both teachers and students, encouraged curriculum integration, made it less likely that key concepts would be omitted during instruction, and supported teachers in providing students with multiple ways to construct meaning.

The curriculum-planning strategy that emerged from our work on Project COMPASS has three major steps. When adopting this approach to curriculum planning, the teacher uses the computer to:

1. Outline the course (or unit).
2. Elaborate with notes.
3. Expand the units (or lessons).

Figure 5 shows a concept map that was created by an instructor who was teaching a course on earth systems. The first step was to identify the major concepts in the course; these are represented in the map by the symbols for *forces, cycles, layers,* and *crustal plates.* These major concepts were in turn extended by adding key propositions (e.g., "Forces can be destructive") and important examples (the four types of cycles and the earth's three layers).

Once the entire course was mapped, the teacher was ready to elaborate the concepts, propositions, and examples with instructionally useful information. Inspiration software allows such details to be put into a "notes" window linked to each symbol. A notes window in Figure 5 can be seen for the concept of *cycles,* showing the types of questions the teacher is planning to ask during a discussion. In the last step, a teacher can expand each major concept (i.e., the units or lessons) into a detailed concept map of its own. Inspiration facilitates this process by allowing the teacher or students to create and link submaps ("child maps") to any symbol.

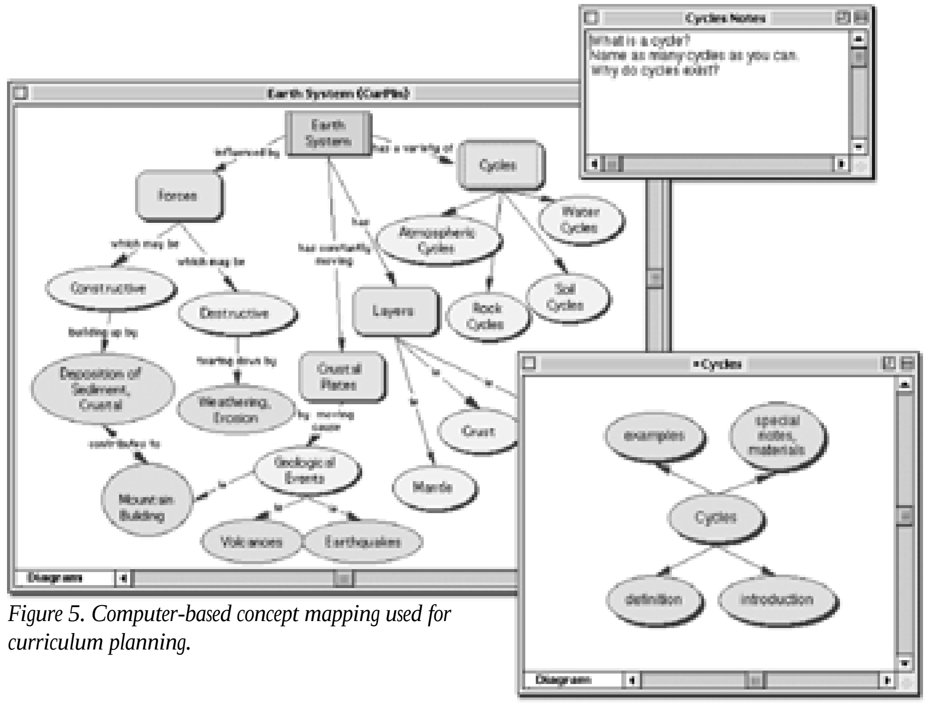


Figure 5. Computer-based concept mapping used for curriculum planning.

These child maps can be used to identify increasingly specific conceptual relationships related to instructional content, or they can be used to record planned activities within the lesson (see Figure 5 for an example).

This computer-based approach to curriculum planning offers teachers a single vehicle for working out the complex interrelationships of a unit's content, while also serving as a place to record mundane details of how that content will be translated into lessons. The process has three distinct advantages over paper-based concept mapping. First, both the content and structure of an instructional unit or entire course can be represented easily and quickly. This encourages teachers to plan well and often. Second, the teacher can more easily adopt a process of continued curriculum refinement, modifying the concept map over time to include new material, reflect changing student needs, and provide multiple perspectives. Because conceptual relationships within the content are highly visible, teachers can easily integrate the new information with the old. And finally, concept maps lead to more explicit representations of a teacher's knowledge than is commonly seen in text. When developed for curriculum planning, such maps also can be used for communicating with students. Willerman and MacHarg (1991), for example, found that concept maps of curriculum content were effective as "advance organizers" because they gave students an overview of key concepts and conceptual relationships before they were exposed to more in-depth instruction. When the advance organizer is an electronic concept map, the teacher has an interactive tool that can focus student attention on specific segments of the curriculum; this can be done by judiciously hiding and showing portions of the map using special built-in software features (Center for Electronic Studying, 1998).

Concept Formation Tracking. The use of concept maps for instruction assumes that an individual's understanding of a conceptual field changes over time, hopefully in response to instruction or new learning opportunities. To track this conceptual growth, teachers can ask students to create concept maps after each instructional activity in a unit. This gives teachers the data they need to determine whether the desired changes in conceptual understanding have actually occurred. This process of tracking concept formation over time has been found to increase "meaningful learning"—that is, learning that occurs when students actively work to integrate new information with prior knowledge and internalize their understanding of the conceptual interrelationships they are studying.

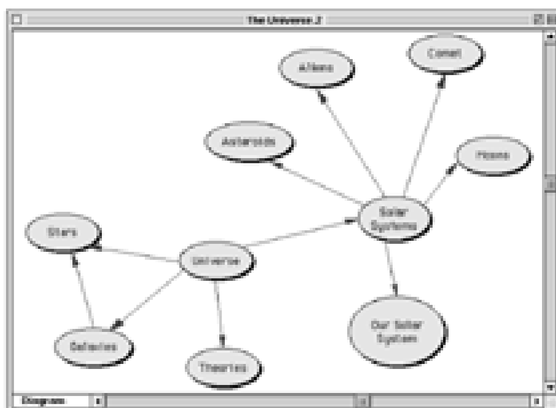
Pankratius (1990), for example, found that students who created concept maps throughout a three-week unit on energy had higher test scores than students who either only created concept maps at the end of the unit or did not create them at all. Okebukola (1990) obtained similar results in a biology course. Students in the experimental group were asked to produce a concept map at the end of each lesson through two different units, one on genetics and one on ecology. The maps were evaluated by the instructor and then returned to the students. End-of-unit tests of meaningful learning revealed significantly higher scores for the concept mapping students on both units.

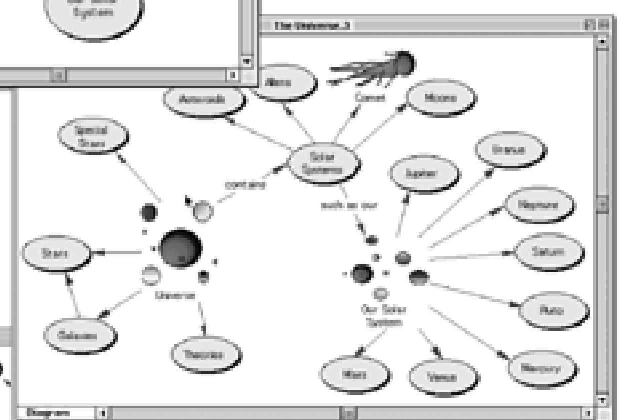
This approach to "concept formation tracking" (more on this below) provides teachers with a clear picture of what students are thinking and also serves as a vehicle for discussing and correcting conceptual errors. Computer-based concept mapping lends itself well to this approach, because electronic maps don't have to be completely redrawn when students choose to expand or modify an existing map after new instruction. Anderson-Inman and Zeitz (1993), for example, describe a study technique in which the student uses the computer to modify a single electronic concept map for a unit on cells. The students can change this one map continually rather than create a different concept map for each lesson.

In working with teachers as part of Project COMPASS, we developed a learning strategy that regularly integrated computer-based mapping into the teacher's instructional activities. Known as *concept formation tracking*, the strategy has three steps:

1. Construct an initial map.
2. Provide learning opportunities.
3. Refine the map using new concepts.

In the first step, students construct a concept map that reflects their understanding of a subject or topic before they receive instruction. This "premap" can be constructed around a set of terms given to the students by the teacher or in response to a more open-ended prompt such as "Make a concept map showing what you know about mammals." The top map in Figure 6 was constructed by a student from a list of 10 words that relate to the concept of "universe."





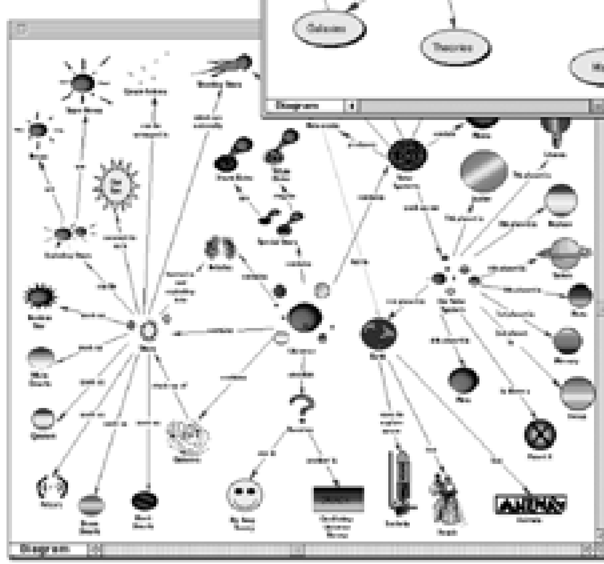


Figure 6. Computer-based concept mapping used for concept formation tracking.

The second and third steps in this strategy are actually part of an iterative process in which the teacher provides instruction and students then revise their concept maps. The second map in Figure 6 reveals the changes made to the universe concept map after the first instructional unit on our solar system and its planets. After two more units, one of which included fairly extensive use of a computer-based game on astronomy, the student had modified, extended, and elaborated the concept map of the universe to look like the large, graphically rich map at the bottom of Figure 6.

By comparing this map with earlier ones, the teacher can track conceptual growth over time and assess the extent to which instruction is having the desired effect on student learning. Consistent with a more in-depth understanding of the content domain, the student has added a large number of symbols and refined the validity of the propositions and examples presented. Furthermore, there is a decrease in the number of unlabeled links, an increase in the number of cross-links and an increased depth to the hierarchy. These changes represent an increase in map complexity that correlates with improved scores on tests of content knowledge (Zeitz & Anderson-Inman, 1992).

Being able to see changes in a student's understanding in response to instruction is tremendously useful for the teacher. The gradually evolving concept maps can be used as a basis for dialogue with students, facilitating discussion aimed at eliminating misconceptions, or clarifying key concepts. Teachers can also use the maps to determine whether a lesson effectively brought the desired change in understanding. In addition, examining concept maps can help teachers also pinpoint which students need more instruction (and on which topics) and which students are ready to move on to new material. Finally, teachers can use the student maps to document learning over time in place of a test or as items for students' portfolios.

One concern regarding concept formation tracking is that it is somewhat time-consuming. It requires a teacher to identify changes in the content and structure of students' knowledge as represented in their concept maps—and to do it over and over again. We tried to solve this problem in Project COMPASS by creating an assessment system that used a computer to generate a concept map report after each student concept-mapping session. We wanted to simplify the task of examining a student's concept map by electronically summarizing information about a given map (e.g., number of symbols, links, and cross-links) and providing a list of the propositions and examples included in the map. To support teachers' efforts to evaluate the quality (i.e., the validity) of this information, we also provided a Likert scale by which teachers could record the accuracy of each proposition or example. Tests of interrater reliability showed a high level of agreement (Kessler, Anderson-Inman, Ditson, & Morris, 1996; Kessler, Anderson-Inman, Ditson, & Stoolmiller, 1996), which suggests that the system is both easy to use and reliable as an assessment tool for teachers. This system is now embedded in the *Concept-Mapping Companion*, which makes it available for teachers who are using the Inspiration software.

Conclusion

As described above, computer-based concept mapping can serve as the basis for a variety of strategies that enhance the teaching and learning process. In addition, it provides a fresh approach to working with students who have not responded well to the heavily text-centered world of school. As illustrated in our examples, computer-based concept mapping can be used to support an individual teacher or student's efforts to communicate his or her personal understanding of a set of concepts and conceptual relationships. In contrast, it can also be used to facilitate the development of group understanding. With either approach, making concepts and propositions visible enables students to reflect on, discuss, modify, and refine them. When concept mapping is conducted in the fluid and flexible environment provided by the computer, desired modifications and refinements are easily integrated into the concept map itself—making real the notion that concept mapping supports the process of negotiating meaning.

The difficulty of assessing concept maps is inherent in many of the strategies suggested for integrating concept mapping into the curriculum, both the learning strategies for students and the instructional strategies for teachers.
It is easy for concept maps to reach a size and complexity that makes interpretation and evaluation difficult. To facilitate teachers' use of concept mapping, researchers and educators have been exploring various ways to monitor student learning and document content mastery. At the Center for Electronic Studying we have focused on providing teachers with a computer-based system for automatically tracking concept map development, thereby facilitating concept map interpretation and evaluation. In short, the more teachers know about the content and structure of students' concept maps, the more those maps can be used as "tools for negotiating meaning." ■

Lynne Anderson-Inman, lynneai@oregon.uoregon.edu; Leslie Ditson, ditson@oregon.uoregon.edu

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Note. For those readers interested in the assessment of concept maps, we draw your attention to a follow-up article that will appear in Learning & Leading With Technology *in the fall. Titled "Computer-Based Concept Mapping: A Tool for Assessing Learning," the article will address the issue of assessment in relationship to concept mapping and describe newly available approaches for assessing concept maps created in an electronic environment.*