Promoting Scientific Thinking with Web-based Concept Maps

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Abstract

In this collaborative research project, six middle grades science teachers have co-developed concept mapping activities tied to soil and air quality environmental issues in the state curriculum. Project highlights include a two-day professional development seminar for teachers, collaborative lesson planning, and classroom instruction designed to promote student thinking skills about priority environmental issues. The project is supported by the freeware Cmap software program for preparing and editing Web-based concept maps. A mixed methods approach is employed with qualitative cases and quantitative control groups. Findings will demonstrate the type and quality of student thinking elicited by mapping activities, as well as potential benefits of mapping on learning outcomes.

Purpose

This collaborative research project between a university researcher and six middle grades science teachers promotes students' scientific thinking skills through Web-based concept mapping. The goal of the project is to increase student awareness of selected environmental problems in the community, as well as actions that can be taken to alleviate the problems. Teachers select topics that tie into the state curriculum, with soil quality and stewardship taught in grade 6, and air quality and stewardship taught in grade 7. Students use Web-based concept mapping software to organize and relate term sets.

Our state's science testing at the end of the 8th grade has an increased focus on processing information and higher-order thinking skills. The focus of this project aligns with these emerging requirements, since it tasks early middle grades students with processing online information sources through the basic thinking skills of qualifying, classifying, and finding relationships (Presseisen, 2001). Building this foundation of thinking skills is important for future science classes that apply end-of-grade tests based on thinking. Concept maps are one of several techniques recommended by National Science Education Standards to promote student thinking (NRC, 1996, p. 144): "Students need opportunities to present their abilities and understanding and to use the knowledge and language of science to communicate scientific explanations and ideas. Writing, labeling drawings, completing concept maps... should be a part of science education." Mapping tools in particular support recommended learning strategies in allowing students to build on what they already know about a subject and revise that understanding through further reading and discussion (Bransford, Brown, & Cocking, 1999).

The project is supported through Cmap software for online concept mapping (IHMC, 2006). With Cmap, teachers can establish and populate student Web folders with raw maps for editing and relevant resources to assist with the task (e.g., articles, Web links, images). Students can access their server-based folders from any Internet-connected computer that has the freeware Cmap tools software program. Students can create new concepts or work with seeded concept sets provided by the instructor. When connecting two or more concepts in a map, Cmap prompts the student to enter a descriptive relationship phrase or "proposition" statement, consistent with the recommended concept mapping approach (Novak, 1998).

Specific project objectives include:

Objective 1: The student will apply basic thinking skills to deconstruct environmental problems: a) *qualifying* or recognizing basic units of identity (creating concept categories), b) *classifying* or sorting pre-selected resources into concept categories, and c) *finding relationships* or patterns and sequences in the data.

Objective 2: Using their completed concept map, the student will engage in the complex thinking process of *decision making* to make recommendations for addressing stated environmental problems.

Theoretical Framework

A void exists in research that investigates concept mapping as an educational strategy to promote student thinking skills. A review of archived articles related to "concept mapping" in the ERIC Education database between 2004-2005 reveals literature more frequently related to:

- non-research descriptions of concept mapping as a methodological or educational tool (Carnine & Carnine, 2004; Goodyear, Tracy, Claiborn, Lichtenberg, & Wampold, 2005; Lee, 2004; Royer & Royer, 2004)

- applications of mapping to address specific needs such as sorting focus group findings (Cousineau, Goldstein, & Franko, 2004), sorting information to help pre-service teachers prepare lessons (Machin, Valeys, & Loxley, 2004), collapsing multiple maps to derive a program theory that depicts group thinking (Rosas, 2005; Yampolskaya, Nesman, Hernandez, & Koch, 2004), deriving remedial instruction paths (Jong, Lin, Wu, & Chan, 2004), or structuring information associated with writing tasks (Riley & Ahlberg, 2004)
- discussions of how to best interpret or assess concept maps (Jong et al., 2004; Passmore, 2004; Riley & Ahlberg, 2004; Van Zele, Lenaerts, & Wieme, 2004; Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2004).

Many researchers have used concept maps to document student knowledge structures, but with different topics, age groups, or under different conditions than the proposed study. Blake (2004) and Lewin (2004) documented individual understanding of rocks and home technology respectively. Kinchin, De-Leij, and Hay (2005) investigated the use of maps to improve undergraduate integration of microbiology course material. And other researchers have modified mapping conditions to determine if different source texts (Graff, 2005), given map structures (Lee & Nelson, 2005), or alternative control structures (Chiu, 2004) impact map development. Only one study investigated similar thinking skills to the proposed study--MacGregor and Lou (2004-2005) discovered concept map templates can assist with recalling and applying knowledge from Web sources during inquiry tasks.

To use concept maps for assessment, at least three things must be accounted for: a task with directions, some format for the student's response, and a scoring system (Ruiz-Primo & Shavelson, 1996). Tasks vary by constraints, with some providing pre-selected terms or propositions to students for mapping, and others asking students to generate their own list of terms or propositions. Response formats vary by mode, including paper and pencil, computer-generated, and interview. Response formats also vary by characteristics and difficulty, with some providing an easier fill-in-the-blank map structure for students on a partially-created map, others providing computer pull-down menus with relationship statements already defined, and some providing no map elements ahead of time.

At the training seminar, teachers were shown a continuum of mapping activities from fill-in-the-blank templates to partially completed seeded maps to completely open-ended maps, with the recommendation that novice students start out with seeded maps until they understand the mapping process and Cmap tool. Seeded maps also provide a common term set to score, making assessment more objective.

More than 20 different scoring strategies are available for maps when considering the variations in map type and the multiple map items that can be scored (i.e., concepts, sets/hierarchies, relationships, cross-links, resources) (Ruiz-Primo & Shavelson, 1996). A general recommendation is to focus on the adequacy of propositions as the most important map element, while downplaying scoring systems that simply count concepts and links (Rye & Rubba, 2002). In this study, teachers were trained to score student maps using a combination method of comparing the student map to their own instructor map (one point for every concept grouped similarly to the instructor's concept sets), and scoring the presence of selected map components (one point for each correct relationship statement and cross-link statement between concept sets).

Method

A faculty research grant was secured from the university during spring 2006 to support teacher stipends and travel to an on-campus seminar and researcher travel to school sites. Applications were solicited from 6th and 7th grade science teachers across the state, through contacts with state technology and science education teacher organizations. Six teachers were selected from different schools based on their interest in graphic organization tools and grouped into grade-level teams of three persons each. Cmap server software was installed at the university, allowing teachers and their students to store and edit their concept maps and attached resources entirely online.

A 2-day seminar was held on June 12-13, 2006, to train the cohort. On day 1, the cohort received direct training on Cmap features and practice generating and scoring maps with sample lessons. On day 2, teachers worked in grade-level teams to select resources and develop expert/instructor maps for two environmental lessons. The 6th grade team developed two instructor maps tied to soil erosion, while the 7th grade team developed two instructor maps tied to air pollution. A student version of each map was then generated consisting of a few seeded terms from the instructor map and the remaining pre-selected terms in an unstructured list for the students to organize and relate.

Currently, students are being assigned folders and passwords on the Cmap server using rosters provided by each teacher. Map templates and applicable resources selected by the teachers during planning will be duplicated and placed in student folders. The free Cmap desktop application will be installed on each internet-connected computer from which students will be constructing their maps. Teachers were required to secure the signature of their school technical support person, agreeing to assist with these installs, as part of their application for the seminar and study. Prior to their first lesson, each teacher will engage students in a short training lesson to learn both Cmap software features and general mapping procedures. The training lesson will task students with developing appropriately structured concept maps using a simple topic (e.g., basketball rules).

This is a mixed methods study with a quasi-experimental two-group control group design and a qualitative case study design. The unit of analysis is a case site comprised of one teacher and at least four classes, allowing for both quantitative and qualitative comparisons across sites. Each teacher will assign at least two classes to a treatment group and two classes to a control group, with an estimate of at least 150 students in each group at each grade level across the multiple school sites. Both groups will receive a pre-test before each of two lessons to measure their prior knowledge of relationships in the instructor maps developed by teacher teams. Both groups will receive the same instruction in the form of readings and regular lab activities. The experimental group will spend up to two extra days per lesson working with Cmap, organizing and relating pre-selected concepts. Both groups will complete a decision-making worksheet based on consequences and values, asking them to use evidence from class activities to justify relevant solutions (Swartz, 2001). This activity will be followed by a class discussion on the best solution options. Finally, both groups will complete a post-test with appended survey questions. Additional data sources include classroom observations at each school site, a teacher journal for reflections, and a semi-structured teacher interview.

Appropriate statistical techniques such as analysis of variance will be utilized to determine any differences in mean scores between pre and post tests. Descriptive statistics will be calculated for such data sources as student surveys and the mean number of correctly identified propositions per lesson. NVivo software will be used to import, code, and sort qualitative data sources (i.e., student survey comments, teacher interview data, journals), to seek any evidence of patterns within or across case sites. This qualitative data should be helpful to interpret the findings regarding any pre-test to post-test gain.

Preliminary Findings

Findings from the completed training include reluctance by teachers to trust their students with mapping of a more open-ended nature. Some teachers expressed concern that their students would not understand how to organize and relate concepts, and their initial student maps were very basic with only 4-6 terms to fill-in on a nearly completed map template. Through negotiation, teachers eventually developed seeded maps with only a few starter terms and multiple unsorted terms for students to organize and relate. The potential to elicit and depict student thinking is much greater in seeded maps than in fill-in-the-blank maps, which is a conception that took teachers some time and practice to understand.

One of the instructor maps created by 6th grade teachers at the summer seminar is depicted in Figure 1. The subject of this map is "topsoil erosion," including human causes, effects, and potential solution options. While Figure 1 depicts the completed instructor map, Figure 2 illustrates the seeded map provided to students. A few of the overarching header terms are provided on the seeded map, but the student is responsible for arranging the unsorted terms using "like" groupings and arrows in the space. The student must then generate written proposition statements to explain the relationship between each set of connected terms. These activities are tied to specific thinking skills--classifying and finding relationships (Presseisen, 2001). As noted previously, students will receive one point for grouping concepts similarly to the instructor (e.g., increased food production grouped with farming practices = 1 point, solid waste and nuclear waste grouped with landfills = 2 points). Students also receive one point for each correctly stated proposition/relationship statement, and one point for cross-links that go beyond the most basic relationships. Pre- and post-tests were developed on the basis of relationships in the instructor map. Based on the map in Figure 1, sample test items include:

1. Due to growing population, loss of topsoil is caused by:
   a. animal waste b. increased food production c. deposition of materials d. use good farming tools
2. Which of the following factors is directly related to construction and industry:
   a. landfills b. glaciers c. slope d. precipitation

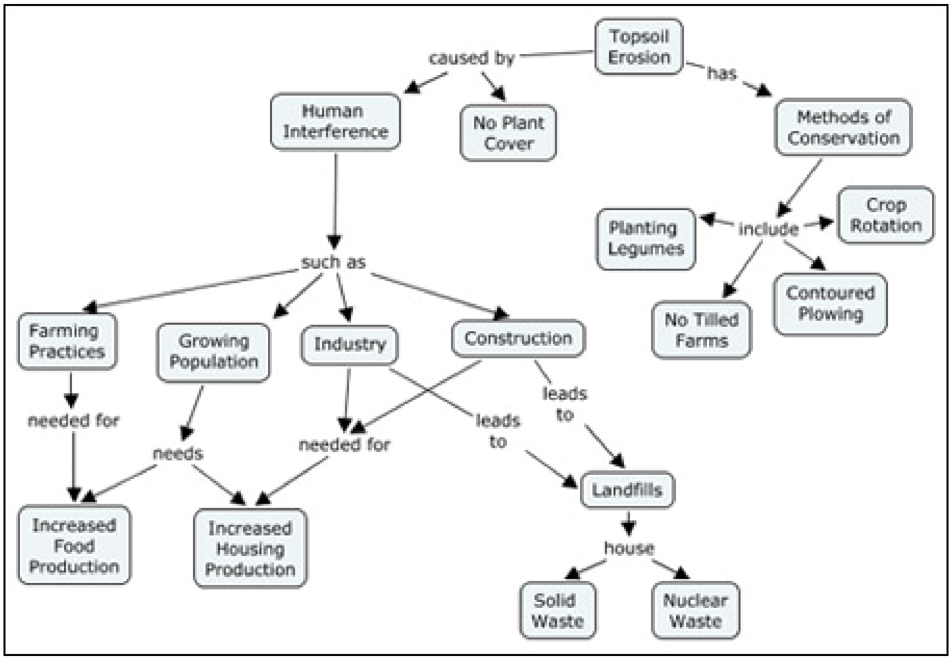

Figure 1. Sixth grade instructor map on human sources of topsoil erosion.

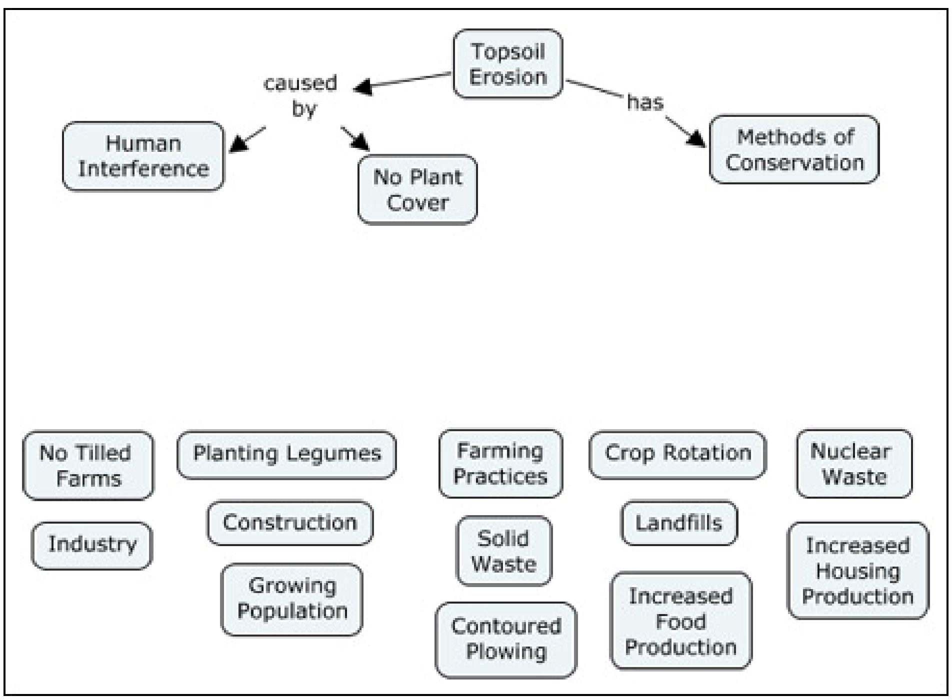

Figure 2. Sixth grade seeded map on human sources of topsoil erosion.

Figures 3 and 4 illustrate one of the instructor maps and student seeded maps created by 7th grade teachers at the summer seminar. The subject is human sources of air pollution. As with the 6th grade map discussed previously, the maps emphasize causes of the air pollution problem, negative effects, and solution options. Pre- and post-test items were once again based on relationships in the map. For example:

1. Ozone in the lower atmosphere causes all of the following problems, except:
   a. lower crop yield b. disruption of water cycle c. death of fish d. severe health problems

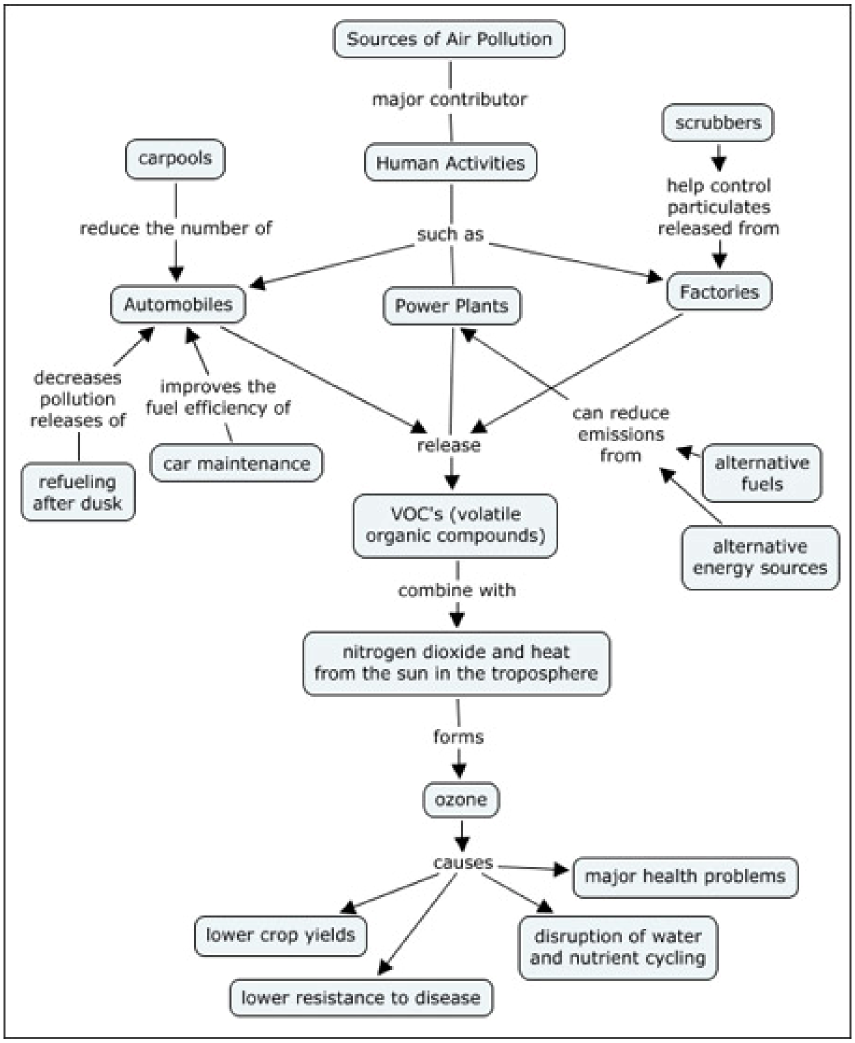

Figure 3. Seventh grade instructor map on human sources of air pollution.

The following research questions will be addressed by the instructional portion of this study, commencing Fall 2006. Multiple data sources are used to inform each question as shown in parentheses.

1. How effectively do students using Cmap classify or sort and categorize pre-selected resources into concept units (Cmaps, discussions, observation, journals)?
2. How effectively do students using Cmap find relationships or the patterns and sequences outlined in pre-selected resources (Cmaps, discussions, observation, journals)?
3. How appropriate is student decision making in terms of recommendations made to solve presented problems (worksheets, discussions, observation, journals)?
4. How much do students learn about presented problems (pre-test, post-test, Cmaps, survey questions, journals, interviews)?
5. How effectively can teachers prepare, implement, and score Web-based concept maps in their instruction (observation, journals, interviews)?

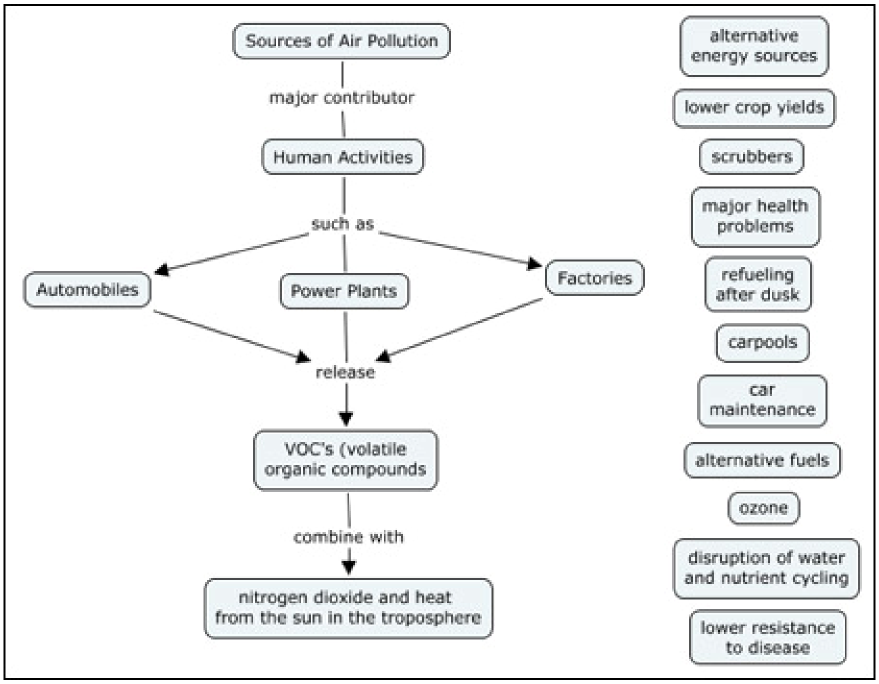

Figure 4. Seventh grade student map on human sources of air pollution.

Importance

Data from this study will be useful to detail the extent and quality of student thinking that can result from mapping activities with tool-based scaffolds. The control group design will help determine if mapping activities help students learn more about problem relationships than students who don't visually organize and relate terms. Qualitative data will help to define specific enablers or barriers to these learning activities across six different school sites and instructors.

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