A n approach to teaching that is centered on students represents a major departure from the traditional lecture-based, passive college learning environment. Felder and Brent (1996) have presented useful guidelines for implementing a student-centered approach. They advocate getting students actively involved in learning, using a variety of tasks (e.g., team-based learning, problem solving, application simulations), and reflecting upon, organizing, and applying what they have learned. Specifically, Felder and Brent (1996) offer their guidelines as a framework to enhance a variety of qualitative outcomes including motivation to learn, depth of understanding, and retention of knowledge.

Although the ideas of Felder and Brent (1996) have the potential to enhance the quality of college teaching, their guidelines do not address the conceptual knowledge that is to be taught. Based upon recent developments in the literature, our concern is that teachers emphasize the conceptual knowledge to be learned in order to produce the student outcomes targeted by the student-centered instructional framework.

Therefore, we suggest concept-mapping techniques as a strategy to include conceptual course content as a complement to student-centered activities. Moreover, we also discuss the role of the teacher in providing guidance through varied ways to use concept maps. We believe that any framework for student-centered instruction must also focus upon the conceptual structure of the discipline through a dynamic, interactive strategy for students.

We will consider concept mapping as a tool for representing conceptual knowledge in learning settings and will summarize research on its effectiveness. Further, we will present a general strategy and some useful variations for using concept maps. And we will summarize the role of the techniques within the context of student-centered instruction and suggest some other ways to use concept mapping.

Importance of Conceptual Knowledge

A number of recent studies have demonstrated why it is important to consider conceptual knowledge in teaching in an explicit fashion. In science, McDermott and Shaffer (1992) found that students' successful completion of problem-solving tasks was not a valid indicator of their conceptual understanding of the underlying physical science concepts. Similarly, Vosniadou (1996) suggested that core concepts within a discipline have a relational structure that directly affects their being understood by students. She argued that the relatedness among these core concepts must be reflected in course curriculum and text-based materials if students are to learn the material.

Similarly, Suen et al. (1997) suggested how concept maps functioned as scaffolds in supporting learning and assessment. Finally, in a comprehensive international study, Schmidt, McKnight, and Raizen (1996) determined that American instructional materials and curriculum in secondary science typically consisted of many diffusely organized concepts that prevented learners from fully understanding the material.

Complementing research in science instruction, researchers examining differences between novices and experts found the conceptual organization of knowledge to be the major characteristic of expert proficiency (e.g., Anderson 1993; Chi, Glaser, and Rees 1982; Novak 1977; Carey 1985). Building upon such a “knowledge-based” perspective (Glaser and Bassok 1989), many cognitive science researchers consider the goal of meaningful learning to be the continued, organizational development of conceptual understanding to move learners from a novice state toward that of expertise.
(Royer, Cisero, and Carlo 1993). Carnine (1992) has shown how the role of “big ideas” as core concepts within a discipline naturally form the basis for a conceptually oriented instructional curriculum. Within his model, the role of instruction is to assist learners in the active development of such core concept understanding (e.g., Muthukrishna et al. 1993).

Role and Representation of Conceptual Knowledge

In viewing learning as a constructive process (Resnick 1989), current cognitive science research (Alexander 1996) considers conceptual knowledge to be the facts, concepts, principles, and their interrelationships that apply to a specific content domain. Thus, conceptual understanding primarily reflects relationships represented in the form of propositions (e.g., objects expand when heated). Such propositions, when used as constituents within procedures, algorithms, or rules, ultimately become forms of procedural knowledge (e.g., to make something expand, heat it).

Taken together, these forms of knowledge are necessary for problem-solving proficiency in future learning (DeJong and Ferguson-Hessler 1996). As viable conceptual understanding evolves cumulatively, one of two things usually happens to learners. Either new knowledge is integrated into their existing knowledge schema (i.e., organizational structures) or existing knowledge schema are restructured into more comprehensive, organized conceptual networks (see Dansereau 1995).

Through this ongoing process, which results in a broader foundation of domain-specific knowledge, students gain more proficiency in problem solving and efficiency in future learning (Vosniadou and Brewer 1987). Thus, the emphasis is on novices gaining the domain-specific conceptual knowledge and, hence, the proficiency of experts (Choi, Glaser and Rees 1982; Carey 1985; Novak and Gowin 1984). In considering the goal of college teaching as the development of students’ expertise within a discipline, then, an emphasis on experiences such as concept mapping serves as a form of guided apprenticeship (e.g., Leichhardt 1989).

Recently, DeJong and Ferguson-Hessler (1996) identified qualities of conceptual knowledge to consider in designing course curriculum and instruction. For example, conceptual knowledge should emphasize core concepts within a domain because students often focus on superficial terminology or isolated facts when left on their own. That superficiality results in inert knowledge (Bransford, Goldman, and Vye 1991), which does not provide a foundation for new learning or potential applicability within a domain.

Similarly, Glaser (1991) pointed out that incomprehension or misunderstanding in the learning of novices is associated with superficial treatment of topics, trial-and-error approaches, and rote learning of isolated factual information. In contrast, he noted that the broad understanding of experts has been shown to be qualitatively different from that of novices. Viable, deep understanding involves the hierarchical organization of conceptual knowledge into integrated and easily accessible schema, which help the student both apply knowledge and acquire new knowledge (Reef and Heller 1982). In comparison to novice learners’ understanding, the hierarchical structure of experts’ knowledge provides the deep thought necessary for abstraction and generalization. And, as such expertise reaches the level of “automaticity,” experts are more able to attend to specific details as they address a learning task or problem at hand.

As for implications for college teaching, researchers (e.g., Kozma et al. 1996) have shown that novice learners cannot be expected to direct their attention to core concepts within a discipline. Rather, novice learners require extensive guidance from experts—teachers—and effective course instruction within the context of an intellectual apprenticeship.

As figures 1 and 2 illustrate, concept maps can be considered as schemes representing visual knowledge in hierarchical graphic networks of nodes and links. In concept maps, nodes (labeled boxes) are used to represent concepts that, in turn, are connected by links (verbs on lines connecting nodes) whose labels depict meaningful relationships between two or more concepts. Those information structures form propositional networks, which (a) display core elements of key conceptual relationships and (b) model the accessibility of knowledge that ultimately would become part of learners’ long-term memory.

Within an instructional context, the initial development and continuing enhancement of concept maps provide a means for both the teacher and learner to track key elements of acquiring and organizing knowledge (Romance and Vitale 1997). Furthermore, by using concept maps to focus upon the core elements in a discipline, we are better able to avoid fragmented or rote learning outcomes that result in students’ minimal understanding and transfer (Vitale and Romance 1992). By focusing on mastering the hierarchical organization of a discipline, students can better understand its true nature.

Research on the Effectiveness of Concept Mapping

In an extensive review on the use of concept maps in science, Ruiz-Primo and Shavelson (1996) reported a number of key findings. Included among these were (1) consistent correlations existed between quality of concept maps and other measures of student achievement (e.g., teacher-made tests, standard tests, class grades), (2) instruction on a specific topic improved the quality of students’ concept maps, (3) concept maps of advanced students majoring in biology were at a significantly higher level than those of non-majors, and (4) concept maps could be used to distinguish experts from novices within a domain.

As an example of a recent representative study, Zeilik et al. (1997) used concept maps as an integral component for topics in a course in conceptual astronomy. As a result, they found that students using concept maps displayed greater achievement on three conceptually based measures: a multiple-choice measure of misconceptions, a fill-in-the-blank concept map instrument, and a general measure of concept relatedness. In a parallel study, Cliburn (1990) showed that the use of concept maps in combination with lecture in a college biology class resulted in significantly better student learning and retention.

Although the research literature supports the effectiveness of concept map-
ping, some guidelines are important. Cliburn (1990) reported that much time was required for the development of concept maps used in his course, that a major commitment of classroom time was needed for students to develop proficiency in constructing their own maps, and that, for a small number of students, the technique was not attractive. Further, Briscoe and LaMaster (1991) summarized benefits and student-use associated with concept maps in college biology. In general, we believe that the research confirms that the benefits of the explicit use of concept maps more than justify the amount of time and effort required.

Using Hierarchical Concept Maps

There are a wide variety of styles and approaches for implementing concept maps (Jonassen, Beissner, and Yacc 1993; Mintzes, Wandersee, and Novack 1998). The general technique described here (see table 1) was originally developed as a curriculum organization aid in a knowledge-based science teaching model (Vitale and Romance 1995) and then adapted as a class-oriented technique for use in college teaching (Romance and Vitale 1997). As table 1 shows, key concepts on a designated topic are initially elicited from students (based upon reading assignments, activities, or students' prior knowledge). The teacher writes each key concept on a "sticky" note and puts it on a chalkboard. Next, this collection is hierarchically organized into an initial concept map using students' input and recommendations (guided by the instructor toward core concepts).

That is accomplished by identifying links among concepts that state how they are related. Thus, each concept-link relationship is refined until it can form a complete sentence in propositional form (e.g., heat is a form of energy; matter has mass, and matter has volume). The resulting initial concept map, therefore, is a visual display of the hierarchical structure of core and subordinate concepts.

As the process continues, the class is encouraged to refine the initial concept map as appropriate. Multiple representations and perspectives are considered in the form of possible alternative concept maps. Also, as the class learns more on the topic, the concept map is further enhanced and refined, as appropriate, particularly in terms of new perspectives implied by broad ideas, as guided by the instructor. Finally, students are encouraged to use cooperative learning techniques to construct and discuss their own concept maps on other topics.

The general guidelines in table 1 will introduce concept mapping as a dynamic instructional process for students and teachers. But more important, engaging the entire class in developing and refining a concept map creates a dynamic interplay between students and teacher and between students themselves. As they discuss how each concept relates to others, they are able to recognize how certain concepts serve as containers; as rich, big ideas; and as organizers of subordinate concepts. Thus, students gain direct experience in identifying how they have organized their own ideas into propositional networks of concepts and relationships.

We (Romance and Vitale 1997) have reported the results of using the preceding technique in college teaching. We found that once students have successfully created concept maps in a classroom setting with the teacher's guidance, they are able to work effectively either in small groups of two to three students or individually to design new concept maps. Students then must organize the ideas and concepts in assigned text materials or in other learning activities.

Further, students are encouraged to consider continual restructuring of their knowledge and understanding to reflect new perspectives on big ideas, similarities, differences, and other new thinking about topics in a particular domain. Such group (or individual) concept-mapping activities provide the teacher with a window into students' thinking and understanding by tracing the development of their conceptual frameworks in-depth. As students continue to refine their own maps, teachers are able to observe and guide their thinking toward a deeper understanding of core relationships.

Variations of the Technique

Before considering different applications of concept mapping, it is useful to point out some variations. The present technique emphasizes the arrangement (and rearrangement) of sticky notes (for concepts and concept links) on a large
Figure 2. A Hierarchical Concept Map Used in an Introductory Course in Educational Assessment
Table 1.—Basic Technique for Building Concept Maps, with Teacher and Student Roles

**Teacher:** Prepares by developing list of all important core concepts for unit or lesson:
- Initiates concept mapping activity by eliciting key concepts from students based on reading assignments, class activities, or students’ prior knowledge
- Uses chalkboard or whiteboard to create initial concept map

**Students:** Offer suggestions to the teacher in terms of:
- Concepts to add or delete
- Concept links expressed as propositional relationships between two or more concepts
- Arrows that represent flow of ideas

**Teacher:** Uses basic operations to construct/edit/refine concept map based upon student input:
- Adds/deletes concepts via “sticky” notes
- Adds/deletes/modifies lines and line labels using sticky notes to represent linking relationships among concepts
- Rearranges sticky notes and lines/labels to reorganize the concept map as necessary
- Uses arrows to indicate flow of ideas
- Saves concept map by transferring it from chalkboard to posterboard

Shavelson et al. (1994) identified a number of variations of the general technique presented here for developing concept maps. These include whether (1) the map is hierarchical or free-form in nature, (2) the concepts are provided with or determined by the learner, (3) the students are provided with or develop their own structure for the map, (4) there is a limit on the number of lines connecting concepts, and (5) the connecting links must result in the formation of a complete sentence between two nodes. Further variations include whether the map (1) is constructed by one student or a group of students, (2) is being created for a specific purpose, e.g., assessment; chapter review; study guide; and (3) will creatively depict the core concepts of a domain.

Thus, teachers have a great deal of flexibility in designing appropriate concept-mapping activities for students. However, all variations require the instructor first to model the concept-mapping process, keeping the number of variables at a minimum. Next the teacher can guide the learners in developing group concept maps, and, finally, invite students to create them individually.

We view concept mapping and student-centered instruction as highly interactive and complementary. The teaching strategies encourage students to engage actively in learning tasks. More specifically, augmenting student-centered instruction with concept mapping involves adding two key strategies:

1. The instructor uses a whole class setting to emphasize the core concepts in the discipline.
2. The students use concept maps to represent ideas and their relationships as a basis for cooperative and/or individual course activities.

Considered together, these two strategies ensure that students considered as novice learners receive explicit guidance emphasizing the core concepts of the discipline and that they are able to construct and discuss various aspects of the course knowledge they are striving to learn.

**Broadening the Applications**

Concept mapping also can facilitate a variety of other instructional applications. For teachers, concept maps are useful tools for analyzing and planning units of study and for identifying gaps in the curriculum. Like an architect’s blueprint, a concept map represents complex ideas, their organization, and their importance. Further, concept mapping can be used to analyze textbooks, thereby revealing the suitability of the conceptual development of the text in terms of teachers’ preferences and students’ needs.

Concept maps can also facilitate metacognitive learning skills in many ways (e.g., note taking, textbook comprehension, organization for papers, project planning, preparation for examinations). Thus, using the maps can promote general conceptual understanding through identifying cause-effect relationships, prioritizing and organizing concepts, and displaying other meaningful patterns of ideas. Finally, in considering transferability and students’ learning skills, Regis and Albertazzi (1996) found concept-mapping skills to be powerful learning tools for enhancing students’ performance.

**Conceptual Context**

Felder and Brent (1996) have suggested how student-centered instruction in college courses can provide the means to involve students in constructing learning. However, their model does not include strategies that ensure that the conceptual organization of the discipline is presented to students in context. Based on recent research that supports the linkage between conceptual knowledge and meaningful learning, this article outlines the rationale and procedures through which concept mapping can be used to augment the student-centered instructional model and to emphasize the conceptual organization of the discipline. We believe that the combination of concept-mapping strategies and student-centered instruction will produce stronger learning outcomes than either approach could accomplish separately.

**REFERENCES**


