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AUTHOR Lyons, David J.; And Others
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ABSTRACT

Research on student use of digital resources identifies the challenges associated with utilizing the World Wide Web (WWW) while involved in on-line inquiry activities in the science classroom. On-line materials alone do not suffice in providing the guidance students require to effectively ask questions, plan searches, and analyze the results of their inquiries. This study explores how students in 6th and 9th grade science classes used the WWW to research student-generated questions and the problems they had while working in the on-line environment. Strategies that the students employed while engaged in on-line inquiry are described along with a discussion on how these strategies affected their success. Recommendations are made for the classroom supports needed to help students be successful. Contains 13 references. (Author/JRH)

An Investigation of the Use of the World Wide Web for On-line Inquiry in a Science Classroom

David J. Lyons, Joseph L. Hoffman, Joseph S. Krajcik, and Elliot Soloway

University of Michigan

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Abstract

Research on student use of digital resources identifies the challenges associated with utilizing the World Wide Web while involved in on-line inquiry activities in the science classroom. On-line materials alone do not suffice in providing the guidance students require to effectively ask questions, plan searches, and analyze the results of their inquiries. This study explores how students in 9th grade and 6th grade science classes used the WWW to research student generated questions, and the problems they had while working in the on-line environment. We also look at the strategies these students employed while engaged in on-line inquiry, and how these strategies impacted their success. As a result of this research, recommendations are made for the classroom supports needed to help students be successful.

An Investigation of the Use of the World Wide Web for On-line Inquiry in a Science Classroom

In this age of the Internet, the number of schools across the United States that are wired to gain access to the information superhighway is growing daily. As powerful computers become less expensive and access to the Internet becomes more available to schools, students are gaining the opportunity to access an unprecedented range of information resources. However, despite much excitement among educators about the educational potential of the Internet and the World Wide Web, there has been little research about effective pedagogical uses of on-line resources in primary and secondary schools. Because pedagogical issues can have a tremendous impact on the success or failure of any new technological innovation (Kedar, Guralnick, Holum, Bareiss, Beckwith, & Kass, 1996), it is necessary to really look closely at how the use of the World Wide Web classroom is affected by how it is implemented by teachers and used by students

Background.

A number of researchers and policy groups (e.g., Brown & Campione, 1994; Krajcik, Blumenfeld, Marx, & Soloway, 1994; National Research Council, 1996) argue that students need to engage in sustained inquiry. Inquiry activities include formulating authentic, meaningful questions, planning tasks, gathering resources and information, predicting outcomes, debating the value of information, evaluating information, collaborating with others, and reporting findings. On-line resources, when used appropriately, can help with these activities (Soloway, Guzdial, & Hay, 1994).

Our research group has been investigating ways of integrating inquiry into the science classroom in a number of different ways. These projects all contain themes common to inquiry based science, as described by Blumenfeld, et al. (1991). These principles of inquiry based science are having students ask questions, plan and carry out scientific investigations, and produce products or artifacts to represent their learning. It is from this rich theoretical base that the principles of on-line inquiry were developed. In on-

line inquiry students explore topics, ask questions, and search for and assess information all within the environment of an on-line digital library.

In 1995, we began to investigate the creation and implementation of digital libraries and on-line learning materials in schools from the framework of on-line inquiry as part of the Middle Years Digital Library (MYDL) project and its parent project, the University of Michigan Digital Library (UMDL). The purpose of this particular study is to evaluate the implementation of on-line inquiry in middle school and high school science classrooms, and to consider the supports necessary to improve student success.

The core of on-line inquiry is that students are allowed to pursue topics of interest to them within the framework of a larger unit. To bring this inquiry process to the classroom requires a supportive environment that encourages students to ask engaging questions, seek information, and construct new knowledge to answer their questions. It also requires a source of information that has enough breadth to manage the diversity of student questions, as well as the depth to allow students to look deeply into their questions. We believe that the World Wide Web and its collection of digital resources can be such an information source.

There are several characteristics of information on the World Wide Web which can support on-line inquiry. Although they are not individually unique to on-line materials, taken together they represent a major departure from the types of materials normally available in K-12 schools and classrooms: (Alloway, Bos, Hamel, Hammerman, Klann, Krajcik, et al., 1996)

1. Content is current. Using on-line resources on the World Wide Web, students can obtain the most current information regarding the questions they are exploring, such as accessing up to the minute weather or earthquake information.
2. Content can be from primary resources. In many circumstances, students can use the same data and information sources as scientists. For instance, students can have access to digital images from NASA missions almost as soon as NASA scientists.

3. Content is comprehensive. In typical libraries used by secondary school students, a small subset of popular and scholarly material on a given subject is available. On-line digital libraries within the World Wide Web can expand the range of that content enormously, giving students classroom access to an unprecedented range of information sources. Also, students can have access to multiple view points of information, which can help them to learn to be more conscientious consumers of information.
4. Resources are represented in various formats. In particular, information is available in digital form for easy manipulation and use by students. Video and sound provide new information (for example, dynamic views of the ozone holes and echoing sounds of earthquakes), and new ways of receiving information, revealing new possibilities from which students can build understanding.
5. Students can publish on-line. Students can create rich artifacts containing video, sound, graphics and text that are easily shared with a wide audience. On-line publishing can also make the task of writing more authentic, which can lead to increased student motivation (Cohen & Riel, 1989).
6. Students can collaborate on-line. Traditional classroom activities involve students sharing information within the classroom, while the World Wide Web offers collaboration between schools, universities, government agencies, and businesses. In addition, students from around the world can exchange data on topics like weather information, ground water quality, and local geography.
7. Content is readily accessible. Information is easily obtainable from a single point of access. That is, students can acquire information with a World Wide Web browser via a single computer in the home or classroom.

Description of the Units

To support teachers in implementing on-line inquiry in the classroom, our group developed a set of on-line materials for students to use. We believed that creating materials on-line, in place of extensive handouts and instructions, would result in several positive

features: the materials would be available to a large audience, the on-line units would be relativity easy to modify, and central storage of materials would insure that all users would have simultaneous updates, both graphics and text could be easily integrated using existing programming and technology, the web-based nature of these materials would offer a degree of interactivity and collaboration not available in traditional printed texts, the materials could be designed with flexibility to allow teachers to use them in different ways and settings (Hoffman, Kupperman, & Wallace, 1997).

Because we felt that there were developmental differences between high school students and middle school students, we developed separate units for the two groups. The middle school units contain more graphics, and limit the amount and complexity of the text. These units also contain quite a bit of scaffolding to help the students in their work on-line. The high school units contain more text than the middle school units, and they also contain less on-line support. All of the units for both age groups have several features in common, though.

One common feature is that they all have a section called "Places to Start" that contained links to sites with general information about the topic of the unit. The purpose of these sites was to help students focus their interests, and to give them the background information they needed to be successful in their work.

Another common feature is the page of Search Engines. Because the World Wide Web has such a large collection of information, students needed to be provided with a wide range of tools to search for information. Search engines such as Open Text, Lycos, and WebCrawler provide these tools.

A typical unit for both the high school and middle school starts with the students spending time on-line exploring sites in their area of interest. The students then form a question on that topic based on personal interest. After forming their question, the students spend several days searching on-line, collecting information from a variety of sites to help

them form an answer to their question. They then put their information together and create some sort of product or artifact to represent the answer to their question.

Description of the Study

This study was carried out in a midwestern community with a population of approximately 150,000. The city has a wide range of SES groups, and is home to a large research university. The data for this study was drawn from two different schools, Pilgrim High School and Kennedy Middle School.

Pilgrim High School

Pilgrim High School serves over 1,400 students and employs over 100 full time staff members. It is a large, sprawling, two story school. The school offers a wide range of courses from mainstream to Advanced Placement (The College Board, 1991) classes. Pilgrim also has an extensive selection of extra-curricular activities. Students can participate in several different music programs, theatrical productions, and a wide number of sports. The school has two computer labs. The lab for this study is on the second floor of the school and contains twenty PowerBook 520c computers connected to an ethernet network. This network is connected by an Integrated Services Digital Network (ISDN) line to the local university for Internet connectivity.

The teacher whose students were chosen for this study, Laura, has been teaching at the school for over four years, after leaving a job as a city planner, and holds a Master's degree in geology from a local university. She is also the Treasurer for the state's earth science teachers' association. Laura had been associated with the research group for two years by the time of this study, and had attended several professional development sessions after school hours. She had also worked quite closely with the research staff in the development and implementation of several of the units used with her students.

The classes chosen for this study were mainstream ninth grade earth science classes that contained a fair mix of students of different genders, ethnicities, and abilities. She had several students who were targeted as having special needs, and had a special education

teacher available during one hour to help teach the course. The students in the course were mostly 14 to 15 years of age, although there were a few older students in the classes. The students chosen for this study were selected by Laura as representing the "regular student" in her classes.

The students in Laura's classes had already completed three units before the data for this study was collected. The first unit, Volcanoes, was designed to help students learn how to use the World Wide Web in the context of a unit on volcanology. The second unit, Conservation, was the first full content unit, and students were encouraged to explore questions on topics ranging from recycling to alternative energy sources. The third unit was on Natural Disasters. In this unit students explored topics ranging from earthquakes to hurricanes, focusing primarily on the impact these events have on humans.

The data that was analyzed for this study was collected during a unit entitled "Weather Events" (Figure 1). The primary focus of this unit was for students to investigate various types of weather events, and to look at the effects of weather on humans. The topics ranged from flooding to tornadoes. There was a significant amount of overlap in the topics chosen for this unit and the previous unit on Natural Disasters. The students were given three non-consecutive class periods spread out over one week in the school's computer lab to work on the unit. They were expected to have a fairly clear idea coming in to the lab of what topic they wanted to study, but they were not required to actually come up with a question until the second or third day of the unit.

Two pairs of students were chosen for this study. The first group, Vicki and Gwen, were two ninth grade girls. Both were active in after school activities, being members of the school's soccer and softball teams. They also both showed good time management techniques when planning time to work after school on the project for the end of the "Weather Events" unit. Both had very busy schedules, but they were able to divide responsibilities and schedule work sessions with very few problems.

The second pair of students, Candice and Jacki, were very similar to the first. These two ninth girls were also quite active in extracurricular activities, being members of either the school's softball team or the track team. They also showed good time management skills and had a remarkably clear picture of what their responsibilities were for the coming week after school. They also spent quite a deal of time discussing how they were going to get the final project finished before the due date, and dividing up the responsibilities.

Kennedy Middle School

The other site we studied, Kennedy Middle School, is located near Pilgrim, and most of its students attend Pilgrim for high school after the 8th grade. Kennedy Middle School serves over 800 students and employs over 40 full time staff members. Mary, the teacher chosen for this study, has eight years experience teaching math and science at the middle school. Mary had been associated with the research group for two years at the time of this study, participated in after school staff development activities, and had used a number of units with her classes. During the summer months, Mary and her Language Arts partner, Julie, worked collaboratively to develop innovative assessment materials to use in conjunction with the on-line units.

The middle school classes chosen for this study were mainstream sixth grade science classes that contained students of various genders, ethnicity, and abilities. The data analyzed for this study was collected during an on-line unit ecology unit. This was the student's second unit on-line, and previously had completed a "scavenger hunt" designed to help students become familiar with navigation, searching, and sharing ideas on the Web. The ecology unit (Figure 2) was structured as a six day activity where students developed questions about groundwater ecology, utilized on-line resources to locate appropriate information, and constructed a small booklet to represent their new understandings During this investigation, students explored a variety of questions that ranged from "What is the most polluted area in our city?" to "How do water dams work to provide electricity?" In

addition, students utilized an on-line form to share their questions with others and published a small critique of a "cool site" they found on the Web.

Two pairs of students were selected for the middle school portion of the study. The first group, Frances and Nicole, two sixth grade girls, had contrasting personalities and abilities. While Frances had average skills and tended to be somewhat quiet during classroom activities, Nicole was bright, strong-willed, and often very vocal. As a result, their planning activities, sessions on-line, and conversations about the ecology unit were often dominated by the more assertive student.

The second pair, Daniel and Derrick, two sixth grade boys, also had contrasting personalities and abilities but not as diverse as Frances and Nicole. Both were characterized by their teachers as highly capable, but Daniel tended to outperform Derrick on graded classroom assignments and tests. Daniel tended to be very conscientious, social, and highly influenced by his friends, while Derrick was more self-centered but quite talkative. In addition, Derrick's teacher noted that he often had difficulty focusing, trouble remaining quiet during most activities, and constantly made distracting noises. This difference in task behavior was characterized during on-line sessions as Derrick was often unsure of the task, and distracted Daniel to sites that were unrelated to their question.

Data Collection

Most of the data for this study was gathered using a technique called Process Video (Krajcik, Simmons, & Lunetta, 1988; Stratford, 1996). To gather data using Process Video, a computer monitor signal is fed to a converter box that changes the signal from a monitor signal to a standard TV signal. This TV signal is then sent to a VCR, where it is recorded, giving the research staff an exact recording of everything the students did on the computer. In addition, the students each wear microphones, and the microphone signals are passed through a mixer/amplifier, and then sent to the VCR to be recorded on the audio track of the video tape, with the student sitting on the left of the computer recorded on the left stereo track, and the student on the right on the right stereo track. This allows the

researcher to hear the conversations of students while they work on the computer. The end result allows the researcher to feel as if he or she is actually sitting between the two students and watching what they are doing. While the students in our study did make occasional negative comments about the microphones, the candidness of their conversation indicates that this method of data collection did not greatly impact their natural behaviors.

The remainder of the data for this study comes from a combination of classroom observations, informal conversations with students and teachers, field notes, and discussions with members of the research staff. Since the beginning of this project, the digital library staff has logged hundreds of hours in the classroom working with students, and their general observations and thoughts have provided a rich account of some of the more global issues that impact how students work in an on-line environment.

Discussion and Analysis of the Data

To analyze the data collected with the process video, classroom notes, and general observations, a set of categories of student activities were developed that mirrored the features of on-line inquiry. The categories were exploring, asking questions, planning, searching for information, and assessing information. Within these categories, certain themes appeared from the data. The data for the high school and middle school were analyzed separately, and these themes from the data were then compared. These themes have also been crossmatched with data collected and analyzed by other members of the research group in their own work, and have been found to be consistent with their findings also. One over all theme is clear from the data: students need a tremendous amount of support to be successful in on-line inquiry.

Exploring

Description. The purpose of exploration in on-line inquiry is to have students gain background knowledge necessary to ask good questions and then to perform searches that will help them to find appropriate sources of information about their questions. Since students might be looking at topics that are not part of their classroom curriculum, it was

necessary to provide them with on-line opportunities to find information about their topics quickly and easily. To facilitate this, each unit has a "Places to Start" page that contains links to sites having relevant general information about the main topic for the unit. These sites have been collected by UMDL librarians based on quality of the information provided and the age appropriateness of the materials ([redacted]).

Missed Opportunities. The results from our data show that the students very often missed opportunities to explore their topic on-line, and therefore to learn enough background information to successfully complete the unit. For instance, at Pilgrim High School, students had a tendency to skip the "Places to Start" section and head directly to the search engines. This habit had a negative impact on how they conducted their searches, and on how they assessed the information that they found.

The middle school groups displayed similar behaviors as they began their research. In both cases, their teacher suggested that students spend a significant amount of time in the Places to Start pages and record what type of information they found. Frances and Nicole did visit these pages when specifically prompted by the teacher, but only briefly read the descriptions related to the sites. At no time did they proceed into the actual site to explore information that might help them develop questions. Daniel and Derrick preferred to avoid the MYDL Places to Start site altogether, apparently viewing this step as not beneficial to their question.

Impact of Limited Exploration. Not exploring for information on-line had a negative impact on the success of the students in the units overall. One striking example of this impact on searching is the case of Vicki and Gwen at Pilgrim High School. These two students spent an inordinate amount of time searching on-line using only the keyword "tornadoes" over and over again. After almost two days of using this one keyword, Vicki went to the school library and brought back a book on tornadoes. By scanning through the book, they were able to find other possible keywords such as "wind shear" and "vertical

wind shear." Unfortunately, this event occurred in the last minutes of their last day of working on-line, and they were unable to continue their searching further.

Another example of this impact from Pilgrim High School is on assessing information. Candice and Jacki showed a similar tendency to skip the "Places to Start" and to limit their use of keywords. This group did use a slightly richer set of keywords, usually "floods AND california AND 1995", but they had a very difficult time assessing the information that came back, since they really did not know what caused flooding in the first place. For instance, when they did find a page with some good information on it, they did not recognize it as such because they did not have the background knowledge necessary to do so.

Support Needed. Students must have some baseline content knowledge to be successful in on-line inquiry. There are several ways to support students in gaining an understanding of their content area. One way is to provide the students with additional materials, such as books and magazines. The first group of students at Pilgrim gave evidence that working with some basic science books can provide the content knowledge to allow students to focus their searches and begin to extract information. The second group showed how lacking the basic knowledge of the mechanisms of flooding kept them from being able to extract good information from the pages that they found. Some introductory reading on the mechanics of flooding would have given them the background necessary to extract information.

Another way to support students is to make sure that they have acquired the basic background knowledge necessary to be successful. Classroom teachers need to make sure when helping students with their inquiry that the students do indeed have some basic concepts. For example, when the students at Pilgrim approached Laura for help with on their flooding research, she could have asked them questions about flooding in general to make sure that they were not missing information due to a lack of background knowledge.

Asking Questions

Description. The purpose of exploration, as described in a previous section, is for students to gather appropriate background information to help them develop rich questions to focus their research. This step is difficult for students, as they are rarely required to ask their own questions in traditional classroom activities. We found during our first units that instead of asking open-ended questions, students too often begin by asking very restricted, close ended questions. These questions often had a single correct answer, and this answer was often numerical (such as "How many people died in Hurricane Andrew?"). The rest of their time on-line was spent looking for a page that has the answer on it. Our goal is for students to ask questions that do not have a single correct answer, but require students to synthesize information from multiple sources (such as "How could the deaths in Hurricane Andrew have been prevented?").

Question Drift. The data from all of our research sites provide an interesting insight into how students develop questions. Students often employ a method that can best be described as "question drift". That is, students will ask a somewhat general question, and then focus it by finding information on-line that had something to do with their topic. If they could not find information to match the original direction of their question, then they would change directions, or sometimes even whole topic areas.

An example of this comes from Kennedy Middle School. Daniel and Derrick developed a rough question relating to the effect that water pollution has on animals, but quickly abandoned the idea when early searches revealed little information. During the course of the five day unit, their question changed to match the available information found on-line. The new questions varied between the effect of pollution on their city, the most polluted site in their city, how automobiles affect pollution, and how automobiles affect the water. On the last day of their research, when they found an interesting site with picture of a bear covered in oil, they returned to their original question on how pollution affects animals.

Impact of Question Drift. The type of questions that students ask greatly impact their success, since questions are the very foundation of inquiry. Since the goal of on-line inquiry is for students to focus on topics and learn about them in depth through asking and answering questions, then question drift can impede this process. By simply looking for easy answers, students never develop the deep understanding of the topic that on-line inquiry is supposed to foster.

Support Needed. First, the manner in which the teacher sets up the task has a great impact on when in the unit students form a question, and how well developed their question is. Laura, for instance, did not require her students to declare their questions until late in the unit, which delayed the development of student questions. While it is good to allow students time to explore their topic, it is also important that they have a solid question in mind when they begin to research in earnest.

Students also need support in forming their questions in general. The classroom teacher not only needs to help the students understand what the characteristics of a good question are, but also needs to help the students in actually formulating their questions. This support can help eliminate question drift, as was shown by the case of Frances and Nicole at Kennedy Middle School. After some support from their teacher on the characteristics of good questions, they arrived at the question: "What is the highest temperature of ground water and why?" and kept that question all throughout their research.

A third support is founded on the nature of tasks in schools. Students know that they must complete the tasks presented to them in order to receive passing grades, and therefore have a tendency to move towards completion. In this light, the strategy of question drift is highly efficient. Teachers need to be aware of this, and need to provide the students with ample time to complete their research. A unit should be spread out over a matter of weeks, rather than simply being completed in three or four days in the computer

lab. This move would also more firmly implant the inquiry process, making it a part of the culture of the classroom.

Planning

Description. How students plan is important to their success. Good planning can increase the efficiency with which they find information, bad planning can lead them to many hours of wasted effort. As with question asking, planning is often not a task that students utilize during normal school assignments. Most planning is done by the teacher, with directions, due dates, and assessments solely in his or her control. In an on-line inquiry learning environment, the responsibility for planning lays squarely on the shoulders of the students. Since students generally work in pairs on our projects, planning is as much a cooperative task as it is a personal one.

Planning the Process. In on-line inquiry, students have to plan their searches carefully to try to find information. Because the time students can spend working on-line is limited, a well planned strategy is needed if the students are going to be successful. As the first group of students at Pilgrim High School who searched the entire time with one keyword indicates, students do not show much foresight in their plans to find information. The other group that used a larger set of keywords did show more of a plan in their searching, but it was still not entirely adequate. The students at Kennedy Middle School also show a lack of planning in their on-line work. In both groups, students seem to focus on the immediate task of searching for the one "correct answer" to their question.

Planning the Product. On-line inquiry calls for some sort of end product to be produced to represent the students' learning. What form this end product varies depending on the teacher. This additional work can put a strain on the time students have to work on school tasks. For example, the students we observed at Pilgrim High School led busy lives. Between their academic responsibilities and extra-curricular involvements, they had very little time to work in extra activities. For their end product, the students were required to work together to put together a final presentation. The time allotted during the school

day was inadequate for this task, so the students had to work outside of school to complete this task. Both groups of students spent a reasonable amount of time each day making plans for completing this task, and trying to work around their busy schedules. It was actually fairly remarkable how well these ninth grade students managed their time, and were able to arrange time to complete their school work. They also worked together well on the process of planning what the end product would look like.

The Impact of Planning. The lack planning for the process of working on-line by the students did impact their success. Because they had not planned their work better, they were limited in what information they located. This then limited the answers they were able to develop for their questions. However, most of the students we have worked with in our research are able to plan enough to produce the end product assigned by their teacher. While the content represented by these end products is sometimes lacking, the products themselves are often of impressive quality.

Support Needed. This is an issue that needs to be addressed in the classroom. Students need to have their planning activities scaffolded to help them map out how they will go about researching and answering their questions. Since most school activities do not ask students to plan their own classroom work, it is not surprising that this is something that needs to be specially supported.

Searching for Information

Description. If the question is the foundation of on-line inquiry, then searching is the cornerstone. The whole focus of inquiry is to allow students to pursue questions that interest them. It is impossible for a teacher or researcher to anticipate every question that students might ask, so it is equally as impossible to develop on-line learning materials that provide resources for every student. This implies that students need to be allowed to conduct open searches on the web using search engines like The Open Text Index and Lycos.

Limits of Boolean Searching. The first main theme from the data is that Boolean keyword searching is difficult for most students. There are many pitfalls associated with keyword searching that influence the search process. Students can choose inappropriate keywords to look for information, or they can simply misspell their keywords. For example, Candice and Jacki at Pilgrim High School spent nearly fifteen minutes searching using variations on the string "flooding AND californa AND 1995". For obvious reasons, the search engine repeatedly returned zero hits. These students spent the entire time trying to substitute terms in for "flooding" and "1995" before one of them noticed the spelling error.

Another problem is that compound Boolean logic is complex and difficult to understand in the context of searching for information. Studies have shown that even adults have difficulty with it. (Greene, Devlin, Cannata, & Gomez, 1990) In the previous example, the students turned to Laura for help. She looked at what they were searching with (and did not notice the spelling error either) and suggested that they instead search for "california AND flooding AND 1995". There is no functional difference between these search strings, since the Boolean AND is commutative.

The students did find some success with AND statements. Our experiences in both high school and middle school classrooms suggest that students can and do use AND statements fairly well at times. Unfortunately, there are often times when they do not use this function properly. The most common misuse is for students to type in a string of keywords into a search engine form assuming that the computer will return hits containing any of the words. This is actually an OR search, rather than an AND search with is more common with keywords. Another example of this is that students are often observed adding keywords to a list of search terms to try to elicit more hits.

Impact of Background Knowledge. As was discussed previously, students need background knowledge to really be able to conduct thorough searches. One major problem that was witnessed over and over again was the restricted range of keywords that the

students had to work with. A previous example has already been presented from Pilgrim High School about Vicki and Gwen spending almost two entire class periods searching in different search engines using the keyword "tornadoes". They only broke from this pattern after one student ran down to the library and found a basic book on tornadoes. Suddenly, their choice of keywords grew rich. Searches were run using the terms "jet stream" and "vertical wind shear."

Limits of Web Based Resources. Because the World Wide Web is not an organized collection of resources, finding information can be difficult. This problem is compounded by the fact that there are no guarantees that the information the students are searching for even exists, or that it will be age-appropriate even if it does. For example, the group at Pilgrim High School that was using only the keyword term "tornadoes" never found a very basic site that explained the mechanics of tornadoes. The group at Kennedy Middle School that was searching for information on the temperature of ground water had no way of knowing in advance whether or not there were actually web sites that contained this information.

Impact of Searching. On-line inquiry depends on students being able to search for and find information on their questions. Without this ability, the whole process falls apart. Thankfully, many students have been successful in finding the information they need on-line, despite the limitations that stand before them.

Support Needed. Several supports are needed to help students search for and find useful information on the World Wide Web. The first is that searching needs to take place in the context of a learning environment that can provide students with the necessary background information to conduct their searches. Without the appropriate background knowledge and vocabulary, it is very difficult for students to choose keywords that will help them successfully find information on the Web.

Students also need the opportunity to use print-based materials during their research. Students can waste an inordinate amount of time searching for basic reference

material that can often be found quickly in the school library. At Kennedy Middle School, for example, Frances and Nicole spent four days searching for information on their question. Finally, on the last day, they commented to a lab support person: "We can't find anything! I bet we could find it in a book." Within the remaining 30 minutes of the class hour, they proudly emerged from the library with two books describing the process of the hydrologic cycle.

Assessing Information

Description. One facet of the World Wide Web is that the content is comprehensive. The wide variety of information is unparalleled in most school environments. This can be a great asset, since there is information that is unavailable to students locally, but it can also be something of a liability. Unfortunately, students often have a tendency to believe practically anything that is written. In the course of normal school activities, the authority of information providers is rarely questioned, since students are generally presented only with accepted textbooks, and with library materials that are in keeping with the library's collections policy. However, in dealing with Web-based resources the question of authority is paramount. Since almost anyone with access to a computer and an Internet account can post information on the Web, it becomes difficult for students to easily assess the quality of the information that is provided.

Missing Assessment. In terms of assessing whether the information that they were presented on a web page was worthwhile or not, the data varies greatly. Sometimes students would realize immediately that the web site they had chosen contained little useful information. Other times they would either linger for quite a bit of time on "dead ends", or would not see that the page they had chosen really did have good information on it. Often times, students would return to the same pages they had visited before and not realize that they had already seen it!

The groups that we have worked with show just how difficult it is for students to separate reputable and questionable materials. Two students at Pilgrim High School, for

example, cited data for a question that was entirely gathered from a commercial web site that was advertising a line of products. They were unaware that the information that they were using applied only to a specific product and was not necessarily the norm.

Impact of Assessment. This lack of assessment can have a negative impact on student work. Without taking the time to really assess the information that they are presented with, students can either be led astray by faulty information, or can miss vital pieces of information. In either case, this can seriously impact what kind of information they use to answer their questions.

Support Needed. This really comes back to the issue that teachers need to insure that students have the appropriate background knowledge to really assess the information that they are reading for its correctness as well as its usefulness. The issue of background knowledge has been extensively discussed in previous sections.

Teachers also need to encourage students to adapt the standard research practice of citing sources of information. In the process of putting together the citation, the students will need to look closely at the author and information provider. This can help students begin to be more knowledgeable consumers of information. This is a very difficult task when dealing with the World Wide Web, since there is no set standard in how to display this kind of information. There are some tricks that can help students to make these kinds of judgments.

Experienced web users know that uniform resource locators (URLs) contain information that can help in determining the quality of materials being offered. The students in this study showed little assessment of the URLs of the web pages that they were working with. Even when information about how to tell the origin of a web site had been discussed with the students, they still showed a propensity to not take this information into account when selecting hits from their search engine returns. They would often choose a commercial site (.com in the URL) over a government (.gov) or education (.edu)

site. By supporting the students in citing information, teachers can help them become more sensitive to where the information is coming from.

Conclusions

The overall theme found in the data from this study is that students need quite a bit of support in their work on-line. The entire classroom culture needs to be structured in such a way that students are able to successfully ask good, rich questions, to learn the background information necessary to search for information about their question, and to assess the information that they select as part of their answers. Students also need support in basic skills such as the planning process and the basic mechanics of searching in an environment such as the World Wide Web.

Along with this support, the students need time to carry out these activities. The various activities of on-line inquiry can be very time consuming, and each group's question can require a different amount of time to generate a complete answer. Students who feel too pressured to complete the task in a short period of time will not be as open to really engaging in on-line inquiry.

The World Wide Web offers an exciting new medium for supporting student learning in the science classroom. However, it is not without pitfalls. Many roadblocks exist that can seriously impact student achievement in locating and assessing information on the Web. Hopefully, further research into ideas like on-line inquiry will help to generate knowledge that can help students and teachers be successful in integrating on-line resources into their classrooms.

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Figure 1. The Weather Events Unit (http://www.umich.edu/~aaps/weath_events/)

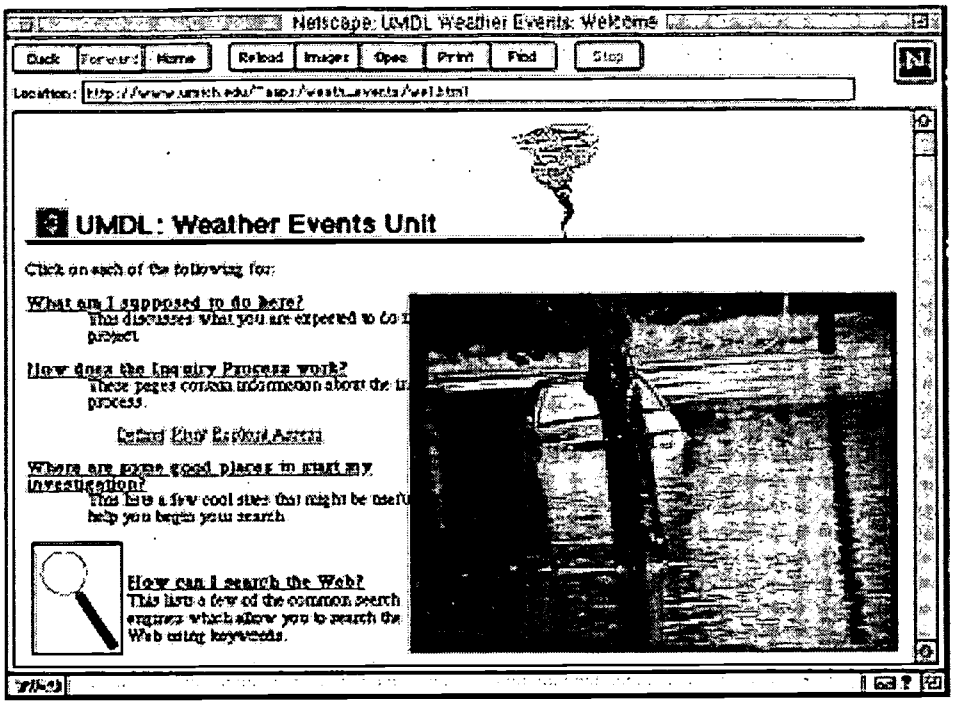
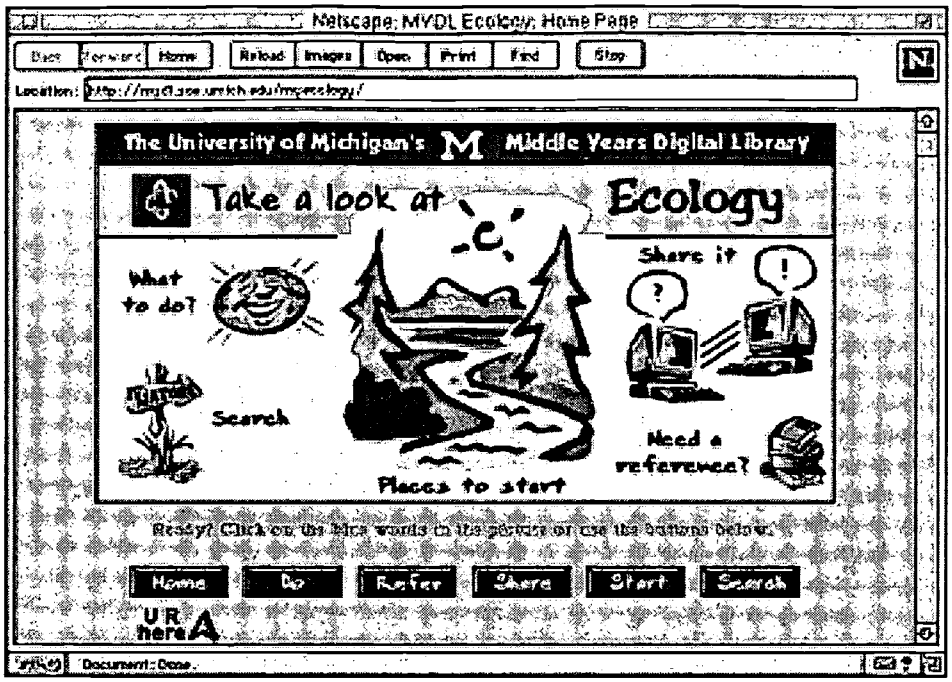


Figure 2. The Ecology Unit (http://mydl.soe.umich.edu/myecology/)



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Printed Name/Position/Title:
David J. Lyons / Research Assistant

Organization/Address:
University of Michigan
1323 SEB
Ann Arbor, MI 48109

Telephone:
(313) 647-2262

FAX:
(313) 763-1368

E-Mail Address:
djlyons@umich.edu

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