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Is concept mapping an effective tool for evaluation of student learning in science?

Linda Jean Foster

IS CONCEPT MAPPING AN EFFECTIVE TOOL FOR EVALUATION OF STUDENT LEARNING IN SCIENCE?

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

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in

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by

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ABSTRACT

Concept mapping is a metacognitive learning strategy which often improves a learner's ability to construct new knowledge. This action research project was intended to determine the level of effectiveness of concept mapping as a student learning intervention. Students in two high school science classes constructed concept maps before and after instruction during a unit of study about volcanoes. The maps were analyzed for increases in complexity and indications of learning. The concept maps were then compared for differences by groups based on volcano unit test scores. Based on the analysis of the matched pairs of concept maps, those maps which contained a higher amount of prior knowledge of the subject matter were associated with maps which showed the greatest amount of increase in knowledge after instruction. These results are supported by the many reasearchers who contend that the the most important factor in learning new information and gaining new knowledge is the amount of prior knowledge a learner brings into the learning situation. The results of this action research project will be applied to the development of future science courses by this researcher.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Herbert K. Brunkhorst, who has assisted me throughout the many years in accomplishing what was necessary to complete this program. I also thank Dr. Bonnie J. Brunkhorst for her cheerful support of my efforts in achieving this goal.

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CHAPTER ONE

INTRODUCTION

The intent behind this action research study is to evaluate the effectiveness of concept mapping as a student learning intervention in two ninth-grade introductory general science classes, and to apply the results to redesigning teaching methods, class assignments, and assessment strategies.

Concept Mapping as a Strategy for Teaching and Learning

There are many options for teaching science, from a traditional emphasis on memorization of facts to a modern approach based on cooperative learning and student involvement in experiments and related activities (Gabel and Bunce, 1993; Helgeson, 1993). Likewise, there are different ways in which a student's understanding of subject matter may be evaluated. While test scores have received an enormous amount of publicity and attention, tests may not indicate what students have actually learned (Johnson and Lawson, 1997).

Concept mapping is supported by the constructivist approach to learning and knowledge acquisition, which emphasizes the active involvement of learners in constructing their knowledge (Lawson, 1994). Concept mapping also involves both communication and reasoning skills. Communication skills have been identified by Project 2061 as one of the benchmarks of science literacy (American Association for the Advancement of Science [AAAS], 1993, p. 196-198). The correct use of specialized terms in science leads to accurate communication, allowing students to demonstrate their learning and knowledge effectively. Project 2061 focuses on what it terms "lasting knowledge and skills" (AAAS, p. XI) (italics theirs) which requires more than the simple memorization of facts. Information combined with science experiences and reasoning leads to the type of knowledge that will outlast a course or final examination.

Although prior knowledge has been shown to influence learning (Lawson, 1994), recent research has also shown that reasoning ability may be an even greater predictor of success in college science courses than prerequisites and prior knowledge (Helgeson, 1993; Johnson and Lawson, 1998). Since science classes in the United States tend to touch on several topics rather than delve deeply and thoroughly into a few, these findings are particularly important to secondary teachers. Lasting knowledge will remain an elusive target as long as facts are emphasized over critical thinking. It is difficult, however, to avoid concentrating on fact assimilation, in part because of the burdensome emphasis placed on standardized statewide test scores. For well over a decade science educators and associations have emphasized the deep, longterm understanding of science concepts which occurs not by covering many topics superficially, but by spending more time with a smaller number of the most important concepts in order to be certain they are learned (Starr and Krajcik, 1990).

Barriers to Concept Mapping as a Strategy

There are three major drawbacks to including concept mapping in high school classes. As noted above, the emphasis in the classroom is often placed on covering all the topics as specified in the curriculum instead of making sure students have attained a high level of understanding of the topic (Tobin et al., 1994). The most obvious stumbling block to using concept mapping as a learning strategy is the large investment of time required to use the technique properly: time to teach the technique itself during class, time for more practice with new concepts in and out of the classroom, and time for checking and correcting progress every few weeks. This is all time which may be seen as being subtracted from the time needed to satisfy the needs of the curriculum. Also, each new student who joins the class after the mapping techniques have been taught needs special tutoring time and an investment of more time to practice. Metacognitive learning techniques do not "speed up" the learning process, which often takes longer than expected (Helgeson, 1994; Wandersee, et al. 1994).

A second problem is more difficult to address in that concept mapping often relies on prior knowledge, which may be flawed or outright erroneous— a particularly pervasive problem in science (Wandersee, et al. 1994). If all the errors in a map are not caught and corrected, it is unlikely the student will detect and correct them. In that case, the student will truly be constructing a individualized knowledge base, one that will resist change and correction (Wandersee, et al. 1994; Morrow, 1999; Johnson, 2000).

A third difficulty has to do with changing the manner in which content material is conveyed and learning is assessed. The limited exposure to concept mapping in preservice courses for teachers does not provide new teachers with practice in teaching students how to actively and deliberately construct their knowledge and communicate their learning. New teachers will teach in a manner similar to what their teachers practiced, which may not lead to changes in learners' conceptions and knowledge (Wandersee, et al. 1994).

Knowledge of how to teach scientific content, and the opportunities to do so, are as important as the teacher's knowledge and comfort with the content and manner of delivery. Dissatisfaction with the high student failure rates in this researcher's science classes, and in the lack of understanding in science in general, has fueled an evolving approach to teaching as well as a search for practical ways students can demonstrate what they've learned besides taking tests. ("Practical" means timely solutions that will work for a hundred to 180 students, a typical workload for secondary teachers in California.)

Benefits to Concept Mapping as a Strategy

By starting at the end and working in reverse, determining what skills and knowledge students should end up with after spending time in the science classroom, methods must be found or developed which will move learners to that point. The next problem is how to find out what students have actually learned, and how the new knowledge compares to and fits in with their prior knowledge.

Age-appropriate metacognitive strategies may enhance conceptual changes and improve students' ability to identify what they know and how their knowledge fits together (Wandersee, et al. 1994). Having students think about how and what they are learning, and mapping out their thoughts leads them into forming their own knowledge consciously. Students deliberately arrange knowledge and link related ideas with each other, move ideas around and consider alternative relationships. Mapping makes students think about their new knowledge and evaluate preconceptions. Since evaluating knowledge and information are necessary for the construction of both knowledge and concept maps, the use of concept maps for evaluating student progress in learning seems logical.

Although concept mapping has been an excellent tool for this researcher's own learning, students may not enjoy the same benefits or use it to the same degree. Teaching concept mapping takes precious time away from curriculum but if a technique improves student learning it should be incorporated, regardless of the class time needed. Five to ten minutes at the end of each class period are set aside for students to summarize the information and activities in that day's class and to make a concept map for the day's topics and activities. Every two to three weeks student notebooks are collected and checked for proper mapping technique and logical grouping of ideas, and include teacher comments and suggestions. Needless to say this is extremely time-consuming. In spite of successful personal experiences and the published results of other researchers working with concept mapping, it is difficult to determine whether the concept maps have significantly helped students learn and relate ideas, or if the process is worth the time required to teach it. The benefits of concept mapping in high school science courses may or may not outweigh the problems encountered by the teacher when doing so.

The benefits of concept mapping appear to be substantial. The metacognition required for the task is one step closer to critical thinking and the ability to evaluate alternatives. The technique allows students to build on prior knowledge. The reduced emphasis on grammar and increased focus on logic has helped many of my students communicate their learning, but these qualities are especially valuable to English learners who struggle with expository exams. Language (or a tentative grasp of it) no longer stands as such a barrier for these learners who, like other students confronted with conventional tests, cannot convey what they have actually learned (Luft, 1999).

Other benefits in the classroom have come out of the end-of-class mapping requirement. Many students seem to enjoy the quiet, reflective time at the end of class when they must concentrate and map out what was done in class and any new information presented. They are encouraged to use colored pencils for emphasis and to make connections more obvious, and a few students have endeavored to do so consistently. They also seem to appreciate the order that is brought to the end of the class, a time which is characteristically hectic and disruptive. Sometimes a few will even stay after class because they want to finish their maps. For some, it seems to be a compelling closure to the class and, to those in the last period, for the day.

An Imperfect Solution

Knowing how science is done, learning how scientists now and in the past came up with their ideas, and understanding the processes and checks and balances within science will lead learners to an ability to critically evaluate claims made not only by scientists but in other areas of their lives (AAAS, 1993). This researcher's students have shown, and a few have even stated aloud, that they feel that science is not attainable for them, that it's too cerebral and made only for the remarkably intelligent, and that it has no value in their day-to-day lives and decisions.

Without connecting the process of critical thinking to discoveries, showing students how science is done, they will not learn it. Without allowing students to experience the process themselves, science remains an abstract idea that's "too hard" for them to grasp.

Concept mapping is one way to provide students with a process they can use in making the connections needed to understand an idea, and in linking that idea with facts, other ideas, and main concepts. When students are asked to make their own concept maps after a unit of study, they and their teacher can use the maps to evaluate the extent of student learning.

Students may tend to resist being this involved with learning. Teens especially will not complete tasks they think involve too much mental or physical exertion, or that don't seem to benefit them in a tangible way. A few students in each class studied in this action research project simply would not show what they learned in a pre-instructional concept map, drawing only a box with the word "Volcano" in it and nothing else. When asked to complete the map they said that they didn't know anything. Such obstacles are difficult to eliminate, but fortunately most students are reasonably cooperative when asked to complete tasks in class.

In the long run, do the benefits of concept mapping outweigh the problems encountered by the teacher who uses the technique? Is the time investment worth it for enough students? Should this strategy be continued or is it truly just a "waste of time" for the teacher? This action researchstudy seeks to provide some insight into the answers to these questions.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Concept maps are an important tool for finding out what learners know at the start of instruction in order to make a comparison with what they know at the end of instruction of new concepts, and how the new knowledge relates to prior conceptions (Novak, 1990, 1991, 1993; Gabel and Bunce, 1994; Wandersee, et al. 1994; Odom and Kelly, 1998). Mapping is also useful to learners themselves, by helping them shape their knowledge and become actively involved in their own learning (Novak, 1990; Wandersee, 1990). Mapping can be useful to teachers as well, particularly if the practice is begun early in preservice education, since they can experience its effects and benefits before entering the profession (Starr and Krajcik, 1990).

Concept Mapping

Concept mapping was originally developed by Joseph Novak and colleagues at Cornell University in the early 1970s, to study the conceptual changes which occurred as students in school learned new scientific ideas over time (Novak, 1990). Its theoretical basis came from the works of D.P. Ausubel, whose theories regarding learning were founded on the idea that the knowledge learners bring with them into the classroom is the most important factor that affects their learning (Novak, 1990; Starr and Krajcik, 1990; Wandersee, 1990).

In establishing how to depict the changes in knowledge frameworks, Novak's groups designed an illustrative system which graphically shows in two dimensions how ideas and concepts connect to each other, with levels of concepts depicted in a specific, hierarchical manner based on the cognitive, psychological structure of knowledge rather than on the logical or linear structure of factual knowledge (Novak, 1990; Starr and Krajcik, 1990; Wandersee, 1990).

Such tools have become increasingly popular among researchers involved in related studies (Jegede, et al. 1990; Wandersee, et al. 1994; Luft, 1999). Often asserted in research articles is the idea that the single most important influence on learning is students' prior knowledge, conceptions and misconceptions alike (Novak, 1990; Wandersee, et al. 1994; Odom and Kelly, 1998; Luft, 1999). It follows that determining what those preconceptions are prior to instruction is crucial. What students already know will influence what and how they will learn, since prior knowledge may interact with new information and ideas to create unintended, hybridized versions of concepts (Wandersee et al. 1994).

Novak and his colleagues found that young learners were thwarted in learning new concepts because of "the quantity and quality of their relevant knowledge acquired through experience and instruction" instead of a limited "cognitive operational capacity," as suggested by Piaget (Novak, 1990, p. 938). Rather than undergoing a series of monumental changes in the way they think, as students become older they acquire more ideas and concepts to which they may anchor new knowledge (Flavell, 1985, quoted in Novak, 1990; Wandersee, et al. 1994; Odom and Kelly, 1998).

Once a learner's current knowledge structure has been evaluated for accuracy, misconceptions or "alternative views" can be targeted for extinction. The integration of new concepts and ideas is influenced and even hindered by student outlook and interpretations of past experiences. The student may think that phenomena occur one way in science class or at school, but occur differently at home. Students misinterpret what they see or witness and can hold onto multiple views that are actually mutually exclusive (Wandersee, et al. 1994).

Unfortunately, not all students enjoy their increased involvement in their own learning— even if they acknowledge that they learn better that way (Morrow, 1999; Johnson, 2000). Some admit to laziness and others wish for the comfort of rote learning since it's familiar to them and they know what to expect.

Concept Maps Aid In Shaping the Learner's Knowledge

Besides determining what learners already know, concept maps aid learners in finding out how they know it and in directing the construction of their own knowledge structures and meanings (Novak, 1990).

A side-effect of concept mapping has been the reduction of anxiety and an increase in confidence of students facing new ideas (Jegede, et al. 1990; Novak, 1990; Wandersee et al. 1994). The lack of control over how and what is learned leads students to feel that they don't understand either what they are supposed to learn or why they are learning it (Novak, 1990). Students can be given unfamiliar tasks that they manage and learn from effectively provided their learning has meaning (Morrow, 1999; Johnson, 2000). Learning is enhanced when student anxiety toward learning is reduced, which can be accomplished by the use of concept maps (Jegede, et al. 1990).

One tremendous hurdle encountered by science teachers is the fact that student views of the world— i.e., preconceptions prior to instruction— are extremely tenacious and resist being revised or replaced, in spite of instruction and experiences that counter the flawed views (Novak, 1991; Wandersee, et al. 1994). Concept mapping, when combined with learning cycle-based lab activities, has been shown to be an effective method to improve student performance in science (Helgeson, 1994; Odom and Kelly, 1998).

Concept Mapping for Teachers

Conventional teaching practices in science have too often focused on the rote memorization of numerous facts and abstract ideas, passing multiple choice tests, filling in blanks, and writing short-answer essays (Novak, 1991; Luft, 1999). In an attempt to cover or get through as many topics as possible, teachers present an ever-growing amount of information. This results in poor performance on achievement tests, especially when compared to those of foreign students, and failure to learn and understand scientific concepts and reasoning skills (Tobin, et al. 1994; Johnson and Lawson, 1998). Because of the enormous quantity of curricular material required, teachers cannot always check to make sure that their students have attained a high level of understanding of concepts. Forced to move along at a pace that hinders learning, teachers rely on a limited number of assessments such as homework, worksheets, and tests.

Student engagement and motivation are usually derived from success on exams and report cards. Traditional "cookbook-style" laboratory activities tend to focus on correct lab procedure and reiteration of facts or principles already presented in class lectures, not on the experience of planning and developing an authentic lab experiment (Tobin, et al. 1994; Morrow, 1999; Johnson, 2000). If teachers mapped out their goals and strategies they could focus on improving the quality of laboratory experiences for their students, replacing the emphasis on procedure with meaningful learning experiences (Starr and Krajcik, 1990).

Teachers can effectively use concept mapping in planning and designing the entire science curriculum (Tobin, et al. 1994; Morrow, 1999; Johnson, 2000). Once they establish what is to be included and why, they can move on to how the concepts are to be conveyed and learned. Their experiences with the usefulness of mapping can provide insight and motivation for teaching the technique to their students (Novak, 1990; Starr and Krajcik, 1990).

Exemplary science teachers whose students show high levels of inquiry monitor student engagement during activities and employ a variety of strategies to enhance student understanding and problem-solving abilities. Students must be engaged in making meaning for themselves and need the guidance of teachers who know how to teach scientific content and can, at the same time, urge students to replace old concepts with new, or aid students in correcting erroneous ideas which are unsatisfactory in explaining phenomena (Novak, 1990; Tobin, et al. 1994). Concept mapping has a place in both meaning-making and in updating the existing knowledge framework (Novak, 1993). Teachers should be taught how to construct concept maps, their importance in changing conceptual constructs, and how to teach learners the procedures involved in concept mapping. Teachers should learn how they themselves learn, and experience the practicality of mapping their own personal knowledge structures. Through such practice they will be able to see the applications of such a skill in organizing and taking charge of learning, in understanding concepts and finding flawed reasoning, and in becoming more effective, exemplary teachers (Starr and Krajcik, 1990). Once preservice teachers use concept mapping for themselves they tend to move away from rote learning, toward making subject matter more conceptually transparent— emphasizing meanings and interrelationships instead of endless disconnected facts. They seek out other metacognitive techniques, such as reflective journals and learning checklists, to help add to their teaching strategies (Novak, 1990; Wandersee, et al. 1994). They are better able to spot faulty learning structures or patterns and are better able to correct erroneous constructs right away.

Teacher education needs to include more than simply a little practice in mapping concepts. Teachers need to be taught how to teach the technique to the variety of students they have in their classrooms. Plus, in addition to helping students and teachers organize knowledge structures, concept mapping can be used to design curriculum and instruction, from the overall concepts down to individual daily lessons (Novak, 1993). Novak's extensive experience with concept mapping has shown him that

> whenever teachers (including university professors) construct a concept map for a lecture, demonstration, book chapter, or laboratory experiment they wish to teach, they gain new insights into the meaning of that subject matter...even a single lecture or lab experiment may involve 30 or 40 relevant concepts, and perhaps another 30 or 40 less-relevant concepts. The number of ways these concepts can be permutated or combined is virtually infinite. (Novak, 1991, pp. 48-49)

Novak makes the point that everyone sees things "at least slightly differently" (Novak, 1991, p. 49). Through concept mapping and other metacognitive techniques, teachers and students can reduce the size of the inevitable differences.

CHAPTER THREE

DESCRIPTION OF THE PROJECT

Student Subjects

The subjects of this action research project were students from this researcher's classes who attended a large public high school in the Perris/Moreno Valley (California) area. The school population for the 2000-2001 school year varied from 2400 to 2800 students and was approximately 50% Hispanic/Latino, 15% Black/African-American, 25% of European ancestry, and 10% of Asian and American Indian ancestry. The students were enrolled in ninth grade General Science, a required first-year science course which focused on Earth Science and served as a starting point for the rest of the students' high school science courses. It was the goal of the school's science department teachers to start all students with the same basic foundation in both scientific knowledge and correct laboratory attitude.

It should be noted that during the time of this action research project the high school had a four-period day with classes lasting eighty-five minutes apiece, providing a good opportunity for students to engage in laboratory and other classroom activities. However, due to severe crowding at the school, this will be the last year for such a schedule, and the high school will revert back to the more common six-period day starting in the fall of 2001.

The General Science Course

The course title is "General Science" but the majority of topics fall into the Earth Science category. Students learn about experimental design, correct use of science laboratory equipment, and correct behavior in the lab, including safety protocols. The rudiments of matter, elements, the Periodic Table, atoms, bonds, and molecules are all introduced. Correct use of measurement devices is taught and students use metric measurements of mass (triple beam balance), volume (graduated cylinder), and temperature (Celsius thermometer). The remainder of the course covers the atmosphere, weather, and climate, astronomy, and dynamic earth processes such as earthquakes and volcanoes. The course is derived from the California state standards for teaching science. Although two other teachers with General Science courses started the year with concept mapping, the two classes used in this action research study were the only classes using concept mapping as a major part of the curriculum throughout the entire term.

The Unit

This action research project concentrated on a single unit of study for which students should have had some prior knowledge: volcanoes. The volcano unit began with a videotape about the aftermath of the 1980 Mt. St. Helens eruption in Washington. This was followed by:

- descriptions
- terms
- facts about volcano types
- eruption events and materials
- how eruptions affect life
- underlying mechanisms of plate tectonics
- the Pacific "hot spot" under the Hawaiian Islands.

The Volcano unit preceded the related unit, Plate Tectonics, which then led into the Earthquakes unit. Specific topics included:

- structure and characteristics of the lithosphere
- three categories of volcanoes: cinder cone, stratovolcano, and shield volcano
- lava composition (gases, water, silica) and its effect on the explosive character of eruptions
- ocean floor spreading and magnetic pole reversals
- convection currents within the lithosphere
- plate tectonics, subduction, and collision
- island and mountain building
- the "Ring of Fire"
- social consequences of predictions, warnings, disasters, and relief efforts
- the effects of volcanic eruptions, longterm and short-term, on human and other life.

Most of the topics above are included in Benchmarks for Science Literacy (AAAS, 1993) and all are aligned with the California state standards for high school earth science.

Teaching Strategies

In order to provide the most enriching learning environment a variety of teaching strategies were employed.

Demonstrations

Demonstrations included a Lava Lamp and colored hot water rising through cold water to illustrate convective heating and cooling; several lava and ash samples collected in the field at Mt. St. Helens, Kilauea, and two Southern California cinder cones; and the baking soda and vinegar reaction to compare and contrast with events in a real volcano. Students were assisted in writing explanations in their science notebooks about why the reaction was inaccurate as a volcano model.

Activities

Students made observations of various lava, cinder, ash, and "lava bomb" samples. They used hand lenses and dissection microscopes, recording written descriptions and drawings in their science notebooks. They also constructed small paper models of stratovolcanoes and made an information pamphlet about three major types of volcanoes. The pamphlet included drawings of the volcanoes in crosssection as well as descriptions, method of formation, and specific examples. They glued their pamphlets into their notebooks.

<u>Videotapes</u>

Two videotapes were viewed, including a NOVA! tape, "Volcano!" and the educational tape about the Mt. St. Helens eruption referred to above. For the NOVA! tape, students made concept map-style notes; for the other tape they filled in answers on a question sheet, which they glued into their notebooks.

<u>Textbook Questions</u>

All students had checked out a copy of the textbook, which remained at home, and was used primarily for reference and review. Questions which were copied off the board often pertained to the information in the textbook. Bonus questions on quizzes and the test were based upon text information not specifically addressed in class, but which could be found in the chapters about volcanoes and plate tectonics.

Instruction in Concept Mapping

Concept mapping directions and practice had been started two weeks before the initial volcano concept map was assigned. Students were directed to first brainstorm all their ideas on their paper. Once the brainstorm was completed they were to use it as a guide for developing

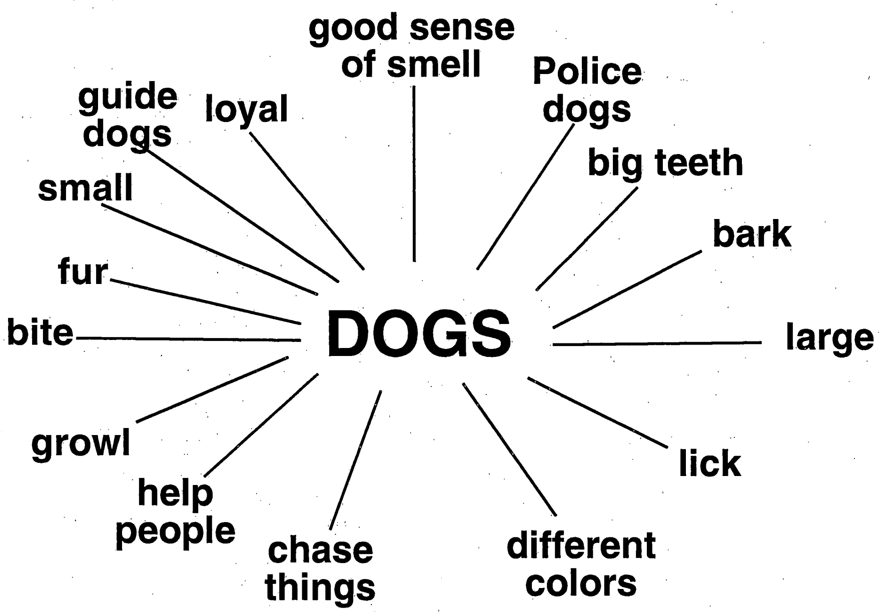


Figure 1. Example of Class Brainstorm for "Dogs".

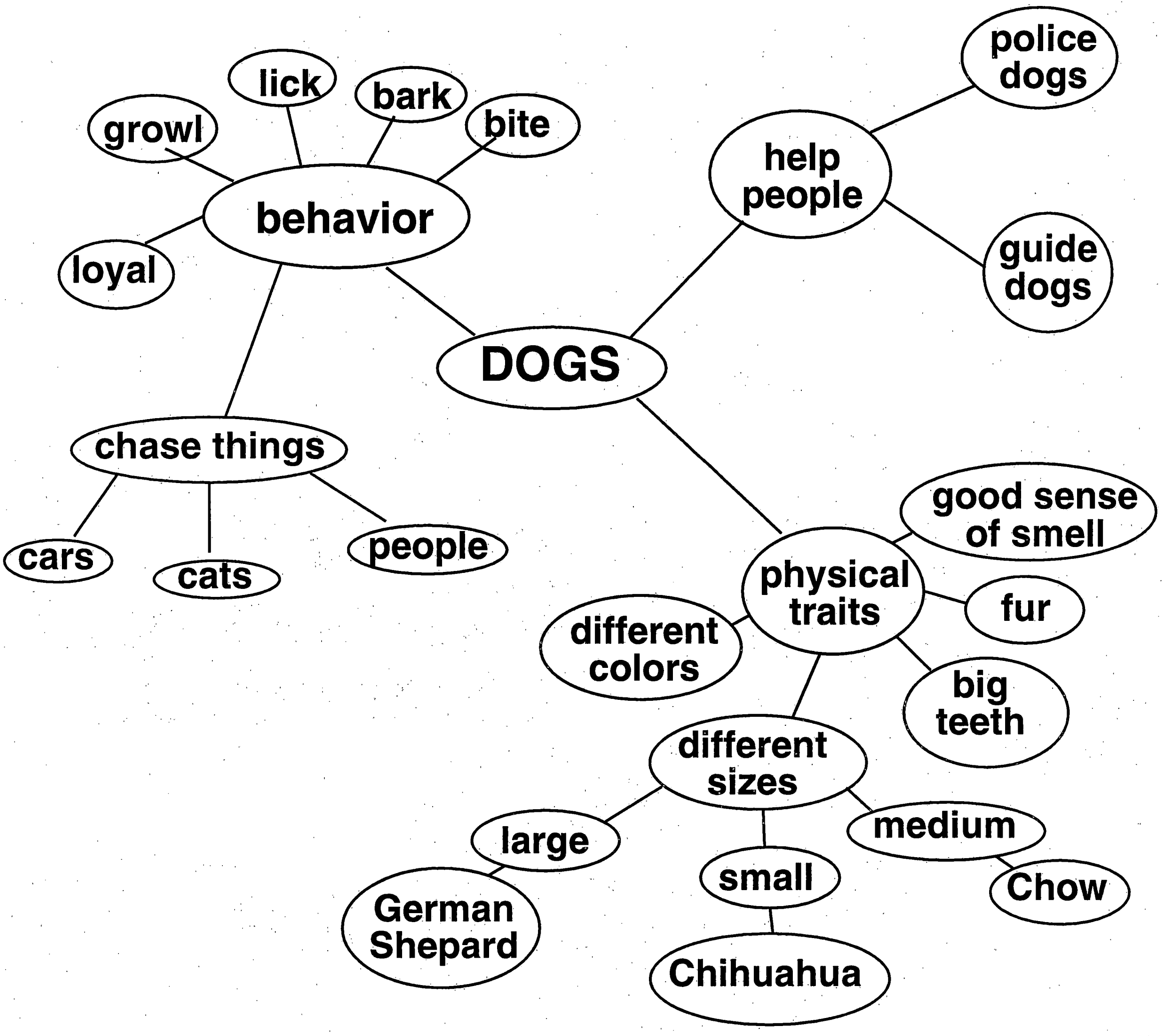


Figure 2. Concept Map Created from "Dogs" Brainstorm from Figure 1.

their concept map. Mapping was demonstrated with familiar topics, such as "dogs." (See Figure 1 and Figure 2 for examples.) Students copied the examples and helped construct other class examples by contributing ideas during discussion-style sessions.

Students were instructed to arrange the items on the map so the items were grouped according to relationships or similarities. Since almost none of the students indicated familiarity with concept mapping, the technique was simplified and differs somewhat from the more complex maps of other researchers. For example, connecting words were made optional, in order to accommodate students with extremely poor writing and language skills. The grouping of terms and concepts consisted of first drawing a "bubble" around the main idea. Terms and concepts that were part of the larger idea were written below the main idea, placed in bubbles, and connected to the main idea by way of lines. Branching and cross-linking were both demonstrated but rarely used by students, as were directional arrows.

For the concept maps used in this action research study, students were allowed as much time as they needed in order to produce a map they felt effectively conveyed the whole of their knowledge regarding volcanoes. Most finished in about fifteen minutes, and all were done in thirty-five minutes.

Prior Knowledge

Prior knowledge of volcanoes was assessed by a concept map assigned before any instruction in the volcano unit began. Directions given to students were to "include everything you can remember about volcanoes" and nearly all students showed that they could recall at least a small amount of factual information regarding volcanoes. A few students made elaborate maps based on several recalled facts and details. Some made use of their colored pencils as using color was encouraged in class.

CHAPTER FOUR

METHODOLOGY

Selection of the Concept Maps

Each student in the study produced one pre-instructional concept map (the "pre-map") and one post-instructional concept map (the "post-map"). Due to student absences when one or both mapping assignments were made, or because one or both maps were illegible, some concept maps were not considered for analysis.

There were 44 useable matched pairs (pre- and post-maps) of concept maps produced in this study. Maps were first ranked based on student scores on the volcano unit test. For both science classes, four representative maps were chosen from each of the the highest third, lowest third, and middle third test scores in order to include typical examples from all levels. No specific students were identified.

Scoring of the Concept Maps

Matched pre-maps and post-maps were evaluated using the same technique. The totals for the matched pairs in each group of maps were compared for assessment of the extent of student learning. Points were awarded according to the criteria described below in order to obtain total points for each concept map.

Relationships

Relationships between concepts were indicated by connecting lines. The connections from one term to the next had to make sense. That is, the connections should have been content correct and grouped with other items that were related to each other in a similar way. Each relationship, as indicated by the connecting line, was awarded one point, unless the relationship was incorrect. Since students were largely unfamiliar with concept mapping, as a first step in learning to use concept mapping, simplification of the process was deemed necessary. Verbs along connecting lines were optional, and the lines were not required to have directional arrows.

Hierarchy

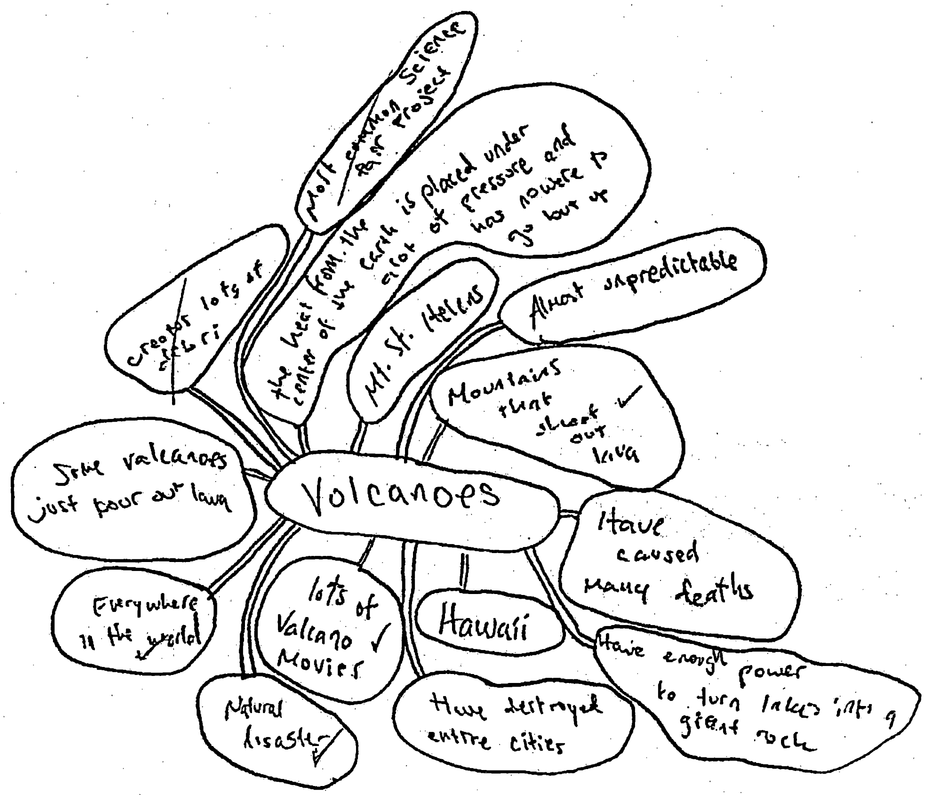
The "starting word" was written on the board: "Volcanoes." The next group of words branching out from that should have been somewhat broad, inclusive terms, such as "types" or "explosiveness." At the level below the inclusive terms, the next terms or words should then be more specific: "strato- volcanoes" or "gas content." If organized properly, each successive level of ideas would connect to the previous level through an obvious and specific line of reasoning. One point was given for each term which was correctly linked to the previous term. Incorrect links did not earn any points.

Branching and Cross-Linking

Sometimes two or three items were related to the previous term in exactly the same way, and multiple connecting lines were drawn from a single word. This was a "branch." For each word which had a branch, a point was earned. Very few maps contained a "cross-link," in which one term was connected to a term in another part of the map. Cross-linking appeared to be a difficult concept for most students at the time of the concept mapping assignments.

Each correct relationship received one point. The maximum number of hierarchical levels for the longest single line of related concepts was added in, along with the total number of terms with branches or cross-links. Although every attempt was made to maintain objectivity in scoring, it is acknowledged by this researcher that the "correctness" of relationships among and between words was the least objective aspect of the analysis, open to different interpretations.

As an example of the scoring system, for the concept map in Figure 3 a score of 9 was obtained. There were 6 correct relationships, 3 levels of hierarchy in the longest "chain" of concepts, and no words which had branches or cross-links. This map was matched with the post-map in Figure 4. Note the increase in complexity and richness of



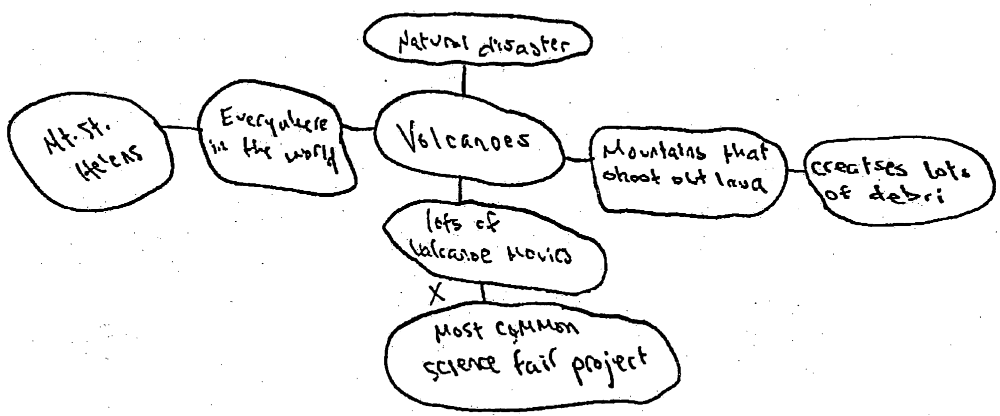


Figure 3. Brainstorm and Pre-Map for Upper Third of Class by Test Scores

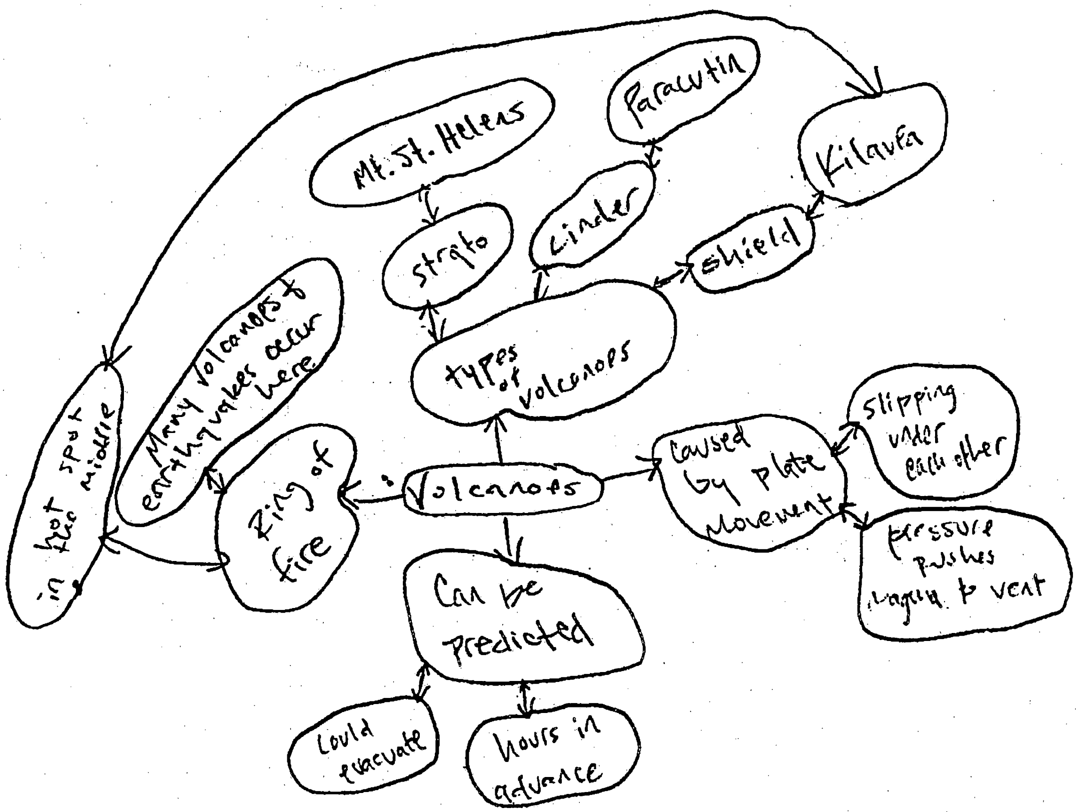


Figure 4. Post-Map for Upper Third of Class by Test Scores

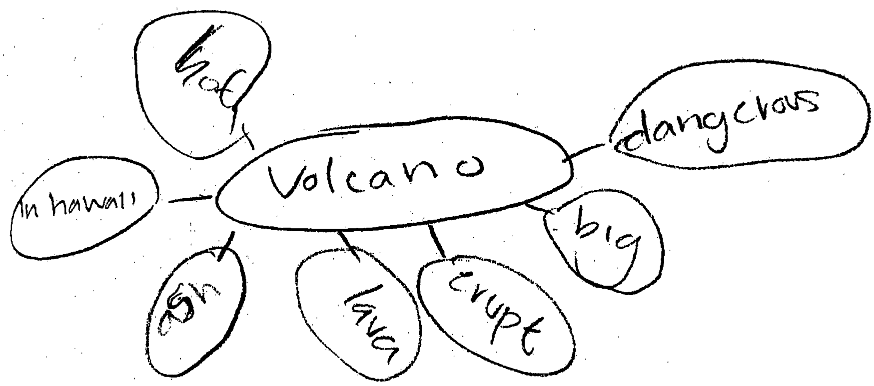


Figure 5. Pre-Map for Middle Third of Class by Test Scores

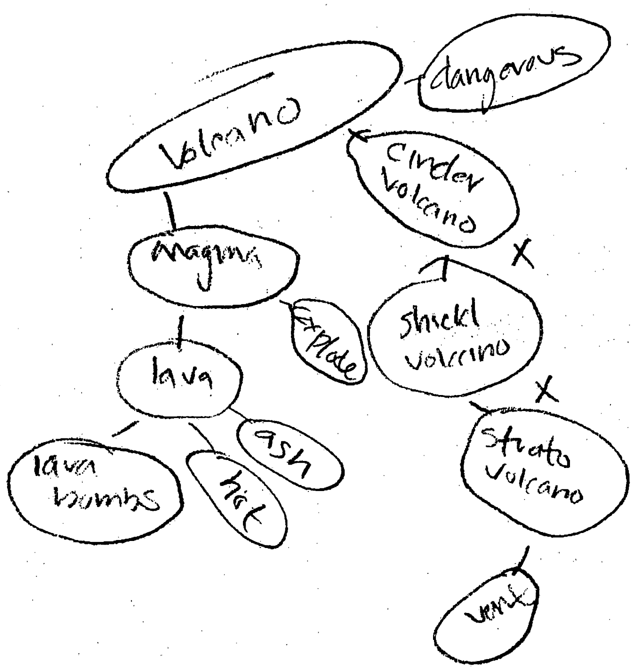


Figure 6. Post-Map for Middle Third of Class by Test Scores

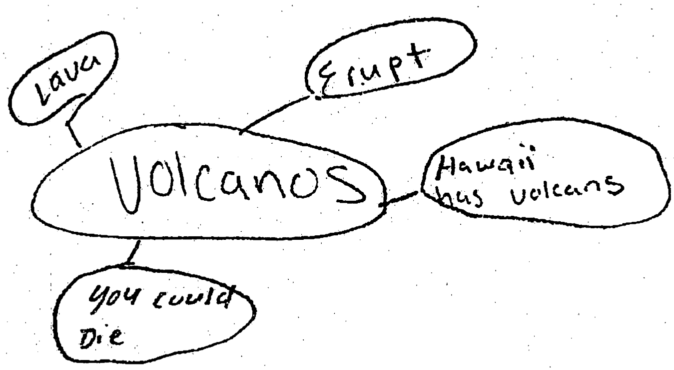


Figure 7. Pre-Map for Lowest Third of Class by Test Scores

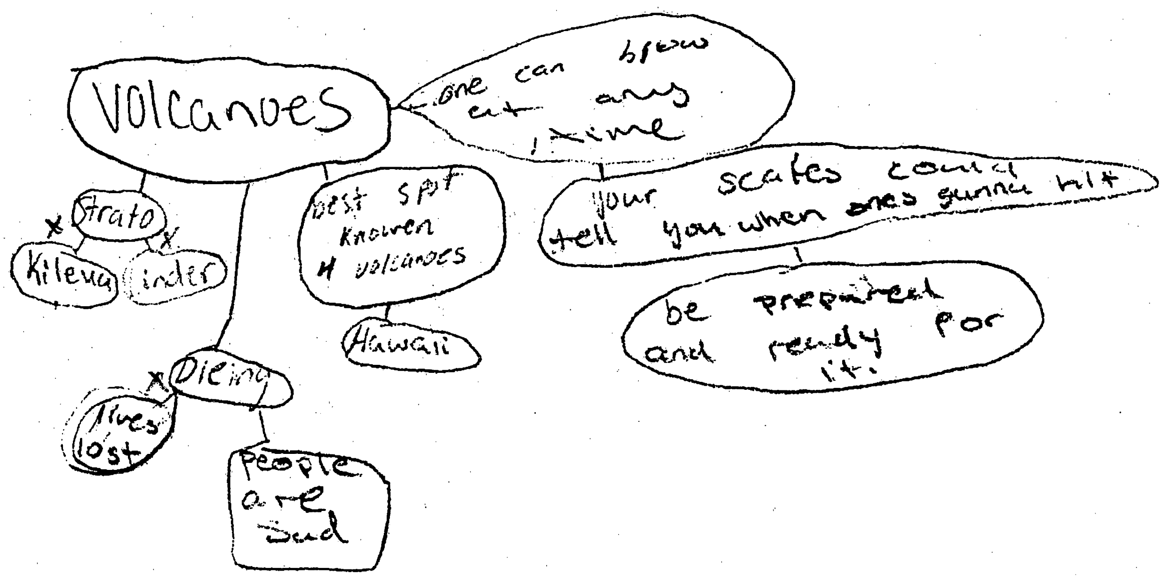


Figure 8. Post-Map for Lowest Third of Class by Test Scores

concepts. The post-map received 27 points. There were 17 relationships, 4 levels of hierarchy, 5 branches, and one cross-link. The volcano test score associated with this map was 91%, within the top third of the volcano test scores.

The pre-map in Figure 5 and its matched post-map in Figure 6 were associated with a volcano test score of 72%, and represented the middle third of the test scores. The pre-map shows a lesser amount of prior knowledge when compared to the pre-map from the upper third of the scores, above. The pre-map rated 10 points while the post-map score came to 15. Each incorrect relationship was marked with an "X." Improvement was more modest, at 5 points. This is a typical comparison between maps associated with a mid-level score and a high score on the volcano test.

Figure 7 shows the pre-map for one of the lowest volcano unit test scores in the class, 41%. Note the scarcity of prior knowledge indicated in the pre-map (7 points), with less improvement in the post-map (13 points) than for the upper and middle two-thirds of the class. Some learning seems to have occurred but not to the same extent as for the maps that indicate a more enriched background to begin with.

Group Results

Maps produced from the upper third of the class showed increases in their scores of 4 to 27 points from the pre-map to the post-map, averaging 18.5 points. Prior knowledge combining with new knowledge is the most likely factor involved in such a substantial gain in complexity and richness of these concept maps.

Conversely, pre-maps that contained evidence of limited prior knowledge showed a markedly lower increase in scores on the post-maps. One actually decreased from 13 to 9 points for a -4, another broke even at a gain of zero, and the rest gained up to only 15 points. The average gain was just 6.1 points.

Concept map scores from the middle third of the class showed a gain of 2 to 21 points from pre- to post-map, averaging an increase of 7.4 points. One post-map had a slightly lower score than the pre-map, but its initial score was 22 and the post-map scored 20, so the decrease was not great.

If the volcano unit test can be relied on to accurately predict the development of knowledge about volcanoes, concept mapping may not be necessary. However, when viewing the maps associated with the lowest test scores, there is evidence that some learning has taken place. Perhaps the test questions did not address the pieces of information learned, or there was confusion about the questions. There may have been confusion about concept mapping as well.

But even when test deficiencies are taken into account, low post-map scores associated with the lowest volcano test scores show that there was little new knowledge constructed, while the organization and complexity of knowledge made an obvious advancement in those concept maps associated with high scores on the volcano test.

CHAPTER FIVE

CONCLUSIONS AND IMPLICATIONS

As mentioned in chapters one and two, many researchers have found that prior learning is of the greatest importance when a learner is confronted with new information and must rebuild or add onto existing knowledge structures. Students who enter a learning situation armed with a rich and varied background and whose knowledge structures already have some foundation, are better prepared to learn more. They can incorporate new knowledge into the old, and rearrange their widening knowledge structure as necessary.

New constructions and rearrangements were evident in many of the concept maps associated with high scores on the volcano unit test. When students exhibited little existing knowledge in their pre-maps, it seemed that they had too little knowledge to build upon and could not demonstrate large changes in knowledge complexity on post-maps.

Evaluation of Prior Knowledge

Concept mapping prior to instruction can be used in two ways. First and most obvious is as a tool for evaluating existing knowledge, much like a pretest would. The teacher can find out what knowledge structures already exist for students, and may be better prepared to provide additional direction for those who lack the background they need. However, it is difficult to envision California secondary teachers with five or six classes of thirty to forty students being able to individualize and tailor instruction for each student. Because of the large numbers of students in classes and the time commitment required to thoroughly evaluate concept maps, concept mapping would be a more feasible alternative to pre-testing at the elementary school level than at the secondary school level.

Metacognition

The second way concept concept mapping may be used as an assessment requires students to think about their own learning constructs. Concept mapping can assist students in becoming more reflective about their own learning by comparing their pre-maps with their post-maps.

Checking for Understanding

Just as the concept maps were used in this action research project, they can be a tool for evaluating the learning of new concepts by comparing pre-instructional concept maps to concept maps made after instruction. Not only do concept maps contain newly introduced words, they indicate how the learner has arranged them in the hierarchy of the subject matter. Mistakes such as erroneous connections, inaccurate groupings, and improperly used terms key the teacher into the student's level of understanding. The teacher can aid the student before the errors become solidified within the student's new knowledge structure. As the learner makes the necessary rearrangements, such changes should be metacognitively reinforced as opposed to test questions being simply marked wrong.

Start Concept Mapping Early

Concept maps may be used to evaluate the increase in knowledge, complexity of constructs, and rearrangement of old ideas to accommodate new ones. These maps may also serve to warn teachers and students of the potential failure to learn new concepts due to the lack of adequate concepts upon which new knowledge is to be constructed. Students should be taught how to use concept mapping as a tool much earlier than in high school. In this way they will become not only active learners, but aware learners, understanding themselves and how they learn and construct knowledge.

Concept mapping has the potential to prevent—or at least reduce— the threat of failure by allowing students to understand how they learn. Its use improves learning and decreases the anxiety of confronting new information. Concept mapping deserves the time and effort required for learners to use it and for teachers to use it effectively as a teaching and assessment strategy.

Further Questions

In this action research project, representative concept map scores showed an increase from the pre-instructional concept map to the post-instructional concept map by 87.5% of the students in the classes. The fact that there were increases in the complexity (number of relationships and levels of hierarchy) and richness (more accurate terms and words) of the maps should not be surprising. After all, the second map was made after almost four weeks of instruction and practice.

The remaining 12.5% of the matched pre- and post-concept maps showed little or no improvement and in some cases a lower score on the post-instructional map. The absence of any gain between pre- and post-map scores learning is perplexing. Since prior knowledge seemed to be such an important factor in student learning, it might be valuable to compare the backgrounds of those students who were able to successfully demonstrate their learning through concept maps with those students who were less successful. Which types of experiences have led students to a knowledge rich in science content and understanding? How do some students learn to construct their knowledge in a manner which allows them to tap into it with ease? How do culture, language, religion, and other social and external conditions affect learners' abilities to collect new information and process it into new knowledge?

LITERATURE CITED

American Association for the Advancement of Science (AAAS) 1993. *Benchmarks for Science Literacy: Project 2061*. Oxford University Press, New York, XI, 73, 74, 163, 166, 203

Gabel, D.L. and Bunce, D.M. 1994. *Research on Problem Solving: Chemistry*. In Handbook on Research in Science Teaching and Learning, Dorothy L. Gabel, Ed. Macmillan Publishing Company, New York, 301-326

Helgeson, S.L. 1994. *Research on Problem Solving: Middle School*. In Handbook on Research in Science Teaching and Learning, Dorothy L. Gabel, Ed. Macmillan Publishing Company, New York, 248-266

Jegede, Olugbemiro J., Alaiyemola, Folusho F., and Okebukola, Peter A.O. 1990. *The Effect of Concept Mapping on Students' Anxiety and Achievement in Biology*. Journal of Research in Science Teaching 27(10), 951-960

Johnson, Karlene. 2000. *Constructive Evaluations*. The Science Teacher 67(2), 38-41

Johnson, Margaret A. and Lawson, Anton E. 1998. *What are the Relative Effects of Reasoning Ability and Prior Knowledge on Biology Achievement in Expository and Inquiry Classes?* Journal of Research in Science Teaching 35(1), 89-103

Lawson, Anton E. 1994. *Research on the Acquisition of Science Knowledge: Epistemological Foundations of Cognition*. In Handbook on Research in Science Teaching and Learning, Dorothy L. Gabel, Ed. Macmillan Publishing Company, New York, 131-176

Luft, Julie. 1999. *Challenging Myths*. The Science Teacher 66(4), 40-43

Morrow, Jennifer. 1999. *When Students Design Experiments.* The Science Teacher 66(9), 44-47

Novak, Joseph D. 1990. *Concept Mapping: A Useful Tool for Science Education*. Journal of Research in Science Teaching 27(10), 937-949

Novak, Joseph. 1991. *Clarify With Concept Maps*. The Science Teacher 58(10), 44-49

Novak, Joseph D. 1993. *How Do We Learn Our Lesson?* The Science Teacher 60(3), 50-55

Odom, A. Louis and Kelly, Paul V. 1998. *Making Learning Meaningful*. The Science Teacher 65(4), 33-37

Starr, Mary L. and Krajcik, Joseph S. 1990. *Concept Maps as a Heuristic for Science Curriculum Development: Toward Improvement in Process and Product*. Journal of Research in Science Teaching 27(10), 987-1000

Tobin, K., Tippins, D., and Gallard, A.J. 1994. *Research on Instructional Strategies for Teaching Science*. In Handbook on Research in Science Teaching and Learning, Dorothy L. Gabel, Ed. Macmillan Publishing Company, New York, 45-93

Wandersee, James H. 1990. *Concept Mapping and the Cartography of Cognition*. Journal of Research in Science Teaching 27(10), 923-936

Wandersee, James H., Mintzes, Joel J., and Novak, Joseph D. 1994. *Research on Alternative Conceptions in Science*. In Handbook on Research in Science Teaching and Learning, Dorothy L. Gabel, Ed. Macmillan Publishing Company, New York, 177-210