The Best of Both Worlds: Using Authentic Data and the World Wide Web to Promote Inquiry.

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Investigating local watersheds presents middle school students with authentic opportunities to engage in inquiry. When participating in watershed explorations, students are engaged in addressing questions about their immediate environment. Investigation activities promote learning in an interdisciplinary context as learners explore relationships among chemical, biological, physical, geological, and historical characteristics of the watershed. Chemical and biological measurements of a watershed help us to understand changing trends in water quality. Analyzing such trends can help students formulate conclusions about the impact of land and water use as well as habitat issues. In addition, historical research of a watershed may help students understand changes and develop possible solutions to protect their watershed.

For the past year, we have worked with area middle school teachers to assist their students in using hand-held data collection tools to monitor creeks in the Lehigh River watershed. The students' data is contributed to a larger water quality database of the watershed maintained by the Lehigh Earth Observatory (LEO). Students use an extensive Web-based learning resource to assist them in their watershed investigations. This article describes our partnership with area schools and provides guidelines for teachers considering conducting their own watershed investigations.

The LEO EnviroSci Partnership

In Spring 2000, we began collaborating with a group of teachers who were working with the Wildlands Conservancy, a local nonprofit group dedicated to river preservation and environmental stewardship that had been monitoring the water quality of the Lehigh River and its tributaries. Students from area classrooms were collecting water quality data, but no mechanism was in place for students to share their collected data across geographical distances in the watershed area. In addition, no quality assurance mechanism was in place for the data that was being collected. The teachers wanted their students' collected data to be used by area scientists involved in water quality monitoring efforts. However, a quality control mechanism had to be in place to ensure that data collected by students would be reliable and accurate in order to be used by scientists. The teachers were also interested in exposing their students to current water quality research and related studies by area scientists. In a partnership with the Wildlands Conservancy, LEO was providing earth and environmental science data sets and collection activities to the public on the LEO Website (http://www.leo.lehigh.edu). LEO was interested in establishing an educational outreach effort to assist area schools in the study of the local environment. As a result of these needs and interests, a collaborative partnership was formed among LEO, the Wildlands Conservancy, and area teachers to enhance the existing watershed monitoring efforts. A main goal of the partnership was to enhance the existing environmental science curricula of the partner schools by developing an educational Website to assist classroom learners in their studies of the Lehigh River watershed.

Instructional Goals

Collaborative design meetings were conducted with our partner middle school teachers to guide the development of curricular materials to ensure that the activities would be aligned to their instructional goals. The teachers wanted their students to understand the "bigger picture" of how ecosystems work, including how they impact ecosystems and how that impacts them. The teachers wanted their students to participate in an authentic scientific investigation that would enhance their existing classroom curricula. It was also important that students learn in an interdisciplinary context that emphasizes student-directed scientific discovery of their local environment.

A key instructional goal was to have students use authentic data. Students would have to make sense of their collected water quality data and understand how it is relevant to their daily lives and the environmental decisions that they and others make. The teachers stressed the importance of having students understand how to contrast different types of collected data and analyze and interpret data on different time scales. In addition, students should have an understanding of the environmental factors that produce observed data.

The teachers wanted additional opportunities to integrate more instructional technology with their students. They were interested in having their students involved in hands-on data collection using probeware. The teachers were also interested in having their students understand how databases are used in real-world contexts. During the design meetings, discussions focused on curricular customizations involving the use of the LEO databases to provide students with opportunities to observe trends and patterns in authentic data sets, thereby exposing them to integrated applications of science and mathematics.

Website Features to Assist Investigations

Our collaboration involved the development of an extensive Website, LEO EnviroSci Inquiry (http://www.leo.lehigh.edu/envirosci/). Learning resources were developed to assist classroom students in collecting data, analyzing data, and working with Global Information Systems (GIS) databases. Aligned to the National Science Education Standards (National Research Council, 1996), the AAAS Benchmarks for Scientific Literacy (AAAS, 1993), and the Pennsylvania Environment and Ecology Standards (2001), the curricular activities that were created emphasize student-directed scientific inquiry relative to their local environment.

A *Water Quality* section contains background information and protocols that assist learners using Vernier CBL (Calculator-Based Laboratory) units and graphing calculators to collect water quality data. The Website provides data reporting forms that enable learners to submit collected data to the LEO water quality database. This data can then be compared to other water quality data located on the LEO Website. Web-based data links to the Lehigh River's USGS (US Geologic Survey) monitoring stations provide river flow data and real-time discharge data.

The *Lehigh River Watershed Photojournal* provides learners with the opportunity to virtually explore the Lehigh River watershed. The photojournal contains MPEG movie watershed flybys that provide the learner with a graphical overview of the topography of the area. Geologic and historic information regarding specific locations is presented. In addition to digital images of the area, the photojournal contains short video clips and QuickTime Virtual Reality panoramas that allow learners to explore physical features and learn about environmental issues that affect the watershed.

A variety of Website sections offer learners interdisciplinary connections to their watershed studies. The Website contains a *History of the Lehigh Watershed* section that presents learners with a unique opportunity to observe how industry has impacted the watershed over time. The Website also contains a *Pennsylvania Geology* section that provides learners with content background on unique geologic features of the watershed. A Web exploration activity allows learners to become familiar with Abandoned Mine Drainage, an environmental issue that has a direct impact on the water quality in the Lehigh River watershed.

Watershed Study

During Summer 2001, participating middle school teachers received training from LEO on the use of CBL probeware with TI-83 Plus calculators for water quality data collection. During the school year, students conducted seasonal sampling field trips to a creek location in the Lehigh River watershed as they investigated questions about their watershed. The *Water Quality* section of the Website was used to provide students with content background about different chemical parameters. The water quality data collection protocols on the Website were used in the classroom to prepare students for their sampling trips. A LEO graduate student performed the necessary calibrations on the instruments and was present on each field trip to make certain that all sampling protocols were followed, ensuring that the data would be accurate and reliable. During the sampling field trips, students used CBL probeware to measure a variety of chemical and physical properties, ions, and nutrients including pH, conductivity, temperature, chloride, calcium, ammonium, dissolved oxygen, and nitrates. Macroinvertebrate sampling was also conducted.

While connecting the electronic devices during training, the students were curious about how the calculators they were familiar with from math class could be used to do science. Once they had learned to make measurements using household liquids, they were eager to test the water in a student-constructed school fishpond. The field trip was anxiously anticipated as students were curious about the health of the creek where some of them had previously fished or waded. They also found the prospect of having their class data posted on the LEO Website and being part of a larger scientific enterprise exciting. The students were careful and serious in their data collection activities and were visibly disturbed by the occasional inevitable battery or other electronic failure. Once they returned from the creek visit, the students submitted their data using the Web-based data report form. The data is now part of a larger database that can be viewed online.

At the end of the school year, students completed the *Dissolved Oxygen* (http://www.leo.lehigh.edu/envirosci/watershed/curricular/dom2/) activity. This activity is a materials-directed Web-based inquiry that uses a reduced data archive to allow learners to investigate the relationship between dissolved oxygen and temperature from data recorded from four different areas of the Lehigh River. Learners are instructed to graph the data and analyze existing patterns to determine the relationship between the two water quality parameters. The activity provides links to explanations provided by water quality experts that permit learners to evaluate their explanations in light of alternative explanations. Learners are then instructed to create a poster presentation to communicate their findings to the class.

Conducting A Watershed Investigation

We have learned a great deal from our experience assisting middle school students with conducting watershed investigations. We offer the following framework to assist teachers in planning experiences for their students to work with data during watershed investigations.

Motivating contexts.

Provide students with a motivating entry point to set the stage for their investigation. We recommend using a locally relevant problem or real-life experience that a student can easily experience. Such motivating contexts provide students with reasons to want to learn more about the water quality in their watershed. Motivating contexts that can be used in our watershed include acid mine drainage from abandoned coal mines, a toxic waste site near a local town, and the siltation of a local creek from runoff from new housing developments

Selecting a sampling site.

When selecting a sampling site, consider the physical access to the site. Can it be reached by foot or motor vehicle? Does the sampling site permit public access or does one need to acquire special permission to reach the site? Be sure to keep in mind the following safety considerations when selecting a site:

- Is the flow rate or movement of the water body too strong for a student to stand in?
- Is the approach to the sampling area flat or sloped?

- Is the area generally free of irritating plants such as poison ivy?
- Is depth of the water adequate for a student to stand in order to collect a sample?
- Are there sudden changes in depth close to the shore?
- Are there any disease causing organisms in the water?
- Are all students wearing proper footwear?
- Is everyone who handles chemicals wearing safety glasses?

Gathering Data.

Protocols for sampling need to be developed or provided. The following factors should be well thought out prior to gathering field samples:

1. Sampling techniques. What is an appropriate way to collect a sample? It is important that students know and practice sampling techniques before conducting techniques in the field. A good water sample is usually obtained in the middle of a stream well below the surface of the water.
2. Availability of data collection tools. What are the proper tools to use for data collection? Decide on which data collection tool should be used for a given parameter. Chemical test kits and probeware may both be used for data collection. It may also be appropriate to conduct a macroinvertebrates survey to assess the health of a water body.
3. Quality assurance and quality control. How do you know that your data is reliable and accurate? To assure that probeware equipment is functioning properly, a calibration should be performed. If using chemicals, be sure to check that stock solutions are not out of date. When collecting field data, students need to follow the specific directions of a protocol exactly as described. Keep track of samples. Be sure that a good recording system is established for labeling samples and recording data.

4. Preparing for the sampling trip. What do you need to bring with you when you sample? We recommend bringing the following items when conducting a sampling trip:

- Plastic sampling bottles with lids for water collection.
- Deionized water for cleaning instruments.
- Extra batteries when working with probes.
- Permanent markers and labels for sample bottles.
- Fine nets for macroinvertebrates.
- Magnifying glasses.
- Collection trays for macroinvertebrates.
- Waders for cold weather and leech-infested waters.
- Data sheets or a hand-held device such as a Palm Pilot to record data.
- Yardsticks and rulers for measurements.

5. Selecting a time to sample. When should you sample? Be aware that some chemical nutrient data produces different values depending on the time of day. How often can you sample? Although a richer data set can be produced with multiple sampling excursions during a school year, patterns may be observed with three seasonal sampling trips.

6. Selecting variables to test. What variables can be tested? What variables should be tested? Consider your access and availability to equipment and your curricular time constraints.

Analyzing data.

Consider the following factors when determining how data will be analyzed:

1. Time scale issues. How much data needs to be analyzed in order to formulate a conclusion? What can students learn from a data set taken at one point in time? Students

may require a large enough data set to observe seasonal variations or annual patterns in a water body in order to formulate a conclusion.

2. Comparing other variables. Which water quality variables will be compared? What do the relationships mean? Some water quality variables such as dissolved oxygen and temperature have an inverse relation.

3. Data Representation. How do you represent your data? Should data be placed in a spreadsheet? A point in a graph? A GIS? Be sure to include units and that students understand what the units mean. Units must be consistent for students to compare data from different parts of the watershed.

4. Scope of the data. How does your data relate to other locations in the watershed? Watersheds are large interconnected systems. Students should think about how their collected data relates to the watershed as a whole.

5. Data Patterns. What patterns do you observe? Does one variable seem to be related to another? Is this what you would expect to see? Why or why not? What about the outliers? Where do they come from? Why? Can you see changes over time?

6. Contributing your data to a larger data set. Data collection must be consistent with acceptable protocols. Consider how data will be shared? E-mail and submissions to Web-based forms may be used. It is often helpful to be able to view data on a Web page or export data from Website to a spreadsheet application. When working with a large data sets, look for obvious trends in the data.

Investigating alternative explanations.

Prompt students with questions to think about investigating alternative explanations.

There are many information sources where students can access relevant scientific knowledge that might lead them to alternative conclusions or explanations. Information may be found in scientific journals, Websites, and newspaper articles. Be sure that resources are accurate and reliable.

Communicating conclusions and/or explanations.

What content needs to be communicated to your audience? Decide if students should select their method of communication or be presented with a layout that guides their presentation. When selecting an appropriate format, have students decide who the intended audience is and how conclusions should be displayed. Communication formats might include a traditional scientific poster, an oral report, a news article, a newscast, a Website, or a lab report.

Summary

Our collaborative partnership was viewed as a success for the teachers, students, and university partners. We developed Web-based curricular enhancement materials to assist student investigations about their local watershed. These investigations provided learners with opportunities to explore relationships among the chemical, biological, physical, geological, and historical characteristics of their watershed. The partnership provided a mechanism for classroom teachers and learners to access and properly use technology-based tools and resources to which they might not otherwise have access, as well as the opportunity to contribute to a larger scientific database. Our collaborative efforts have shown that partnerships between universities and schools can be successful vehicles for assisting teachers in implementing watershed investigations into their classrooms and motivating students to do real science in the real world.

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