Web Adventures in K–12 Science

By Edward A. Friedman, Beth McGrath, and Joshua Baron

All educators search for ways to make learning more engaging, increase student motivation, elucidate difficult concepts, and link students in isolated classrooms with the vast resources of the outside world. With the Internet, knowledgeable teachers in supportive school environments can achieve many of these objectives. But results aren't achieved willy-nilly. Specific Internet resources must be identified, curriculum matches made, cognitive development nurtured, opportunities for exploration guided, and excellent lesson plans developed.

At Stevens Institute of Technology, we have been exploring applications of the Internet in K–12 science classrooms for several years. As recipients of a National Science Foundation grant, the Center for Improved Engineering and Science Education (CIESE) has been working with more than 700 New Jersey schools that are engaged in an NSF-funded State Systemic Initiative (SSI), a broad-based science reform effort. We also work with non-SSI schools that are designated as economically disadvantaged.

In promoting classroom applications of World Wide Web technology, we have sought to emphasize uses that are unique, compelling, and not easily duplicated with any other technology. For this reason we have discouraged Web applications that could be easily implemented using CD-ROMs or computer software. While the Web can be a convenient and economical vehicle for delivery of text, images, or software, we have preferred focusing on attributes that allow exploration of new territory.

Working with Real-Time Data
We have found that the most exciting opportunities for Web use in classrooms are those that engage students in acquiring real-time data, communicating with peers, and accessing experts. Experiencing constantly changing sources of information and dynamic human interactions beyond classroom walls not only motivates students but also opens important new possibilities for science study.

By working with real-time data students can “do” science instead of reading about science, as has so often been their experience with textbook-based lessons. Students get opportunities to investigate issues, draw inferences, develop hypotheses, then test their conjectures by analyzing new data. New national science education standards push students not just to memorize facts and figures but to apply them to solve real-world problems.

The Internet can equip educators with a new dynamic teaching tool to meet this challenge. This “blackboard for the 21st century” can supply the classroom not only with real-world scientific data and communications with peers and scientists around the globe but also with real-time data from scientific instruments such as satellites, telescopes, and microscopes—all of which make science real for students. [For examples of CIESE-developed curriculum activities, see “From Freshwater Ponds to Ships at Sea,” page 23.]

Training

Bringing the Internet into the Classroom

Stevens Institute of Technology's Web site is http://k12science.stevens-tech.edu.

Three Data Sources
Real-time data can be generated in various ways for transmission via the Web. We can summarize our experience in terms of three basic mechanisms by which data can originate: measurements by peers at remote locations, publicly available Web sites, and instrumentation in scientific laboratories.

Peer-developed data is usually transmitted during a collaborative project. The Web is particularly valuable in this context, providing types of data from remote locations that are not available locally. Examples of successful collaborations we have conducted include investigating relationships between the boiling point of water and elevation, observing inherited genetic traits in large
populations, measuring water quality from regions around the world, investigating the relationship between average weekly temperature and latitude, and investigating the effects of warm ocean currents on the climate of remote land masses.

We have used publicly available Web data such as satellite observations of weather, ocean, and land conditions; volcano and earthquake data; data from ships at sea and oceanographic instruments; and EPA air-quality data. In collaboration with the Waksman Institute of Rutgers University, we have had notable success having students tackle challenging problems in molecular biology and genetics that required them to access online genome databases.

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Our project has promoted the use of instrumentation in scientific laboratories through two noteworthy initiatives. In collaboration with the Princeton Plasma Physics Laboratory we have made real-time fusion research data available to students. With the Stevens Material Engineering Laboratory we have provided students with customized images of their own samples from a research-quality scanning electron microscope.

Surfing by Teachers
In preparing teachers for use of the Web in their classrooms, we have found that simply providing teachers and students with the technical facility needed for using and searching the Web is not enough. It is a fallacy to think that skill with surfing is sufficient for educational improvement. In fact, surfers can become overwhelmed and confused. To think that surfing abilities necessarily lead to better teaching and learning is like thinking that all teachers who learn word processing will be able to write meaningful textbooks.

It takes a great deal of time, effort, and knowledge of Web resources, pedagogy, and science content for an individual to enrich the classroom experience. While some teachers can certainly do this, it is a challenge for most—particularly at the pre-high school level, where instructors trained in U.S. teacher colleges are often ill prepared in science content.

Even when lots of knowledge and skills come together, it is important to test materials in various classroom settings and for the science content to be reviewed by an expert. Web materials often are in domains that are somewhat new to teachers, and care must be taken to validate the science underpinnings. These testing and review opportunities are often difficult for classroom teachers to implement. Therefore, it is important to have resource centers where collaboration and consultation are possible.

School System Support
Web-based education is critically dependent on having a technological infrastructure that supports teachers' efforts. While a great deal of publicity has gone to wiring school buildings, it is important for schools to get their feet wet before jumping into a new technology. With grants of just $1,000 we have taken an existing computer in an economically disadvantaged school and added a modem, telephone line, and one year of Internet service. With that one computer in a classroom, a trained teacher is able to accomplish a great deal. But even this basic configuration, which is an excellent starting point, is absent from many U.S. classrooms.

Access and equity are among key policy issues confronting government at all levels as well as local school boards. Affluent families are overwhelmingly voting for Internet use in education by making it available to their children at home. Mechanisms need to be found to provide access to these resources for all schoolchildren. Having at least one connection in every classroom would be a good start.

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Teachers need to know how to handle potential problems with connectivity. Most teachers cannot afford to miss a lesson because an Internet service provider is not operating. To obviate such possibilities, we have emphasized the need to preload Web sites before classroom use, to have backup plans, and to use software such as Web Whacker to save static Web pages.

Teachers need to have strong school system support not just for installing and maintaining technology but also in providing time and resources for curriculum development. The most effective model we have experienced is one in which master teachers are sponsored by the school system. These master teachers then promote technology integration in specific classrooms with the full support and authority of the central administration.

Beyond curriculum support, school systems must also recognize the importance of providing reliable tools to their staff and faculty. If teachers cannot be sure the technology will work as reliably as a textbook or a blackboard does, they are unlikely to use it. School systems must dedicate funds to hire the necessary support staff to maintain local and wide area networks, computer labs, software and hardware, and Internet services.

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FROM FRESHWATER PONDS TO SHIPS AT SEA

You can find many of the curriculum activities developed by the Center for Improved Engineering and Science Education at Stevens Institute of Technology at our Web site (http://k12science.stevens-tech.edu). Here we give a few examples that illustrate some of the concepts presented.

A Water Quality Collaborative
Three years ago, students in eighth-grade science classes in Jersey City learned about ecosystems by reading a textbook. Today they visit a local freshwater pond to collect samples. Next, using new equipment, they analyze the samples under microscopes. Then, on the Internet, they establish communication with classes in Japan, South Africa, and England that are conducting similar investigations. After making predictions about whether the same organisms that populate Jersey City's ponds will be found in the foreign sites, they are able to observe, through pictures posted on their farflung partners' Web pages, that the very same creatures do indeed exist in all four sites.

Remote Scanning Electron Microscopes
Powerful optical and electron microscopes at universities and research centers are available for classroom use via the Internet. Electron microscopes make images accessible in classrooms with magnifications that previously were available only to research scientists.

At Stevens we are developing a microscope initiative as a prototype of what can be accomplished through remote access to these scientific instruments. We provide students with opportunities to submit samples of airborne particulate matter from their schools for electron microscope analysis. These samples are processed by graduate students who are in contact with the submitting high school via CU-Seeme Internet two-way video.

In their classrooms, students are able to see how the electron microscope operates and get direct access to the resulting images. By reviewing images with magnifications of 3,000X to 10,000X and comparing them with reference images, students have been able to identify chalk particles. This activity not only helps students understand concepts of size and scale but also is directly relevant in terms of understanding the new Environmental Protection Agency air-quality standards, which call for control of particles as tiny as 2.5 microns.

Data from Ships at Sea
Hundreds of ships in the world's oceans regularly report their precise locations along with basic information about weather and sea conditions. The data can easily be obtained from a database maintained by the National Oceanographic and Atmospheric Administration, which updates the information several times each day. While the volume of information can be overwhelming, it provides an exciting way for students to engage in vicarious travel.

Pretending they are frightened stowaways on a ship who happen to have access to laptop computers and cellular telephones, fifth-grade students try to determine the location of the port to which their ship is bound, using sequential reports of location and Internet resources to calculate the speed and direction of the ship. With this information, students can determine the ship's arrival at a port city, where they can call their parents to pick them up.

This type of activity allows students to apply facts, such as the equation for the speed of an object, to real-life situations, giving them a context for learning that other technologies can't supply. Most students find the activity engaging.

We have now arranged for students to be in direct email contact with senior staff members of major cargo vessels. This new dimension gives students the chance not only to communicate directly with professionals in the shipping industry but also to have their work checked and to engage in scientific conversations about weather conditions. The response from both the students and the officers on board the vessels has been quite positive, and we hope to expand this project schoolwide.

We use an extension of this unit with seventh- and eighth-grade stowaways who decide to stay on board a ship and accept work assignments. They become the captain's Internet weather advisers, tracking the progress of the ship and monitoring weather conditions from real-time satellite sources to determine whether the ship needs to change course.

Email to South Africa
While we direct our efforts at science topics, we have found that using the Web often leads naturally into other learning areas as students exchange emails about themselves, their culture, and current events. A notable exchange took place with two separate student groups in South Africa, one that wanted to achieve a common culture for South Africa and another that advocated the preservation of native traditions.

Such an educational experience would have been hard to implement in any other fashion. It stimulated so much dialogue that the Jersey City teacher had to ask her students to curtail the exchanges!

Map displaying the current position of ships (green dots) and buoys (red dots) in the Pacific Ocean.
PROSPECTS
Current research and development activities in the computer
world tell us that the Internet will undergo significant changes
in coming years. Higher bandwidth, real-time interactive video,
virtual reality, push technology, and improved Web-based pro-
gramming languages are among the tools that will become
available for teaching and learning. With the fusion of video,
voice, and data transmissions, Web access will be as common
in homes of the future as television is today.

While it is difficult to predict specific time frames for par-
ticular changes, it is certain that educators must learn to adapt to
rapidly changing technological environments that promote
learning in schools and in homes. Administrators must be ready
to move forward but cautious enough not to invest in obsolete
systems. They must coordinate acquisitions of hardware and
software with teacher preparation and curriculum applications.

Of paramount importance is the need to provide access to
these resources for all sectors of society. These challenges for
the future can be met only if school systems engage in active
exploration of the opportunities that have emerged so explo-
sively since 1994.

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