Mapping Student Minds

By Ariel Owen

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Audience: Teachers, teacher educators
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Technology: Causal Mapping Software, Internet/Web
Standards: NETS•S 3;NETS•T II (www.iste.org/standards)

Water is like a magnet—it attracts kids (and grown-ups). But, connecting student observations and data about our local creek to a deeper understanding of the interplay of factors that influence its health is not so straightforward. I teach sixth-grade science at Foothill Middle School (FMS) in Walnut Creek, California. My teaching partner, Jeff Parrish, and I attended an Aquatic Outreach Institute (AOI) workshop known as Kids in Creeks, which helped us introduce our students to water quality and creek health and teach them about the relationship between their activities and the local creek. (*Editor's note:* For AOI's and other Web addresses, see the Resources section at the end of the article.) Through actual and virtual field trips, students experience the dynamic aspects of Pine Creek, an intermittent creek five miles from FMS. With the help of an online database and a causal mapping tool, both part of the Web-based Inquiry Science Environment (WISE) project based at the University of California at Berkeley, they understand that Pine Creek is more than a place to get wet and muddy.

Gathering Data

A field trip to Pine Creek includes a hike of about two miles and lots of wading. Kids are encouraged to pick up trash, identify native and non-native plants, and to observe the geology of a creek watershed. We test six different sites, the closest being right up the street, the furthest being about 10 miles southeast of FMS. Students gather data, including dissolved oxygen, phosphates, pH, nitrates, temperature, silica, sulfates, and turbidity, from various tests. Students also observe local flora (aquatic and land based) and fauna. Until recently, students reported all test results to the student "data master" at each site, who hand entered all the information onto a ditto form. At school, other students then keyed the data into an Excel spreadsheet. Now we are using a Palm Pilot data form that can be downloaded directly to the WISE database. This is a great way to eliminate the potential for errors inherent in writing and keying data.

Students return with plenty of data and observations for a two-week Pine Creek investigations unit using the WISE Web site. The data is enhanced with weekly trips by an after-school environmental club that collects additional ongoing water data from the creek. Students enter all data in the WISE online database of chemical test results for dissolved oxygen, nitrates, nitrites, sulfates, and so on. Our challenge is to connect the information to cause and effect in the annual changes of the creek. Because we can only take the kids out twice a year, it is difficult to see how the data lends itself to describing the health of the creek. Students often see the information as a one-time measurement that is interesting but not really integral to the creek's health. However, by looking at the data over time, students are able to see the variations in measurements and begin to understand that the creek is a dynamic entity that changes according to weather, season, and other factors.

Building Causal Maps

Working in groups of two, students build a causal map that shows relationships between measurable factors (their data) and the health of the creek. Students first generate and define various water quality factors such as dissolved oxygen, rain, pH, and others, which display as words in boxes. Then students create relationships between these factors, which display as arrows linking the words in a relationship. For example, an arrow pointing from the word "rain" to the word "vegetation" indicates that rain increases streamside vegetation (Figure 1). The students' understanding of cause and effect is developed throughout the process as they define relationships, create a causal map, refine the map, and present it to others.

Figure 1. A simple causal map showing that rain increases streamside vegetation.

Defining relationships. This is a challenging task for sixth-grade students, especially when finding inverse relationships. In fact, it was tough for me to understand it the first few times as well, so I had a lot of compassion for the struggle. This tool gave me a real insight into how hard it is to learn something new—an expectation I have of my students every day. To help students with this difficult concept, I usually model a causal map on my whiteboard. The topic is "How to get a good grade in science class." Students generate lots of factors that could affect their science grade—good (study a lot, attendance, good test scores) and bad (talking in class, tardiness, bad test scores, not studying). Then they create direct relationships (illustrated with blue arrows) and inverse relationships (illustrated with red arrows) between the factors (Figure 2, on next page). This really helps them get a handle on the process without also having to get into the data.

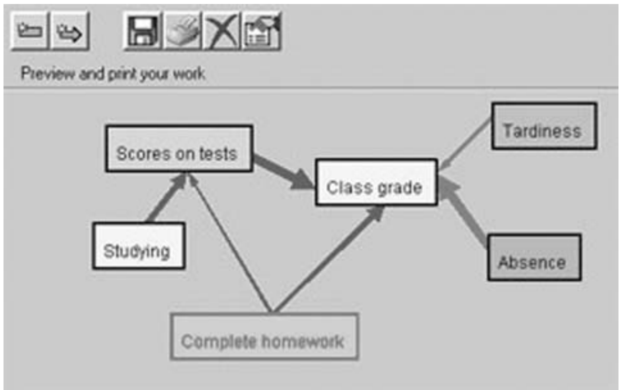

Figure 2. A causal map demonstrating factors that can affect a student's grade in class. Relationships are illustrated by line color and thickness.

Creating the map. Once students get the hang of showing cause-and-effect relationships, they set off on their own mapping journey, building the first of many iterations of causal maps in the Pine Creek investigations. An initial map is built based on a brief overview of information about the creek. Students haven't looked at the data yet and are setting up the map based on a real or virtual field trip. Then the unit leads them into fairly detailed descriptions of the various water quality tests and their relationship to a healthy or unhealthy creek. Students visit "evidence pages" on the Web describing the various tests and what they reveal about the creek and its surrounding area. For example, most students are unaware of how phosphates operate as fertilizer in creeks, and the evidence pages from the EPA and other water quality sites help the kids get a handle on exactly what is being measured in these trips and how to use the information. Students return to their initial map and change or add to it, based on this new information. Figure 3 (on next page) shows a basic causal map demonstrating that an increase of phosphates increases algae, which decreases dissolved oxygen, thus decreasing water quality.

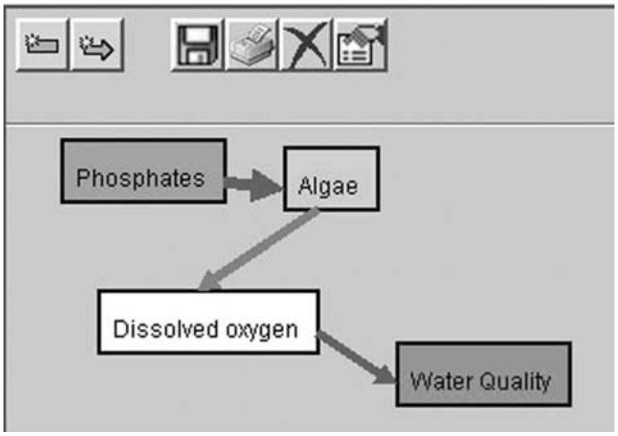

Figure 3. A causal map showing the relationship between phosphates in the stream and water quality.

With each map revision, pairs of students must negotiate and defend their reasoning as they build and adjust their cause-and-effect relationships. They begin to think out loud and articulate their understanding of the creek, digging deeper into the relationships they see and challenging each other's reasoning. In one case, two students were discussing the viability of "safe" ratings for water, because the E. coli count for drinking water is much lower than that of swimming water. One student insisted that swimming water should have the same count as drinking water since swimmers often unintentionally ingest the water. The students discussed the issue and finally agreed that swimming and drinking water should have the same E. coli count. It was difficult for me to stay out of the conversation, but I learned a lot about how students were thinking and evaluating data.

Refining the map. The evolution of their maps offer a window for me to see their understanding (Figure 4). As the map becomes more complex, it is fascinating to ask the students to explain their factor relationships. Some care is needed here, and this is one place where my teaching has really been changed by this tool. Instead of trying to hint and guide the students to the "right" answer, I have learned to ask probing questions that help them think about the relationships. Often I will learn a great deal about how my students are thinking and learning as I investigate these maps with them. A relationship that doesn't seem correct to me may in fact be quite logical once explained by the student team, or an illogical step might be altered and clarified by the students during the explanation process. I cannot count the number of times a kid will stop right in the middle of an explanation and say, "Wait—that's not right. Let me fix it and then come back." For me, that is the real test of learning—when a student can self-correct and move forward. Revisions of factors are essential in this unit because the students are continuing to learn more about each water quality test and the application of that test to the condition of their local creek.

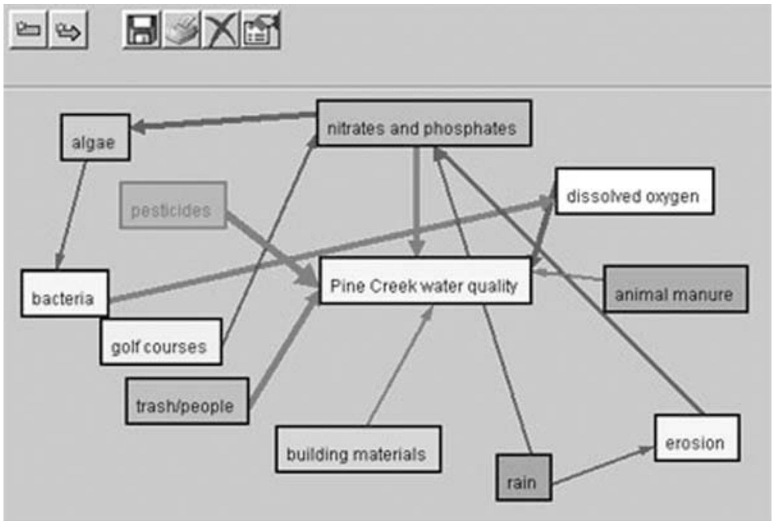

Figure 4. A complex causal map relating various creek factors to each other and to how they affect the water quality of the creek.

Presenting the map. At the end of the unit, students make a final causal map that is used in a culminating event. They choose one of four positions to present to the city council, and support the position with the causal map, based on the creek data. Students not presenting act as the city council, asking questions about the map and its accuracy. In the last part, the class votes on the best position based on the science of the causal models. Thanks to an idea from Jeff, students always have one “absurd” position, such as placing a water filtration plant at the head of the creek. Those who select this option generate a great discussion about scientific rationale and common sense. Other such positions include hiring gardeners to remove “bad” plants or restricting human access to the creek. It is really fun to listen to these presentations, and I often see future lawyers, politicians, and philosophers! I’m hoping to have students incorporate PowerPoint presentations into future discussions.

Troubleshooting

Some kids tend to generate so many factors and relationships that you feel as though you are looking at a psychotic spider’s web rather than a causal map. They have a difficult time letting go of irrelevant or redundant factors. I’m not sure if this is pride in authorship, a fear of throwing away something important, or just an inability to let go of visible factors, but it is a very difficult step. My students tend to keep a boneyard pile of “dead” factors that no longer apply and appear on their maps as a stack of words off to the side. I encourage these students to think about what idea they think is most important to show and realize that not every factor and relationship is required for understanding of the idea. If I cannot make sense of the map within about 10 seconds, I ask the students to try to remove at least two factors. Part of science is simplicity, and in these maps it is essential.

Summing Up

For students having a difficult time in science, this mapping project helps illustrate relationships in a very visual and tactile way. Students generate the factors and describe the relationships. Though some of these maps may be simple, the understanding in them is deep and thorough. The complexity can become daunting as the number of factors and relationships increase. Student teams will often debate intensely as they navigate through the data. These discussions are illuminating and lead kids to a deeper understanding of the water quality factors and relationships. Gifted kids have a great time with this tool. It really gives them an opportunity to go deep and wide in their explorations of cause and effect in a system.

The causal mapping tool cannot be applied to every situation, but wherever there is measurable data and dynamic cause-and-effect relationships in that data, this is a terrific tool for focusing and expressing students' thinking.

Resources

Online

AOI: www.aoinstitute.org
WISE (Database and Causal Mapper): http://wise.berkeley.edu

Print

Anderson-Inman, L., & Horney, M. (1997). Computer-based concept mapping: Enhancing literacy with tools for visual thinking. Journal of Adolescent & Adult Literacy, 40(4), 302–306.

Zietz, L. E., & Anderson-Inman, L. (1992, April). *The effects of computer-based formative concept mapping on learning high school science.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

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