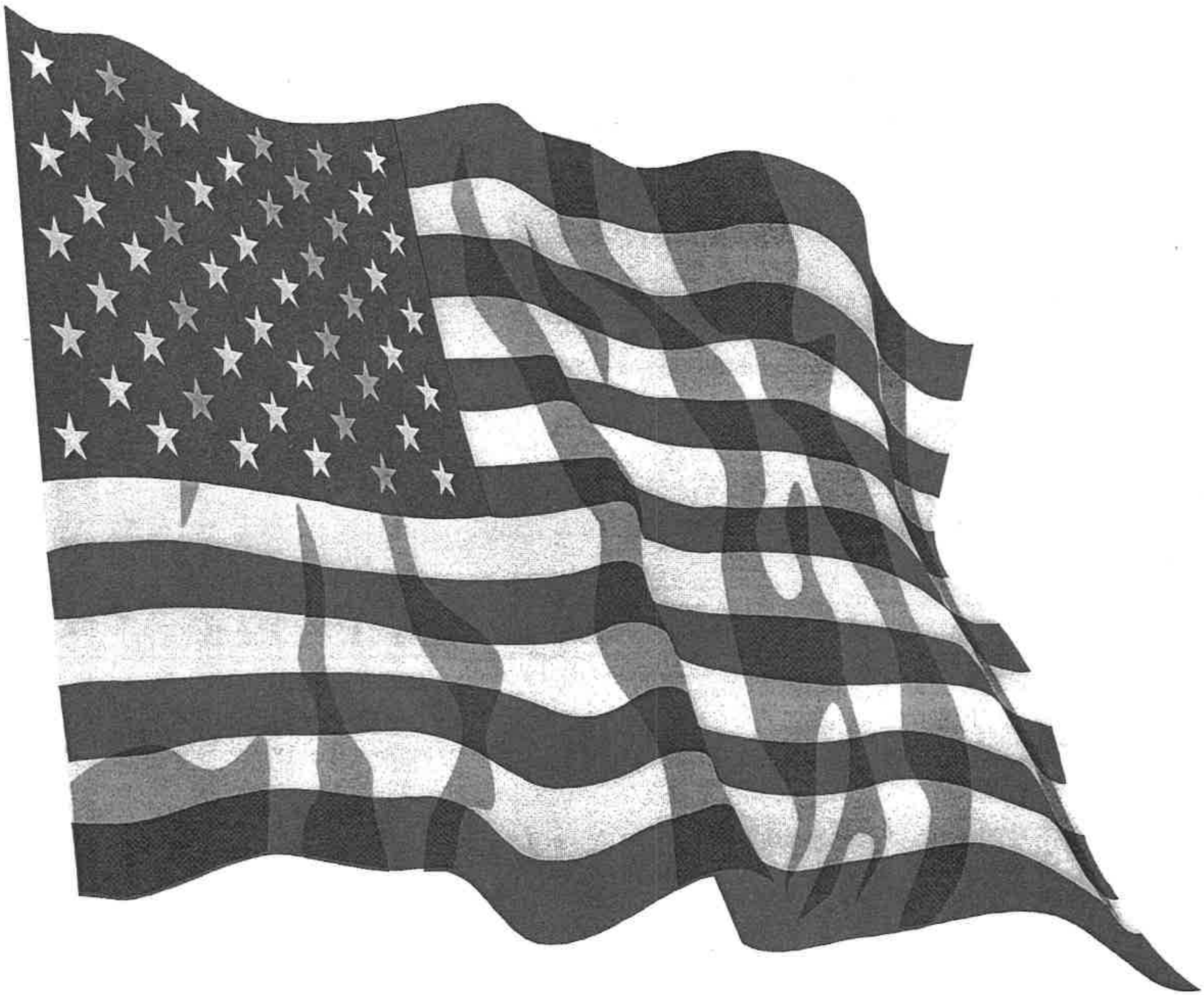
Tennessee Educational Leadership



Spring 2003 XXX, No. 1

Tennessee Educational Leadership

Volume XXX, Number 1

Contents

Making Connections with Concept Mapping: A Tool for Under-Achieving Middle Grade Science Students

Donald Snead and Barbara Young

(Snead: Assistant Professor, Educational Leadership, MTSU; Young: Associate Professor, Educational Leadership, MTSU)

Introduction

The goal to increase student learning in the area of science is a fundamental concern of science teachers. The National Science Education Standards (NRC, 1996) provides insights into learning techniques, strategies, and other guidelines for effective science instruction. Many of these standards are in effect and have produced favorable results. Data reported by the National Assessment of Educational Progress (NAEP, 2001) indicate that overall, students in fourth and eighth grades performed better in 2000 than in 1990 and overall, American students showed academic improvement in science. But, in spite of enormous amounts of time, effort, and money spent to implement strategies suggested in these Standards (NRC, 1996), the problem of underachievement is still of concern to science teachers. Data from the NAEP (2001) indicate eighth grade students are performing at a lower level than fourth grade students. Although, test scores of minority students with regard to middle grade science are higher than they were four, eight, or twelve years ago, these scores still are not acceptable.

Teachers agree science is a complex discipline because it consists of a myriad of unfamiliar concepts involving complex relations (Schmid and Telaro, 1990). Although some traditional instructional strategies (i.e., lecture, recitation, drill, controlled independent practices) for teaching unfamiliar materials are successful for tasks that demand rote memorization, they have not been shown to be effective for teaching higher-order thinking, enhancing problem solving skills, or helping students build a foundation for learning scientific concepts involving complex interactions (Von Seeker and Lissitz, 1999). In other words, students learn verbatim the facts with little or no understanding of the nature or scope of these facts (Novak, 1984).

In other words, students must make a conscious effort to relate new knowledge with what they already know.

Pendley, Bretz, and Novak (1994) identified three major factors that contribute to students' failure to understand scientific concepts. They report that:

- Students are learning predominantly by rote, rather than actively seeking to construct their own meanings for the subject matter;
- Science content is "conceptually" unclear to students, and they fail to recognize key concepts and/or concept relationships needed to understand science; and
- The instruction may fail to present key scientific concepts or concept relationships and thus students remain conceptually opaque. (p. 9)

Asubel (1968) and other researchers (Novak, 1977; Niehaus, 1994) all agree that meaningful learning involves more than rote memorization without conscious effort to relate new knowledge to what is already known. Ausubel defines meaningful learning as "nonarbitrary substantive, nonverbatim incorporation of new knowledge into cognitive structure." In other words, students must make a conscious effort to relate new knowledge with what they already know. Novak (1984) defines meaningful learning as "cognitive structure," which is the "framework of knowledge" that is sorted, stored, and allowed to grow and develop in the mind over the course of a lifetime. Niehaus (1994) relates meaningful learning to grafting a plant stem into a different tree. The tree accepts the plant stem and the stem is nourished, grows, and becomes a part of the tree. Therefore, meaningful learning occurs only when a learner can connect new knowledge onto a pre-existing framework.

Therefore, in order for a student to actually learn a concept in a meaningful manner, the student must make a conscious effort to identify key concepts in new knowledge and relate these concepts to pre-existing concepts. Meaningful learning, therefore, is evidenced when the student is able to internalize new information and to apply the new knowledge to other situations. For example, students are engaged in a unit on weather. One objective is to learn factors that contribute to weather and predict weather patterns and weather conditions based on these factors. If a student simply memorizes verbatim that temperature, humidity, air pressure, and cloud coverage are weather factors without consciously thinking about what and how these factors are interrelated, then rote learning has occurred. Most likely students will not understand how these factors collectively create weather patterns and systems to form various weather conditions. Therefore, students may perform well on a recall level test, but such learning has little practical value and actually may hinder later learning (Novak, 1984).

Brief Literature Review

Several science educators recommend concept mapping as an effective teaching strategy for moving from traditional teaching (i.e., lecture, recitation, drill, controlled independent practices) toward teaching that fosters more meaningful learning (Callison, 2001, Dorough and Rye, 1997; Mason, 1992, Novak, 1993; Al-Kunifed and Wandersee, 1991; Okebukola and Jegede, 1988). Lawless (1994) states that concept mapping is an important technique because of its emphasis on relationships between concepts, their nature, and the visual display of these relationships. Because middle school students do not in many instances learn scientific concepts in a meaningful manner, it follows that a technique such as concept mapping should be explored in an effort to teach in a more meaningful manner.

Several studies (Mohamed-Wafaied, 1997; Willerman and MacHarg , 1991; Pankratius, 1990; Jegede, and others, 1990; Hawk,1986; Novak, and others,1983) have reported significant effects that concept mapping has had on student achievement in science. Still other studies (Snead, 2000; Novak, 1994; Penello, 1993; Schmid and Telaro, 1990; Lehman, Carter, and Kahle, 1985) have reported that students who used the concept-mapping learning strategy perform better than students who did not use concept mapping as a learning strategy.

John D. Novak (1977), who is credited for developing concept mapping, has studied the use of concept mapping and how concept mapping affects science teaching and learning, and he makes a connection between concept mapping and meaningful learning. He suggests that concept mapping and meaningful learning: (1) involves the assimilation of new concepts into existing knowledge; (2) involves organizing knowledge into structures for long-term memory transfer; and (3) involves mental processes that help students think more critically and more creatively.

What Is A Concept Map?

A concept map is a drawing that represents a person's understanding of a particular concept and the concept's linkage to other concepts and ideas (Appendix A, See Figure 1). The concepts are organized in a hierarchical arrangement from the most general to the most specific (Okebukola, 1990; Novak, and others, 1983). Lines are drawn between concepts that the individual views as related. Written on each line are words that express the nature of the relationship between the adjoined concepts. In other words, it is a drawing and a brief description of how a student cognitively organizes and relates certain concepts as shown in Figure 2 and Figure 3 (Appendix A).

The students' ability to diagram the concepts is the key to assessing their understanding of the subject matter. Concept mapping allows students to connect concepts in a variety of relationships, based on their understanding of the concepts. Students increase their understanding of subject content as they search for personal meaning of concepts, without which they cannot make connections in the map.

There are no set ways to construct a concept map. A simple method is for the teacher to give students a list of related concepts and have them construct a map, placing the most general concept at the top and then showing successively less inclusive concepts at lower positions in a hierarchical manner. A second method is to have students identify key concepts in text, from lecture notes or other materials, and then use these concepts to form a hierarchical map (Okebukola, 1990; Ault, 1985). As shown in Figure 4 (Appendix A), a concept map consists of three notable features:

13 Concept names written inside loops, rectangles, or other shapes represent concepts.
14 Linking lines show the connections between two concepts.
15 Linking words, which label linking lines, describe the relationships between concepts.

The uniqueness of using concept mapping in science teaching results from its emphasis on visualizing relationships between concepts. A finished concept map is similar to a road map, with every concept depending on others for meaning (Mohame-Wafaie, 1997). Novak (1991) describes concept mapping as a procedure for helping students organize concepts into meaningful structures. Broody and Bartels (2000) suggest that concept mapping is a valuable technique to help foster learning because understanding involves seeing a connection between explicitly defined concepts.

What Role Can Concept Maps Play in Meaningful Learning?

Because concept mapping can improve and facilitate meaningful learning, it may very well prove to be an effective learning tool at the middle school level and beyond to (1) engage in extended science discourse, and (2) help students construct an understanding of concepts.

Constructing concept maps is an excellent activity that allows students to engage in extended science discourse. When engaged in the mapping process, the learner is forced to actively think about the relationships between terms or concepts. Mapping exercises require learners to think in multiple directions and to switch back and forth between different levels of abstractions. Mapping forces learners to learn the language patterns of science before locating the concept in the appropriate place on the map. This aspect makes concept mapping especially useful to studying science because it moves learners away from simply memorizing facts. The National Science Education Reforms encourages the notion of learning science as an active process and professes that such can facilitate the central goal of having students understand science content (NRC, 1996, Dorough and Rye, 1997).

What Can Concept Mapping Achieve?

In several studies (Snead, 2000; Pénello, 1993; Schmid, and others, 1990; Malone and Dekkers, 1984), concept mapping was shown to promote meaningful learning among underachieving students (lower ability students) in the following ways:

1. Organizing information on a topic. Disorganized information is relatively useless and difficult to understand. Useful knowledge must be organized so as to facilitate understanding and problem-solving ability. The information-process system of learning strongly emphasizes organizing information into meaningful chunks to enhance transfer into long-term memory. Lower-ability students need cognitive tools to construct hierarchical forms of knowledge

organization. The information-process system of learning strongly emphasizes organizing concepts (order information about the properties of objects, events, or processes) into meaningful chunks to enhance transfer into long-term memory. Concept mapping organizes knowledge into categories and sub-categories so that it can be remembered and retrieved. It is based on the idea that concepts do not exist in isolation but depend upon others for meaning.

2. Motivate the study of a topic. Many public school teachers who teach in low-performing districts will agree that motivation is lacking in most of the students they teach. Behaviorism suggests that learning can be increased through use of incentives. Because incentives may be central to learning, motivation may be enhanced by incentives. One of the key ingredients for incentives to learn is accomplishment. Accomplishment or a sense of accomplishment is derived when students are more mastery-oriented than social- oriented. Their goals are generated by interest, challenge, and enjoyment of the task. On the other hand, students who are social-oriented focus on accomplishment being derived from competing for rank, avoidance of attention, or judgment. Concept mapping allows student to develop meaning and understanding from their own ability levels while challenging them to move to a higher level of thinking or reasoning. There is no one way in which to demonstrate who is the best or better in the mapping exercise. Snead (2000) observed that lower-ability students who engage in concept-mapping exercises expressed satisfaction or a sense of accomplishment because of the immediate and frequent positive feedback they receive from its use. In this study, once students gained mastery with the mapping process, they usually received a grade of 80% or higher for constructing a map. For many lower ability level students, a grade of this magnitude was the best grade they had every received. Furthermore, data from concept-mapping studies indicate that concept mapping taps different abilities and/or performance characteristics than do conventional measures (Novak, 1990; Schmid and Telaro, 1990). Thus, concept maps provide feedback so students can actually "see" what is known about the topic.

3. Encourages active participation and logical reasoning. Concept mapping is process-oriented; the user is forced to interact with the target material while creating a map. Mapping requires students to think in multiple directions, engage in the "if-then," or deductive reasoning—moving concepts back and forth, thinking about logical arrangements, and thinking about the relationships among concepts. This approach avoids the esoteric nature of many mnemonic techniques, but it allows for a great deal of individualization. Furthermore, data from three studies (Snead, 2000; Novak, 1990; Schmid and Telaro, 1990) indicated that concept mapping had greater gains when students were involved in performance-based activities, which were measured through alternative assessments. Because performance-based items/activities require a higher order of thinking than recall or comprehension levels, the demand of logical/or higher ordered reasoning is imperative.

4. Underscores personal interpretation or creative expression. At the heart of science reform is helping students to construct their own understanding and connect it to relevant knowledge. There is no one correct way of doing a concept map. A completed map undergoes many changes, and the final product depends on its purpose and what concepts and relationships are considered important. For example, when students construct a map, they are diagramming their mental framework of a group of concepts. In most cases, concept maps show students'

misconceptions or indicate valid, creative thinking about the concepts.

Summary

Because it requires no special materials, concept mapping is inexpensive. At first, however, concept mapping may not be an easy task for students to master. Students may even resist learning and utilizing the strategy. The following tips may be helpful in getting students started with concept mapping (Baroody and Bartels, 2000):

- Begin with structural tasks and move gradually to less-structured task. Give students a simplified model of a concept map alone with a list of concepts. Let students perform a fill-in-task and come up with their own proposition to write on the connecting lines.
- Start with concept maps involving a few key concepts. A simple map may be a labeled connection between only two concepts. Begin with a few key concepts. Have students diagram three or four concepts in an area. Additional concepts can be added gradually as a topic is developed at more in-depth levels.
- Work together as a class to get students started on concept mapping. Teamwork may build individual students confidence in map construction. Teamwork will help students to understand that individual differences in maps are allowed. No two students may diagram alike. In addition, teamwork will provide immediate feedback on the quality of a map and remind students of any specific missing feature.

According to Brandwein (1991), science teaching itself is not a science of the laboratory, but a science of practice. Teachers generally agree that critical thinking, reasoning, and problem-solving skills are important results of teaching science. However, the nature of teaching these outcomes may not be as clear-cut as it seems. As discussed, concept mapping is a strategy recommended by several researchers to enhance meaningful learning. This strategy may prove to be quite effective in encouraging and providing for meaningful learning among middle-grade science students. It will serve the middle grade science teachers/students well to utilize this strategy, not as a "one-cure-for all" strategy, but as a help to provide meaningful learning experiences for all students.

References

Ausbel, D. (1968). *Educational Psychology: A Cognitive View*. New York, Holt, Rinehart & Winstin.

Al-Kunified, A., and J. H. Wandersee (1990) One Hundred References Related to Concept Mapping. *Journal of Research in Science Teaching* 27 (10) 1069-1075.

Ault, R. A., Fr. (1985). Concept Mapping as a Study Strategy in Earth Science. *Journal of College Science Teaching* 15(1), 38-44.

Baroody, A. J., and B. H. Bartels (2000). Using Concept Maps to Link Mathematical Ideas. *Mathematics Teaching In The Middle School,* 5 (9) 604-609

Brandwein, P. F., (1991). A Permanent Agenda for Science Teachers: What is Good Science Teaching? *The Science Teacher* 64 (1) 36-41.

Callison, D (2001) Key Words in Instruction: Concept Mapping. *School Library Media Activities Monthly* 17 (10) 30-32.

Dorough D. K., and J. A. Rye (1997) Mapping for Understanding: Using Concept Maps as Windows to Students' Minds. *The Science Teacher* 64 (1) 37-40.

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

Hawk, P.P (1986) Using Graphic Organizers to Increase Achievement in Middle School Life Science. *_Science Education* 70(1) 81-87.

Lawless, C. J. (1994). Investing the Cognitive Structure of Students Studying Quantum Theory in an open University History of

Science Course: A Pilot Study. *British Journal of Education Technology* 25 (3), 198-216.

Lehman, J. D., C. Carter, and J. B. Kahle (1985). Concept Mapping, Vee mapping, and Achievement: Results of a Field Study with Black High School Students. *Journal of Research in Science Teaching,* 22, 663-673.

Malone, J. and J. Dekkers (1984). The Concept Map as an Aid to Instruction in Science and Mathematics. *School Science and Mathematics* 84 (3), 221-231.

Mason, C. L. (1992). Concept Mapping: A Tool to Develop Reflective Science Instruction. *Science Education,* 76 51-63.

Mohame-Wafaie A. E.(1997) The Use of Concept Mapping in Learning Science Subjects by Arab Students. *Educational Research* 39 (3), 311-313.

Moreira, M. A. (1979). Concept Maps as Tools for Teaching. *Journal of College Science Teaching,* 8, (5) 283-286.

National Assessment of Educational Progress (2001) Office of Educational Research and Improvement, U. S. Department of Education, Washington DC 20006.

National Reseach Council (1996). National Science Education Standards. Washington D. C: National Academy Press.

Niehaus, J. (1994). Learning by Frame Working: Increasing Understanding by Showing Students What they already Know. *Journal of College Science Teaching,* 24 (2) 22-25.

Novak J.D., (1993). How Do we Learn our Lesson: Taking Students through the Process *The Science Teacher* 58 (7), 51-55

Novak, J. D. (1991). Clarify with Concept Maps. *Science Teacher* 58(7), 45-49.

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

Novak, J. D., (1984) Application of Advances in learning Theory and Philosophy of Science to the Improvement of Chemistry Teaching. *Journal of Chemistry Education* 61 (7) 607-612

Willerman M., and R. A. MacHarg (1991). The Concept Map as an Advance Organizer.

Novak, J. D., D. B. Gowin, and G. T. Johansen (1983). The Use of Concept Mapping and Knowledge Vee mapping with Junior High School Students. *Science Education,* 67, 625-645.

Novak, J. D. *A Theory of Education.* Ithaca. NY. Cornell University Press, 1977

Okebukola, P. A., (1990). Attaining Meaningful Learning of Concepts in Genetics and Ecology: An Examination of the Potency of the Concept-mapping Technique. *Journal of Research in Science Teaching* 27 (5) 493-504.

Okebukola, P. A., and O. J. Jegede (1988). Cognitive Preference and Learning Mode as Determinants of meaningful learning through Concept Mapping. *Science Education* 72 (4) 489-500.

Pankratius, W. J. (1990). Building an Organized Knowledge Base: Concept Mapping and Achievement in Secondary School Physics. *Journal of Research in Science Teaching,* 27 (4) 315-333.

Pendley, B. D., R. L. Bretz, and J. D. Novak (1994). Concept Maps as a Tool to Assess Learning in Chemistry. *Journal of Chemical Education* 71 (1) 9-15.

Penello, H. R., (1993). The Effects of Concept Mapping and Cooperative Learning Experiences on Achievement, Transfer, Problem solving ability, and Attitudes toward the Instructional Experience of Middle School Science Students. (Doctoral dissertation, Florida, 1993). *Dissertation Abstracts International.*

Schmid, R.F., and G. Telaro (1990). Concept Mapping as an Instructional Strategy for High School Biology. *Journal of Education Research,* 84, 78-85.

Snead, D. (2000). Concept Mapping and Science Achievement of Middle Grade Students. (Doctoral dissertations, Kentucky, 2000) *Dissertation Abstracts International.*

Von Seeker, and R. W. Lissitz (1999). Estimating the Impact of Instructional Practices on Student Achievement in Science. *Journal of Research in Science Teaching,* 36 (10) 1110-1126.

Journal Of Research In Science Teaching 28 (8) 705-711

Figure 1

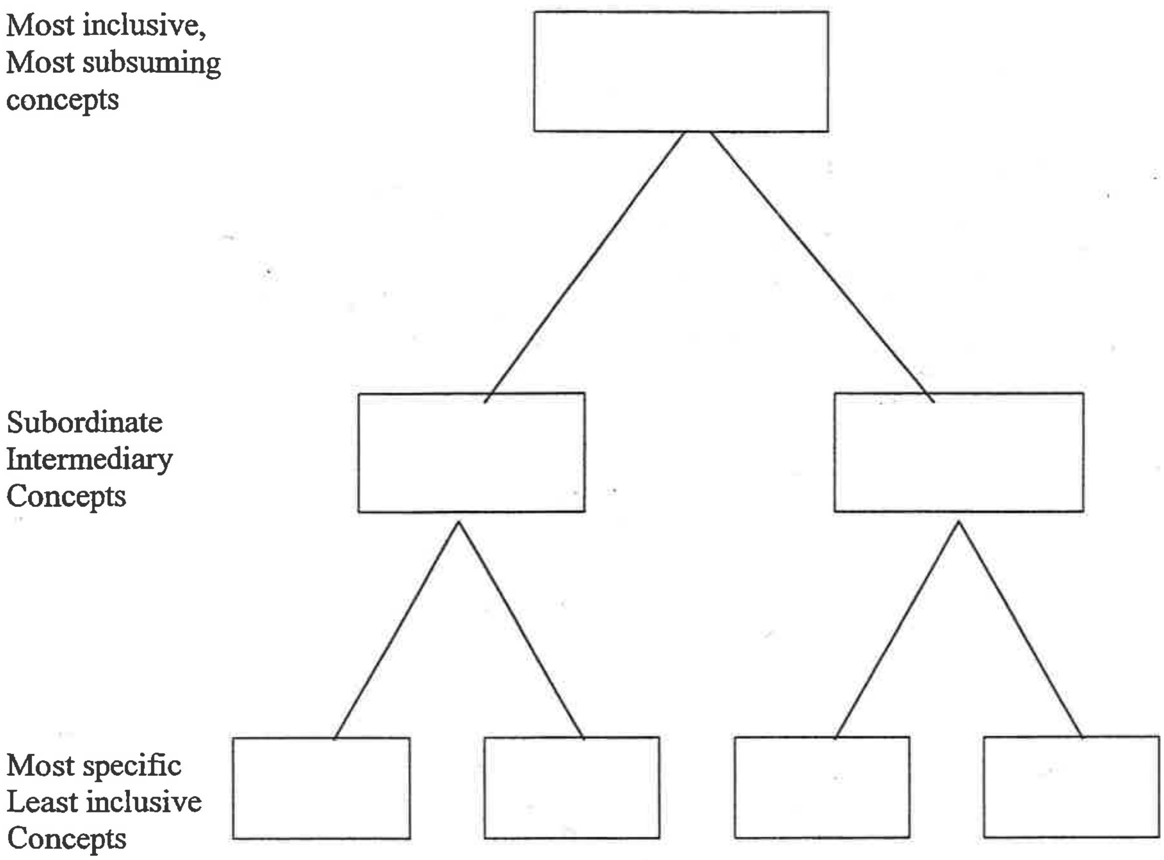


Figure 1. A simplified model for concept mapping (Moreira, 1979)

Figure 2

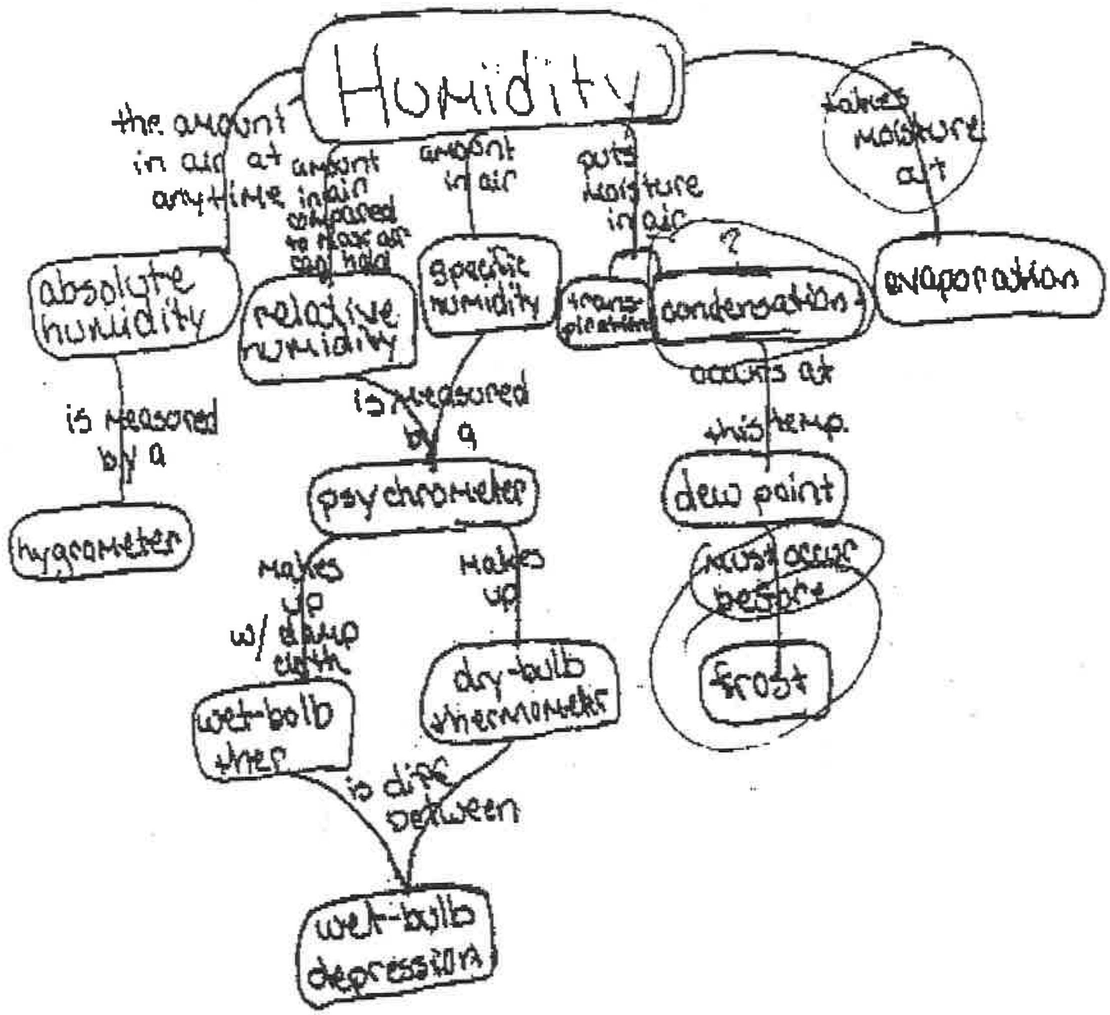


Figure 2. A student generated concept map.

Figure 3

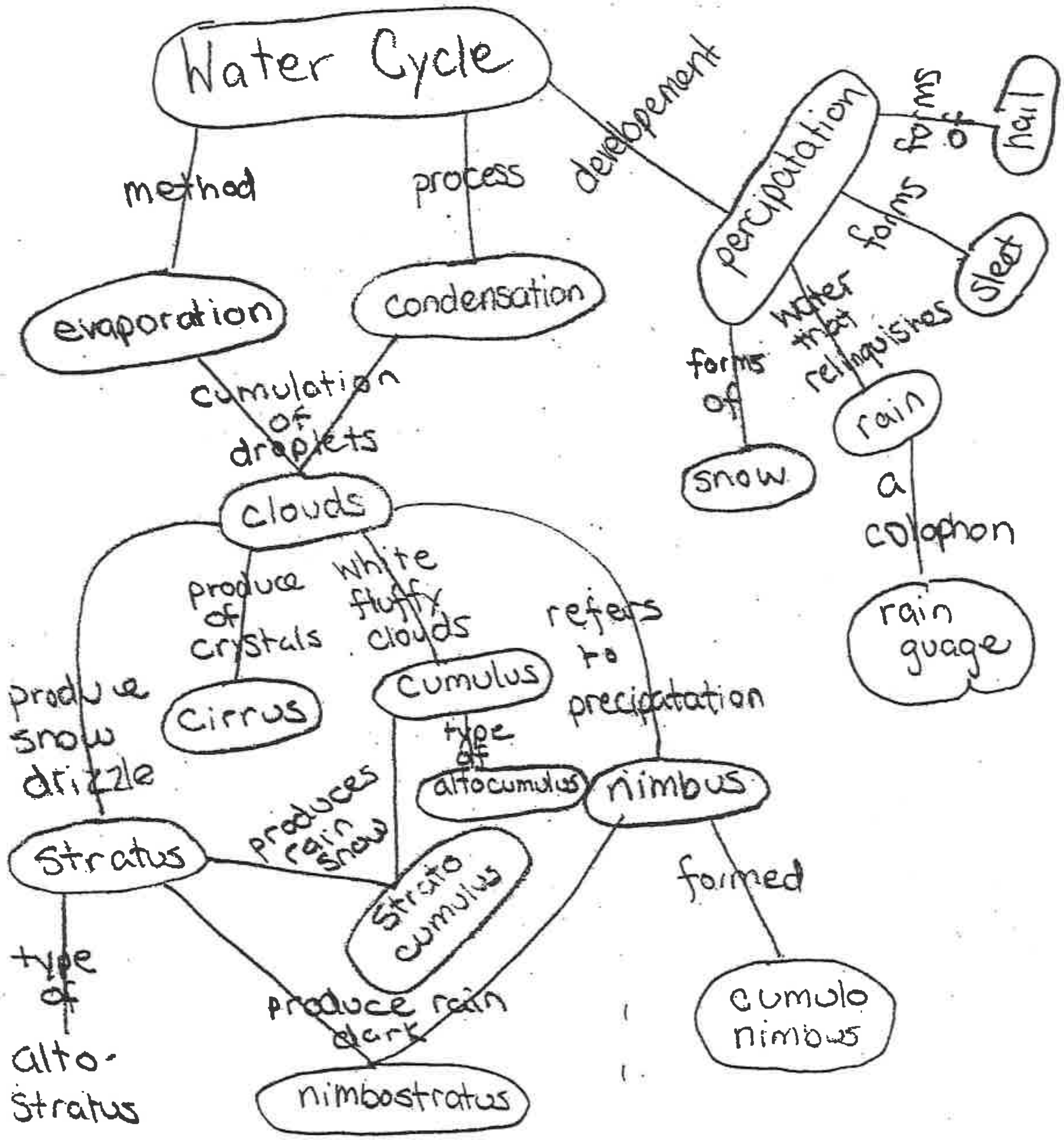


Figure 3. Student generated concept map on the water cycle

Figure 4

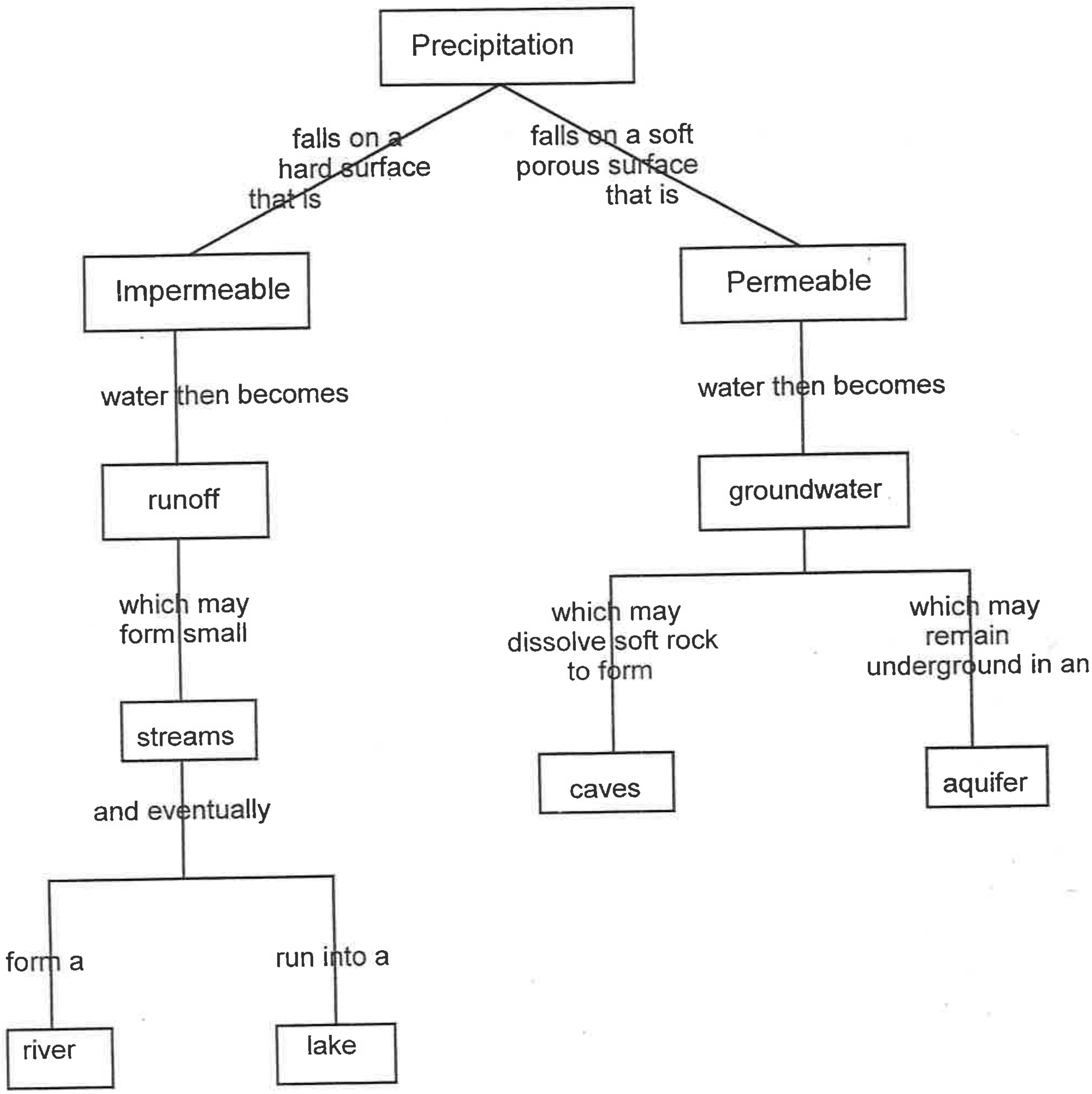


Figure 4. A complex concept map showing relationship among numerous concepts.