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Internet Tools for Facilitating Inquiry

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Although the science education community values inquiry-based science instruction, the goal remains illusive. In the absence of significant changes designed to provide teachers with better support for inquiry teaching, true inquiry-based instruction is probably not a realistic option for many science teachers (National Research Council [NRC], 1996), especially novice teachers (Crawford, 1999; Huber & Moore, 2001a; NRC, 1996; Wong, 1998; Wong & Wong, 1998). Viable support for inquiry teaching can come in many forms, all of which are aptly dubbed as 'pathways to reform' by the *National Science Education Standards* (NRC, 1996). The reforms called for in the *Standards* focus on the changes required to ensure excellent inquiry-based K-12 science instruction for all students. Viable pathways to such reforms include a variety of options ranging from content-based plans (e.g., Crawford, 1998; Matthews, 1998), to general process-oriented strategies (Greene, 1998; Huber & Moore, 2001a; Liem, 1987).

New technologies may also offer a pathway to reform (NRC, 1996), and this pathway certainly includes better use of the Internet (Bodzin & Park, 1999; Huber & Harriett, 1998; Huber & Moore, 2001b; Moore & Huber, 2001; Warlick, 1998; Watson, 1999). Interactive educational Internet utilities are a promising resource not receiving the attention they deserve. This article considers possible roles for such utilities as resources offering students engaging invitations to inquiry while simultaneously mitigating many of the traditional barriers to inquiry, which include the following:

- Constraints of time, supplies, and equipment.
- Difficulties in material—and classroom management.
- Distractions of experimental noise (which can be very disruptive to children conducting hands-on science explorations).
- Assessment practices that drive instruction away from inquiry.

This article argues that interactive Internet resources provide effective means for teaching inquiry-based science at the upper-elementary through introductory college levels. A case is presented for promoting more extensive use of inquiry Internet resources in grades 4-14 science instruction and in pre- and in-service science teacher professional development programs.

Inquiry-Based Science Instruction Defined

No universally accepted concise definition of the term 'inquiry-based science instruction' exists, but there is broad general consensus regarding the fundamental nature and value of inquiry-based instruction. Similar positions have been articulated by the National Science Teachers Association ([NSTA] 1990, 1998), the American Association for the Advancement of Science ([AAAS] 1993, Rutherford & Ahlegren, 1990), and the (NRC, 1996). The nature of inquiry-based instruction is perhaps most clearly described in the 'vision' of the *National Science Education Standards*. As envisioned in the *Standards*, inquiry-based teachers function as facilitators and supporters of student learning rather than as disseminators of knowledge. The vision of the *Standards* is one of dynamic learning communities working within enriched learning environments supported by an educational system that has been overhauled to provide the support those communities will need. Within this setting, the *Standards* recognized the central and iterative roles of mathematics and technology in both scientific work and science instruction. The response to the *Standards* has been strong and supportive (Bereiter, Scardamalia, Cassells, & Hewitt, 1997; Bybee 1995; Bybee & Champagne 1995; Collins, 1997; Huber & Moore, 2001a; Lederman & Niess, 1998; Loucks-Horsley, 1998; Mergendoller, 1997; Moore & Huber, 2001; Pratt, 1995; Riechard, 1995; Zeidler, 1998).

Inquiry-Based Science Presents Science Content Within Meaningful Contexts

The *Standards* stress that excellent teachers of inquiry-based science instruction present science content within a contextual framework to facilitate children in developing understandings about the nature, philosophy, history, and relevance of science. This context emphasizes the connections among science content and (a) the history, philosophy, and nature of science; (b) the content of other disciplines, especially mathematics and technology; (c) issues of importance to the world at large, and (d) issues important in the daily lives of students. The *Standards* discussed this dimension of inquiry in terms of 'the enacted curriculum,' which reflects a blending and balancing of planned learning objectives, student interests, and 'the daily life of the classroom,' which includes content from other disciplines extensively. Thus, as emphasized by Martin (2000), an integrated curriculum is common in inquiry-based science instruction, due to the constructivist underpinnings of the pedagogy.

Inquiry-Based Science Emphasizes Experiential Learning and Problem Solving

In the inquiry-based classroom, students are actively engaged in cooperative, "hands-on and minds-on" learning activities that emphasize problem solving and creative thinking. Through these experiences, curriculum goals are met as students construct meaningful, broadly applicable, well-structured, information-rich knowledge, skills, and affective domain attributes. The *Standards* discussed hands-on activities in terms of 'full- and partial inquiries.' The *Standards* defined 'full inquiries' as activities consisting of the follwing steps, with partial inquiries consisting of some subset of the steps:

1. Students pose a question that is congruent with planned learning objectives and that can be meaningfully explored within the constraints of the classroom.
2. Students design an investigation directed towards answering that question.
3. Students carry out the investigation, gathering the applicable data in the process.
4. Students interpret and document their findings.
5. Students publish or present their findings in an open forum.

Throughout the process of facilitating the inquiry, the teacher uses questioning strategies extensively to guide and direct students' ideas towards success and away from frustration (NRC, 1996, especially pp. 32-37). For example, at the beginning of the process the teacher *must* direct students towards a question that can be answered with the materials at hand and that invites students into a productive inquiry. Elstgeest (1985) provided an excellent discussion of how science teachers can facilitate students in articulating such questions, which he called 'productive questions.' As described by Elstgeest,

A good [productive] question is a stimulating question which is an invitation to a closer look, a new experiment, or a fresh exercise. The right question leads to where the answer can be found: the real objects or events under study where the answer can be found (37).

As this statement implies, to be productive a question must be sufficiently congruent with planned objectives to fit within the enacted curriculum. Such a fit is necessary because inquiry is used to teach other content, not merely for its own sake (NRC, 1996). Once a productive question has been posed, additional questioning and brainstorming activities can be used to facilitate students' planning of an experiment (Huber & Moore, 2001a). Questioning in the latter stages of the inquiry directs students to reflect upon what they have done and what they have learned (Huber & Moore, 2001a, Mathews, 1998; NRC, 1996).

Inquiry-Based Science Requires Authentic Assessment

Finally, the model of inquiry-based science envisioned in the *National Science Education Standards* recognizes that teaching and assessment are interdependent. Assessment practices and curriculum content drive each other. Thus, approaches to assessment emphasizing the memorization of isolated facts work against inquiry-based instruction (NRC, 1996; Huber & Moore, 2000; Huber & Moore, in press). Some of the Internet resources discussed in this article offer substantial promise as a base for authentic inquiry-based science assessment.

What the Internet Has to Offer

What are the characteristics of a good inquiry-based science inquiry Internet site? Among the Internet sites supporting science instruction, two overlapping categories of sites stand out as especially promising for promoting inquiry-based science instruction. The first of these categories consists of Internet sites that, in essence, place virtually millions of dollars worth of scientific equipment or other research resources within a few mouse clicks of the science classroom. These applications place an array of *virtual* equipment and *simulated* resources within student control.

The second category allows students to access and interact with large educationally relevant data sets. The best of these data set sites also provide impressive interactive data visualization tools, which facilitate students in conducting inquiries using the data. Using resources from these two sets of sites, students can actively engage in inquiry-based explorations on topics ranging from genetics to ecology to Newton's laws of motion.

When using these Internet applications, students are not merely looking up facts. These resources are designed to facilitate students in conducting full and partial inquiries. The Internet resources reviewed in this article are particularly powerful in facilitating such inquiries because they transcend many classroom limitations and, in so doing, increase the range of 'productive questions' available to students. For example, using ExploreScience.Com to explore the mechanics of pendulums renders the question, 'What would happen if I tried this on the moon?' into a question that can be productively explored and answered with the resources at hand.

These Internet resources are all excellent tools for facilitating students in exploring the natural universe around them, either by means of direct observation of simulated events or through open-ended explorations of meaningfully displayed authentic scientific data. The resources are well suited to facilitating students in framing their own research questions, as well as facilitating their efforts to design and carry out online explorations directed toward answering those questions. Finally, some of these Internet resources are linked to educational Internet sites containing features that can be used to facilitate students in publishing their research.

Inquiry Internet Sites Providing Access to Equipment and Resources

The Internet sites included in this category allow students to access and then interact with a wide variety of simulated scientific equipment. Often the sites allow students to interact with equipment, which, in the real world, would be prohibitively expensive or otherwise inaccessible to students. These include x-ray machines and oscilloscopes. Some of these tools go far beyond the constraints of real-world equipment and settings. For example, using simulations available at http://ExploreScience.com, students can (a) explore Newton's laws of motion on a friction-free air track; (b) test, in a matter of seconds, predictions about occurrences of recessive traits emerging over the course of multiple generations of mice, and (c) conduct experiments in which they can manipulate the force of gravity (e.g., the mass of a planet). Students can also explore off world phenomenon at any number of NASA sites (see http://questdb.arc.nasa.gov/lesson_search.htm#search for a good search engine of NASA education sites).

Exemplary Inquiry Internet Sites Providing Access to Equipment and Research Settings

Internet sites providing especially valuable and/or promising tools for conducting simulations include http://ExploreScience.Com, Nova Hot Science (http://www.pbs.org/wgbh/nova/hotscience/), and 'Soundry,' included in a library of over 4000 educational sits at http://www.thinkquest.org/library/index.html.

ExploreScience.com provides about four dozen interactive applications, most of which are appropriate for middle school through introductory college grades. The site includes tools that can be used to facilitate inquiry in the following areas:

- mechanics and astronomy, (principles of velocity, acceleration, inertia, etc.);
- wave motion;
- electricity and magnetism;
- optics (bending light, color addition and subtraction); and
- life sciences (vision, genetics, medical imaging technologies).

Students can explore the relative gravitational forces of planets in our solar system at http://kids.msfc.nasa.gov/puzzles/weight.asp. The Soundry site (http://www.thinkquest.org/library/index.html) allows students to turn their computer monitor into an oscilloscope and then manipulate the appearance of the graphed sound wave and hear how the manipulations change the quality of the sound.

Nova Hot Science (http://www.pbs.org/wgbh/nova/hotscience/) provides an extensive array of interactive Internet applications, all of which represent extensions of science programs that have aired on the Public Broadcasting System television program, NOVA. The scope and organization of activities available on this site is broad, with many of the activities being suitable for upper elementary through middle school grades. While some of the resources accessible from this site are more suitable to classroom application than others, the site provides a number of impressive activities including the following:

- 'Lunar puzzles' provides a useful tool for helping students build sound mental constructs of the relative motion of the Earth, moon, and sun.
- 'Skydive from the Stratosphere' is an excellent tool for exploring the structure of Earth's atmosphere.
- 'Move a Moai' invites students to engage in a problem solving activity in which they must balance conflicting tradeoffs of resource management as they attempt to move a Moai stone statue across Easter Island.

The Soundry site at ThinkQuest (http://www.thinkquest.org/library/index.html) is an example of one of the several thousand educational sites developed by teachers and students contained within the 'Thinkquest' library of Internet sites. Soundry includes a variety of utilities for learning about the physics of sound and how humans perceive sound, including interactive applets (small programs embedded on a web page) that allow students to see and manipulate sound waves. Students can, for example, simulate an oscilloscope on their computer screen, manipulate the shape of the wave, and hear the resulting changes in the quality of the sound corresponding to the visual wave representation. Students can also interactively explore various wave actions, such as wave interference and the Doppler effect. This site includes other educational information on sound, such as an illustrated encyclopedic entry on the human ear.

Using Sites That Provide Access to Equipment and Resources for Teaching

Literature on the important role of 'discrepant events' in inquiry-based science instruction suggests that interactive Internet applications, such as those described above, should only be used in lieu of actual hands-on activities with caution. In both traditional hands-on instruction and inquiry-based science classrooms, students are shown (or allowed to discover) counter-intuitive observations'discrepant events'as a stimulating means of introducing a hands-on activity (Annenberg/CPB Math and Science Project, 1995, Huber & Moore, 2001a, Chiappetta, 1997; Edwards, 1997; Elstgeest, 1985; Liem, 1987; Martin, 2000). However, in the inquiry-based classroom, discrepant events are not intended to merely stimulate interest, but to challenge students' preexisting misconceptions (Annenberg/CPB Math and Science Project, 1995; Huber & Moore, 2001a). For example, through simple verbal drill most students may easily memorize the 'fact' that

red light + green light + blue light = white light.

However, when merely learned by rote, discrepant facts such as this are most likely to be memorized without any meaningful comprehension or internalization of the underlying concepts. Thus, it is preferable that students experiment with stage lighting, flashlights with colored cellophane filters, or some comparable manipulative in order to discover, firsthand, the unexpected colors that emerge when pools of filtered light are overlapped. In a similar manner, concepts such as conservation of energy and matter are easier for children to parrot than to truly comprehend or, for that matter, to believe (Annenberg/CPB, 1995; Harlen, 1985). In inquiry-based science, real world discrepant events play an important role in challenging students to reconsider their preestablished views of how the universe works, and, in so doing, to make room in their mental frameworks for alternative explanations, which are more congruous with established scientific views. In other words, discrepant events are used to create the cognitive dissonance important in Piaget's model of learning (Martin, 2000). At this time, there is limited information about how effectively simulations of discrepant events will inspire children to question their pre-existing beliefs, and it is certainly possible that they will respond by questioning the validity of the simulation instead. Thus, students should be engaged in real-world hands-on discovery of discrepant events as much as is possible and practical.

Although it appears best to ground hands-on explorations in the direct and personal study of real-world phenomena, there is no reason to believe that all explorations need to occur in the real world. Additionally, the prospect of using simulated events gains appeal in light of consideration of the ease with which repeated and varied practices of experiments involving the events can be conducted. For example, students could begin by learning the basic principles of additive colors using flashlights and colored filters to observe the counterintuitive results that occur through the blending of colored lights. Once the basic principles of additive colors are grasped, the students could move on to explore and review the mixing of light in the virtual world of ExploreScience.Com, where they can work more efficiently.

In a similar manner, students may be introduced to the process of measuring density using real-world balances and graduated cylinders, and then practice using those tools and techniques in the virtual world of ExploreScience.Com's density laboratory. In both of these examples, the most obvious advantage of the computer is to simplify material management and increase opportunities for student exploration.

The value simplifying material management and other aspects of hands-on explorations, by computer simulations or other means, should not be underestimated (Huber & Moore, 2001a; Wong, 1998; Wong & Wong, 1998). For example, consider the case of a hands-on exercise in measuring density in a class of 30 students limited by the resource of six balances and a 55-minute class period. In this scenario, the teacher might, reasonably, divide the class into six cooperative groups of five students each and supply each group with a number of objects to be evaluated, a graduated cylinder, a drainage container, and a balance. The students should measure the mass of each object using the balance and also measure its volume through water displacement, using the graduated cylinder. Students would then divide the mass by the volume to compute the density of the object. The exercise might include instructions to predict densities and compare predictions with measurements and to graph the results, along with other activities designed to get the students thinking and communicating about what they are doing.

Typically, some portion of every class period must be devoted to administrative matters (e.g., attendance, collecting and assigning homework, intercom interruptions, etc.). Additionally, time must be allotted for giving instructions, checking for understanding, and repeating all or portions of the instructions. Finally, some class time must be devoted to setup and cleanup activities. Given this scenario, it is likely that some of the less proficient groups might complete only a few tests. Further, if the students within each group take turns performing tasks, some students might not even have the opportunity to perform all of the parts of a single test.

By contrast, working individually or with a partner, a student working in ExploreScience.Com's density lab could complete several tests in 5 or 10 minutes. Similar comparisons could be made for numerous activities. Thus, it seems likely that a good balance of cooperative hands-on, real-world explorations and time working with the online simulations would be ideal in many cases. Such an approach provides the power of authentic real-world discovery of discrepant events with the power of repeated spaced practice facilitated by the Internet application.

The computer simulations available on the Internet can also be used to extend the explorations beyond those practical within the classroom under even the best of conditions. As noted previously, examples of such extensions include (a) simulated physics activities involving gravitational forces different from those on Earth (see, 'Orbit Simulator,' 'Black Hole,' and 'Simple Harmonic Motion' at ExploreScience.Com), (b) genetics experiments involving artificial selection (see 'Mouse Genetics' at ExploreScience.Com and 'Engineer a Crop' at Nova Hot Science), and (c) explorations of Newton's laws of motion on a friction-free air track (see 'Air Track' at ExploreScience.Com).

Using Sites That Provide Access to Equipment and Resources for Assessment

The tools discussed in this section may play an important role in assessing student learning, especially given the explosion in standardized and accountability testing currently impacting curriculum development and teaching practice in America's schools. To a substantial degree, standardized testing is growing as a driving force in establishing curriculum goals and methods (Brandt, 1989; CNN, 1999; Huber & Moore, 1999; Jones, Jones, Hardin, Chapman, Yarbrough, & Davis, 1999; Kunen, 1997; Neil, 1998; Shapiro, 1998). As aptly stated in one popular press publication, high stakes accountability testing has become 'the latest silver bullet designed to cure all that ails public education' (Kunen, 1997). Unfortunately, that which is easy to test is not necessarily that which is important to learn, especially in the sciences. Standardized testing typically emphasizes the memorization of objective facts, rather that the development of rich structured knowledge and upper-level thinking skills (Huber & Moore, 1999; Jones et al., 1999; NRC, 1996). Thus, in the absence of more authentic assessment strategies than those that are typically employed in standardized testing, the contemporary wave of political support for educational reform through standardized testing can be expected to push science education practices away from inquiry-based instruction (Huber & Moore, 2000).

In the virtual world however, what is important to learn is not necessarily difficult to assess. For example, assessment of students' learning about density could begin with online activities requiring students to 'click and drag' objects onto displays of balances and graduated cylinders. Students would then be required to read data from the online measurements of the virtual objects and perform calculations of the objects' densities. Scoring could be based not merely on students' obtaining correct answers but performing correct processes, as monitored through a computer utility that tracks their actions in performing the online tasks.

These technologies can be used for formative assessments with built-in tutorials, as well. It is a relatively straightforward task to program a computer to recognize common errors on a test and direct users who make those errors to relevant tutorial information. After walking the user through the selected tutorial, the program can then reassess and redirect the student (either to additional tutorials or forward to the next assessment item). Both ExploreScience.Com and, especially, Nova Hot Science have a number of activities presenting users with online puzzles, challenges, and quizzes that provide examples of starting points for developing such assessment tools.

Inquiry Internet Sites Providing Access to Large Data Sets

In addition to sites that facilitate experimentation using virtual resources, a number of Internet sites use applets to give students access to large sets of authentic scientific data along with powerful tools for displaying and exploring that data. Some of these data visualization tools render pictorial representations, while others present more abstract representations, such as data maps and graphs. These images go far beyond those possible in traditional media. For example, two of the sites discussed here present animated line/color-gradient graphs that change in response to user input.

Exemplary Internet Sites Providing Access to Large Data Sets

Among the Internet sites providing animated graphical displays of quantitative information are 'Water on the Web,' (http://wow.nrri.umn.edu/wow/index.html) and 'River Run,' (http://www.uncwil.edu/riverrun/) both of which allow students to explore and interact with large sets of data pertaining to the ecology of specific bodies of water. The 'River Run' site also includes interactive geographical data maps. A third site discussed here, 'Visible Human' (http://www.dhpc.adelaide.edu.au/projects/vishuman2/) allows students to explore a model of the human body compiled from a large set of medical imaging data.

Water on the Web (WOW) (http://wow.nrri.umn.edu/wow/index.html) provides water quality data collected from remote underwater sampling stations placed in five Minnesota lakes, which continuously sample and analyze water from different depths in the lakes. 'Data Visualization Tools,' accessible from the WOW web site, allow students to see and explore relationships among the data points that would probably be lost to them were the data merely displayed as matrixes of numbers. Importantly, students can, with a few points and clicks, change parameters defining the dynamic graphic displays. Thus, the utilities provide simple and engaging mediums for open exploration and powerful effective tools for hypothesis testing. For example, in an inquiry-based classroom a teacher might direct students to use the 'color mapper' data visualization tool to explore lake stratifications. Under this scenario, the teacher might have students define the parameters so that water temperature is color-graphed and dissolved oxygen is shown with a line graph, as shown in Figure 1 (note that different students could be looking at data from various lakes and at various time frames in this example). Through the teacher-guided inquiry, students should quickly discover how sharp gradients in temperature and dissolved oxygen define the epilimnion strata at the surface of lakes. Students could then form hypotheses of how other variables might behave around this boundary and, ultimately, change system settings, and 'run' animations to test their hypotheses.

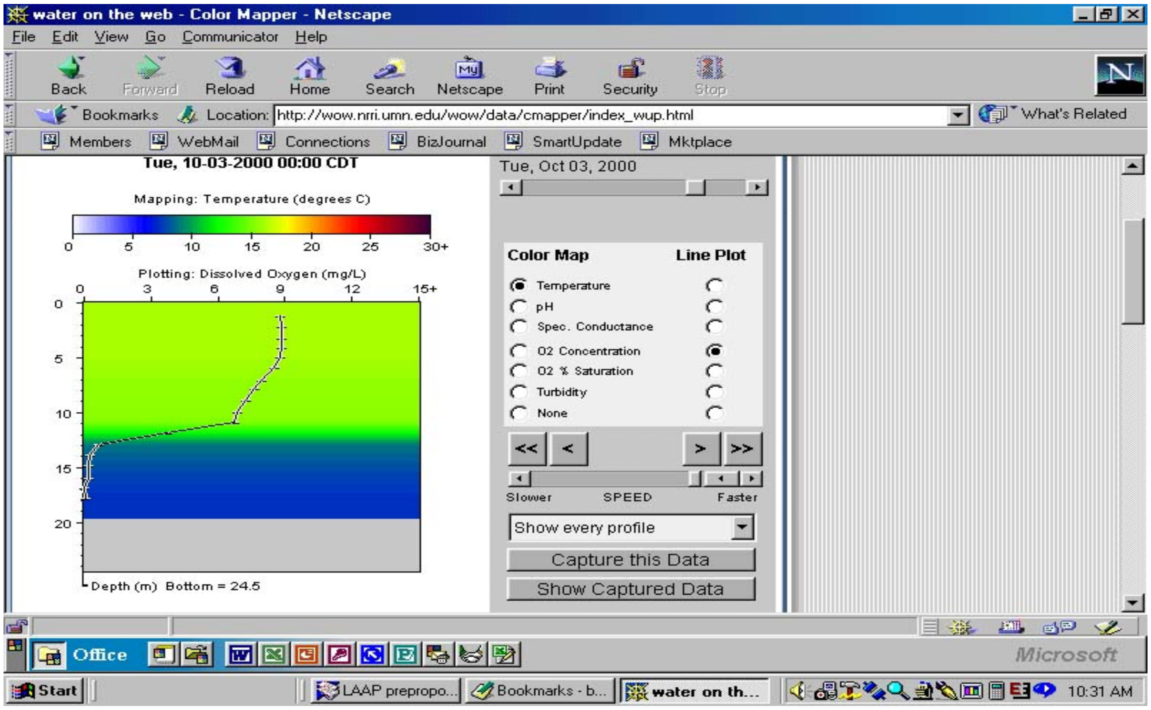

Figure 1. Example of water temperature and dissolved oxygen stratification from *Water on the Web*.

Data visualization tools within WOW are also well suited for presenting clear pictures of various complex phenomena that occur within lake ecosystems. For example, because water is at its densest at 4¡C, in a deep lake the water at the bottom of the lake remains at 4¡C year round. Consequently, as surface waters cool to this temperature in the autumn and warm in the spring, the waters of a deep lake can dynamically 'turn over.' The color mapper tool is an ideal resource for exploring and displaying the impacts of this dynamic event.

River Run (http://www.uncwil.edu/riverrun/) offers two main interactive data displays, the Geographic Information Service (GIS) and the Data Visualization Tool (DVT). GIS is a computer utility for mapping and analyzing geographic locations and numerical data of events that occurred at those places. This tool gives the user the power to link databases and maps to create dynamic displays. The Data Visualization Tool is similar to the color mapper for lake data described above, with the exception that the *X*-axis of the displayed graphs is analogous to the *Y*-axis in the lake data. That is, in the lake graphs the vertical dimension is used to map lake depth, whereas in the river graphs the horizontal axis of the graph maps the flow of the river (from upstream on the left to downstream on the right). The River Run program is linked to Internet-based science educational program site, 'Students as Scientists' (http://smec.uncwil.edu/SAS_trial/SAS/index.htm). The Students as Scientist Internet application provides an excellent venue for students working within that program to publish their work (Moore & Huber, 2001).

Visible Human (http://www.dhpc.adelaide.edu.au/projects/vishuman2/) uses an applet to process 14 Gb of imaging data allowing the user to produce detailed two- and three-dimensional slice images of the human body (and organs and tissues from the human body). This site draws upon a human anatomy imaging database developed by the National Library of Medicine's Visible Human Project (http://www.nlm.nih.gov/). Using this site, students can explore the images from different angles and adjust viewing controls in various ways to highlight different features or aspects of the images.

For example, students can move around within the heart to observe valves and chambers from various angles. Such activities facilitate students constructing understandings of how form follows function in biological system.

Using Sites That Provide Access to Large Data Sets

Perhaps the most valuable use of these sites is to incorporate their use within inquiry-based units of study focused on the science content to which the data is directly relevant, in order to make the data come alive for the students. For example, the Visible Human site would be an excellent resource to use within a unit on human anatomy or biology. River Run and WOW might be used within units on environmental sciences, the atmosphere, or the hydrosphere. For example, Huber and Moore (2001b) described how the River Run data visualization tool can be used to invite students into inquiries about the impacts of Hurricanes on River Systems (http://www.ncsu.edu/meridian/archive_of_meridian/win2001/internet/index.htm). In their example, students are directed to explore the database using the animated graphic displays and try to find 'anomalies,' or sudden dramatic changes in the data displays. Students might discover the frame shown in Figure 2, which shows, among other things, a dramatic spike in fecal coliform bacteria and a drop in dissolved oxygen. Through guided explorations of the River Run database and other sources of information (which are available online) students can 'discover' that these events were caused by the hurricane-induced failure of a sewage treatment plant.

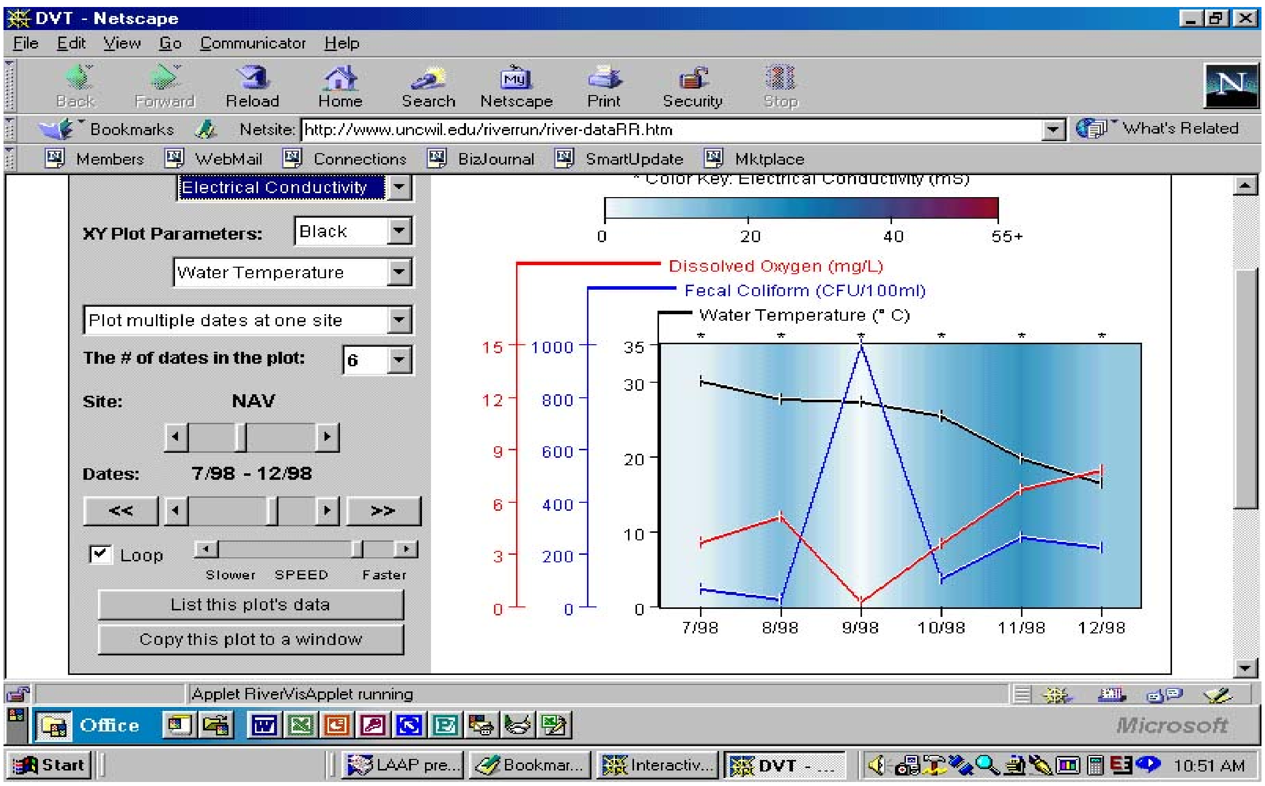

Figure 2. The effect of Hurricane Bonnie on four water quality parameters from River Run.

The interactive nature of these sites, combined with the authenticity of their data, allows students to engage in meaningful inquiry using visual displays of data. Further, because the sites contain extremely rich data sets, they are well suited to ongoing studies that will give students repeated spaced practice in developing science, mathematics, and graphing skills. Consider the following example of how the River Run site might be used within a unit applying the 'issues-based' approach to inquiry valued within the science-technology-society philosophy. In this example, the River Run data visualization tool (DVT) and Geographic Information System (GIS) would be used within a science class study of water quality. Students could use the DVT to manipulate various water quality parameters to see the changes that occurred in different parts of a river system over time. Students could also use the GIS to plot the location of various types of farms in the area of the rivers and compare data from the two sources to look for evidence of water quality degradation caused by agricultural run off. Such an exercise would give students an enormous amount of practice working with graphs, maps, and technology within a meaningful and engaging context.

Internet applications such as WOW and River Run, which expose children to literally hundreds of graphs within meaningful and engaging contexts, may be far superior to traditional graphing activities where students work with no more than one or a few graphs over the course of an entire science or math lesson. Certainly the efficacy of such Internet resources for teaching graphing warrants further attention and research.

Conclusion

There is good reason to believe that interactive Internet science education utilities can be used to facilitate inquiry and promote educational reforms congruent with those envisioned in the *National Science Education Standards.* Two types of Internet sites appear especially promising, those that offer simulations of research equipment or settings and those that allow students to interact with large relevant data sets. Sites within this first set might be especially effective as extensions of hands-on activities and as assessment tools. Applications for sites within the second category include activities that make quantitative information come alive for students and allow students to perform inquiries in which science information is studied within a context that cuts across traditional curriculum boundaries.

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