DOING science on the Internet

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ABSTRACT
The role of the Internet reaches beyond information dissemination, services, entertainment, and convenience, but is fast becoming a tool for education. The Internet has the capability to communicate an infinite amount of information with the world. Unfortunately, information is not knowledge, and knowledge is not wisdom. Learning takes place when meaning is constructed out of information based on what the learner already knows, thus transforming information into knowledge. The learning cycle is an established didactic approach that promotes learning, and nourishes cognitive development in the classroom. The pedagogical framework of the MARS (Monterey Accelerated Research System) Education website is modeled after the learning cycle. This is an inquiry-based, interactive website that gives learners the opportunity to do scientific research on the Internet utilizing actual, real-time or near-real-time data from the Monterey Bay, California. The site is divided into four sections presenting different components of scientific research: Research, Resources, Data, and Publications. Learners “do” science in the Research Section by engaging in a guided tutorial that leads them through the scientific process via open-ended, inquiry-based questions. On-line support, such as ocean concept descriptions, oceanographic equipment available and used in MARS, suggested literature, and links to other oceanographic sites, is located in the Resources Section. The Data Section holds the raw data, web cameras, and data analysis displays. And finally, learners are able to publish their original work on-line, communicate with experts at MBARI, and participate in on-line discussion groups in the Publications Section.

INTRODUCTION
The World Wide Web (a.k.a. the Internet) is just as the name proclaims, an international network of information, services, and entertainment. Its popularity and accessibility has increased tremendously in recent years, as evidenced by the all the w-w-w-dot on everything from milk cartons to clothing. The versatility and convenience of the Internet makes it an enticing medium for educational use. As Montelpare and Williams (2000)
pointed out, incorporating multimedia in traditional learning environments enhances the presentation style, and it can potentially increase the learner’s retention. The business industry research suggests that web-based learning and instruction is a cost-effective communication method (Michalski, 2000).

However, the glitz and glamour of new technology coupled with immediate access to seemingly unlimited information ought to be taken with a grain of salt (Downs et al., 1999). Televisions and VCRs were touted as revolutionary breakthroughs when they became mainstream. But researchers soon realized that popping in a video or tuning into even an educational program does not translate into information learned and knowledge gained (Shortland, 1987). Learners passively sit in front of the television screen, vainly attempting to absorb something from the program. Evidently, technology becomes a hindrance to learning if care is not taken into the presentation of information.

The Internet efficiently and effectively provides access to reams of information in multiple media formats. Nonetheless, that information is not knowledge and knowledge is not wisdom (Winn, 1997). Information is a structured representation of data, which people learn by turning it into knowledge, i.e. they “decoded” the information, and construct meaning from it in terms of what they already know. They assimilate and accommodate the new information into their existing cognitive framework (Wadsworth, 1979). Perhaps counter intuitively, posting pages and pages of information on the Web does not translate to pages and pages of information learned.

The Internet is a medium with a virtually endless capacity to hold information. Due to the ease of creating and publishing websites, a lot of information is made available with the assumption that “web surfers” will learn the material that is posted. Mioduser et al. (2000) discovered that 65% of the 436 educational websites they evaluated consisted primarily of information dissemination. Unfortunately, without proper guidance that information does not become knowledge.

As Piaget stated in 1964:
Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it … an operation is thus the essence of knowledge.

With that in mind, the goal of this MARS Education website is to capitalize on the versatility and accessibility of the internet by making actual, real-time or near-real-time scientific data from the Monterey Bay, available on the Internet in an interactive, inquiry-based, educational website. The Internet makes it possible to bring the ability to “do” science into classrooms, living rooms, and any room imaginable with a level of interaction fostering problem solving, creativity, and inventiveness not common on the Internet (Mioduser et al., 2000), that makes this challenge all the more exciting.

MARS is an acronym for the Monterey Accelerated Research System, a proposed system of seafloor observatories in Monterey Bay. A network of cables will interconnect nodes anchored to the seafloor, providing real-time data of ocean processes over an extended period of time that will be available for scientific and educational purposes. Since scientific data arising from MARS is still to be determined, the MARS Education website is organized and structured to be flexible and accommodating. This site is designed to give learners the chance to access actual scientific data and conduct research on the Internet. Until MARS data is available, raw data from other instruments can be streamed into the site. This website is only one-way to communicate all the science that will arise from MARS. Rather than focus on any particular science discipline that emerges from MARS, this website concentrates on guiding learners through the scientific process to nurture formal thinking.

PEDAGOGICAL FRAMEWORK
As proposed by biologist and psychologist Jean Piaget, an individual passes through four distinct intellectual-development phases from birth to death (sensory-motor, pre-operational, concrete operational, and formal operational) (Renner, 1978; Wadsworth, 1979). Although “…the order of succession is constant, the chronological ages of these stages vary a great deal” (p. 178, Piaget, 1964) among individuals. Since early learning needs to be established before later learning can occur (Renner, 1978), expecting students
to be able to perform formal operations before they have developed their formal thinking abilities will prove unfruitful.

Piaget has broadly grouped age ranges for each stage of cognitive development (Wadsworth, 1979). Children exhibit concrete operational thinking beginning at age seven, and advance to the formal stage of intellectual development at 11-12 years of age that becomes fully developed at ages 15-16 (Lawson & Renner, 1975; Cantu & Herron, 1978). Renner (p. 64-65, 1978) defines them as follows:

**Concrete-operational thinkers** are concerned with the actual data they extract from objects, the organization of those data, and the mental experiments they can do with them … [but] does not formulate hypotheses outside their realm of direct experience; they accommodate their thinking to events in the real world … Concrete thinkers can perform mental operations with the information they receive from concrete objects.

**Formal-operational thinkers** are individuals who think beyond the present and forms theories about everything … they are no longer restricted to thinking only about concrete objects, events, and/or situations … The formal thinker not only performs mental operations with reality but also can perform operations on the operations used in mental experimentation.

This suggests that students should be formal thinkers, or at least be transition-to-formal thinkers by the time they enter high school. However, many students are still concrete operational thinkers throughout high school, and into college (McKinnon & Renner, 1971; Lawson & Renner, 1975). Chiapetta’s review of the literature revealed that the majority of adolescents, and young adults function at the concrete operational rather than formal operational level in regards to their understanding of science concepts (1976). In fact, a large proportion of the American adult population never advances much beyond concrete operational thinking (Elkind, 1962; Kohlberg & Mayer, 1972; Kuhn *et al*, 1977).

In 1967, Physicist Robert Karplus and science educator Herbert Thier defined a didactic approach, the learning cycle, which has been found to provide students with a significantly better understanding of concepts compared to traditional, formal approaches (Stephans *et al*, 1987, Marek *et al*, 1994, and Barman et al 1996). Traditional, formal instruction focuses primarily on verbal and printed words, rote memorization, and is
instructor driven (Schneider & Renner, 1980). The students are told what they are expected to know, and concepts are presented in as methodical and all-inclusive manner as possible. Textbooks, lectures, filmstrips and videos, and demonstrations are the typical forms instruction. The three phases of the learning cycle (Exploration, Invention, and Expansion) place the primary role of learning in the hands of the students, while the educator serves as a facilitator to aid the learner construct their own understanding. They are in accordance with Piaget’s theories on learning (Karplus & Their, 1967; Purser & Renner, 1983; Abraham & Renner, 1986; Renner et al, 1988).

Learning begins with the assimilation of data into the learner’s mental framework (or schema) via exploration. Assimilation is the “process of fitting reality into one’s current cognitive organization” (p. 67, Miller, 1993). Thus, students begin to learn concepts as they assimilate the results of their observations, manipulations, and data collection. It is important that the educator provide minimal instruction during the Exploration Phase of the learning cycle. As the students continue to explore and assimilate, they will encounter new information that does not fit into their current mental framework, resulting in a state of disequilibrium (a.k.a. cognitive conflict). To make sense of the new information, the students will adjust their mental framework (or schema) to accommodate the new experiences because these experiences do not fit into any preexisting schema. Therefore, “new knowledge is assimilated to old, and old knowledge changes to accommodate new” (p. 2; Winn, 1997). The educator facilitates this sense-making process in the Invention phase with discussions and term introduction. This is followed by application of newly invented concepts (i.e. the Expansion phase) to new situations, text, or activities that enables the students to organize their recently acquired thoughts with their already existing thoughts. Ultimately, this learning approach is indistinguishable from the scientific method.

Concrete operational and transition-to-formal reasoning students taught with the learning cycle tend to have higher achievement for concrete concepts than those taught via traditional lecture styles (Schneider & Renner, 1980; Ward & Herron, 1980; Purser & Renner, 1983). This form of teaching also promotes intellectual development (Purser & Renner, 1983) among concrete thinkers (Schneider & Renner, 1980), as well as improves
their comprehension of formal concepts (Cantu & Herron, 1978; Ward & Herron, 1980). Furthermore, the learning cycle is an effective strategy for enhancement of reasoning ability (Boylan, 1988) and logical thinking capabilities (Linn & Thier, 1975).

The pedagogical framework of the MARS Education website is modeled after the learning cycle. One may question whether it is feasible for learning to take place over the Internet. The learner does not get to actively manipulate or explore, and there is no teacher, instructor, or educator physically present to guide the learners through cognitive reorganization. However, Musheno and Lawson (1999) compared the use of text written in the traditional style with text written in the learning cycle format, and found that science text presented in the learning cycle format is more comprehensible for readers at all reasoning levels. Analytical studies have not been conducted for educational websites.

After evaluation of the pedagogical and information dissemination features in 436 educational websites, Mioduser et al (2000) concluded that use of the Internet for educational purposes is in a period of transition. Educators are beginning to incorporate the technology available with existing didactic frameworks, in a transition from simply posting text and electronic worksheets to more interactive, collaborative, and constructive learning environments. Modeling the MARS Education website after a pedagogical approach that has been shown to nurture formal thought processes and promote concrete understanding of scientific concepts is appropriate.

It is necessary to modify the learning cycle approach to adjust it to the MARS Education website on the Internet where the “student” can be any person interested in the subject, the “teacher” is the website itself, and the “classroom” can be anywhere there is access to the Internet. Adding to the problem, potentially the learners can be any individuals interested in conducting scientific research on the Internet, although the targeted audience is high school and college level thinkers. Learners are not only being taught a scientific concept, they are also encouraged to investigate the process and test out their hypotheses with actual data. While the learners do not get to actively engage in “exploratory experiments,” the open-ended format and resources available gives them the opportunity to explore the concepts virtually in order to review and deepen preexisting
comprehension as well as encounter unfamiliar problems, invent and organize their own understanding along with the introduction of terminology, and then expand upon the knowledge gained by testing the consequences of using the new concept.

**MATERIALS AND METHODS**

Microsoft Front Page is used to produce all MBARI websites, including this MARS Education site, and the format and style are consistent with the External web style guidelines set up and posted on the *Canyon Head*, MBARI’s internal website ([http://mww.mbari.org/style/styleguide/](http://mww.mbari.org/style/styleguide/)), by webmaster Nancy Barr. Each web page is composed of the MBARI standard header, footer, and table of content navigation bar surrounding the page contents. As MBARI continues this project, more details can be incorporated to make the website more user-friendly and aesthetically pleasing to the audience. In the present version, the plain text is what the learner should read. Further editing will be required to make the text more readable. This website is left at this very primitive stage for several reasons:

1. MARS is still in development, and the science topics and content have yet to be determined;

2. This website needs to fit within MBARI’s existing external web format, thus complete creativity is restricted;
3. Due to the limited time available for the project, and the author’s lack of experience with Front Page and Javascript, the creative output on this first version is narrow.

Text in brackets indicates special features to be provided to the learner as they browse through the site, as well as instructions to the web designer. These include pop up messages, rollovers, check and entry boxes, special text messages, and so on. The pop-up windows from North Carolina State University’s on-line tutorial LabWrite (http://www.ncsu.edu/labwrite/res/gh/gh-graphtype.html) provide a good example of communicating definitions and special messages. A smaller browser window pops up to reveal a special message or definition without the main window having been lost.

Science education websites produced and maintained by other institutions were consulted during the initial stages of development. An informal assessment of their format, features, pedagogy, and content was made to develop ideas as well as generate attributes that would be unique to the MARS Education website.

Since the main purpose of this website is to provide the learner with the opportunity to do real science over the Internet, actual real-time or near-real-time data should be accessible on-line along with the capability to run simple analyses, plot graphs, and create charts and tables. Literature and observation opportunities should also be available to prompt the learner’s natural curiosity. Thus the MARS Education website is divided into four sections presenting different components of scientific research: Research, Resources, Data, and Publications.

Five MBARI scientists were interviewed regarding their approach to scientific research. Four of the five interviews were tape recorded and transcribed, and personal experiences and research philosophies from all five scientists were incorporated into the website. This contributed to the non-linear, three-dimensional on-line experience. The following segment of this paper discusses the objective of all four sections, and details of its corresponding subsections.
DESCRIPTION OF THE WEBSITE  (Results & Discussion)

Home Page

The MARS Education website opens with a description of the function, purpose, and goals of the site. Since this is the learner’s first impression of the site, the opening page must be visually attractive and easy to understand, as well as fast loading. Hyper linked to this page will be an optional, 5-7 minute visual tour of the website, highlighting the special features of each section, instructions regarding how to use the site efficiently and effectively, and explanations of the rationale behind the site’s organizational structure. This tour will be a useful tool for both educators and learners because it describes the features, functions, and educational opportunities offered on the website.

Since observations play an important role in science inquiry, graphs, diagrams, and web cameras highlighting certain oceanographic data also displayed on the home page give the learners their first opportunity to explore the oceans over the Internet. A hyperlink to the web cams and graphs in the Data Section enables the learners to continue their observations.

Each section of this website presents an element of the scientific process. Depending on the learners’ interests and objective, each section can be used independently or in collaboration with one another. In this way, the locus of control is with the learners. The learners are in command of what they learn, and the pace at which they learn, thus potentially improving the learning process (Piccoli et al, 2000). They are free to “move through a corpus in an idiosyncratic manner” (p. 1, Jones & Berger, 1995). Giving learners the opportunity to inspect a given body of knowledge from many different perspectives can lead to a more robust understanding of the relationships among the concepts (Jones & Berger, 1995). However, availability of guided tutorial via the Research Section provides a road map to guide the learner through essential skills, thus keeping the learner focused and on task (Downs et al, 1999). These characteristics make the website a versatile learning and teaching medium.
Research Section
The opportunity to “do” science resides in the research section. Unfortunately, there are no tangible objects with which to act or experiment. The format of the website along with the resources and special features discussed below will serve as tools to aid concrete and transition-to-formal thinkers progress through the site. Thus the learners are given the opportunity to actively be involved with what they are to learn. The learner has the option to be guided through the scientific process via open-ended questions, or to access the raw data directly, and conduct analyses on-line. In both cases, password log in is required to gain access to any MARS data. This enables MBARI to track anyone utilizing MARS data, and enables the learners to store work on an MBARI maintained database. Learners create an account, and each submitted project will be stored up to six months from initial submission. A regular school semester lasts four months, thus six months gives the learner an extra two months to complete a project. The option to request for extensions will be available in 6-month intervals.

The Internet is a mentally one-dimensional medium, i.e. the user views only one page of a website at any one time. In an attempt to make the experience more “three-dimensional” and non-linear, separate indices are created for certain sections so that more than one browser window can remain open. This enables the learners to compare different components of their project. This is an important feature for visual learners, and those transitioning from concrete to formal thought. Since there is no tangible object around which they can formulate an understanding, availability of the images can serve as a substitute.

The learners will begin with open-ended questions that guide them through the subsection. The purpose and rationale of the subsection will be explained at the end with the opportunity for the learners to review and edit their entries before submitting their work and moving on to the next subsection. This is an attempt to not “spoon feed” the learners through the scientific process. Traditional teaching methods tell the learner what they will learn, give them a chance to verify the lesson through manipulations, experiments, or other hands on media, and then reiterate what they were supposed to have learned. This “tell, show, tell” format works well in speeches but takes the element of
constructing their own knowledge away from the learners. Incorporating the learning cycle into the website initially seems a little backwards, but this more scientific approach to learning (Karplus & Their, 1967) intends to give the learners a chance to construct their own understanding of doing science.

At the end of each subsection, the learner has the opportunity to review and edit their responses prior to submitting their entries, as well as review all of their entries thus far in their Manuscript Draft. Introduction of the manuscript, and its function is established at this stage to prepare the learners for the final stage of the scientific process, and the preparation of a research report. Publication submission is optional, and is dependent upon the quality of the work, and the originality of the discoveries. Reviewing the manuscript draft give the learners the chance to take a step back, assess their work in progress, and perceive how each piece of their research fits together like a puzzle. The Proposal Maker (http://powayusd.sdcoe.k12.ca.us/mtr/ProposalMaker.cfm) from the Planet Earth website developed by Poway Unified School District and the Museum of Television and Radio has a good example of how this entry form could work. Although their format is much simpler than what is proposed here, the idea is the same. Questions are posed to learners regarding a topic, and entry boxes are available for them to submit their responses on-line. After a click of the “Submit” button, their statements are compiled into a readable document using the words entered by the learners.

The categories available for inquiry and further studies are organized by science topics instead of scientific disciplines. For example, understanding cold seep communities can involve geology as we ask how they are formed, chemistry when we inquire about their maintenance and structure, and biology and microbiology as we wonder about cold seep inhabitants. Organizing the categories into linked topics attempts to present science as a multi-disciplinary field.

Observations & Background. This subsection prompts the learner to better understand their chosen topic. This is to be one of the Exploration phases. The intention here is to give the learners the opportunity to fit new information into their existing schema as well as challenge them. The literature referenced here is hyper-linked to the literature available in the Ocean Science Concepts subsection in the Resources section. This
eliminates the workload redundancy while bringing forth and making more accessible a resource within the website that learners might not be aware of otherwise.

**Question.** The learner is required to consider what they have done in the previous section, and focus their research.

**Hypothesis.** From what they know and have read, the learner gets the opportunity to propose answers to the question they pose, or explanations of the problem they put forth.

The previous two subsections, Question and Hypothesis, require the learners to draw meaning from the information they gained, and apply it. In a sense, this is the beginning of the transition of information into knowledge, and requires formal thought. The open-ended questions will lead the learner into formulating these thoughts.

**Framework.** It is important for the learner to be aware of how their research contributes to the scientific community. This adds an element of purpose and importance to their work, and thus the learners’ performance may improve. Whether the discoveries will be a scientific breakthrough or simply contribute to the better understanding of a certain field, the learner should contemplate how their work fits into the work of their peers in the scientific community. This point is revisited in the Discussion and Interpretation subsection as the learner is asked to relate their results to the greater understanding of the topic at hand.

**Methods.** This subsection and the following two sections embedded within Methods are the heart of the Research section, are abstract, and can become confusing. The inexperienced learner needs to understand their question and hypotheses well enough to produce an experimental design, perform experiments, analyze preliminary data, and return to the experiment for modifications if necessary.

This exercise is abstract because the learner needs to mentally visualize the steps of their experimental design, execute them on-line, and analyze the meaning of their results. They need to envision the experiments, possible outcomes, and how the outcomes might relate to the hypotheses so that they are able to prepare potential analyses, graphs, and interpretations. Since the entire process is experienced virtually
using a computer screen, providing separate browser windows for Methods, Experiment, and Analysis attempts to decrease the confusion, and aid the learner visualize the experiments and their outcomes. A change in either window prompts an automatic update in subsequent windows so the learner is able to immediately see the effects of their modifications.

**Experiment.** Data acquisition is the hands-on experience that is omitted in on-line science. In that regard, Renner *et al* (1985) drew an interesting conclusion regarding data acquisition during the exploration and expansion phases of the learning cycle. They found that students perform equally well whether they collect the data themselves, or whether it is given to them. Students think they are learning more when they actively collect the data, are more interested in learning science, and have a much higher rate of retention. Although learners do not get to actively collect the MARS data, they are controlling their data acquisition through selection of data to be collected by the computer, and interacting with the experiment “virtually.”

**Analysis.** Learners can toggle between Methods, Experiment, and Analysis as they work through their experiment. When they click “OK” to run an experiment or plot a graph from the Experiment, the output is displayed in the Analysis. Each output type has a corresponding example that illustrates how that type of output or result can be interpreted. The learners use the example to help guide their own interpretation, and to decide whether that interpretation relates to the question and supports their hypotheses. This is part of the cognitive invention. The examples serve to emulate educator guiding the learners through the construction and organization of their conceptual understanding. The most common misconception regarding the exploration, inquiry-based learning, and other constructivist didactic approaches is the assumption that allowing the learners to explore and structure their own understanding equates to giving no guidance from the educator. The educator must allow the learners to assimilate and accommodate the information. However, once the learners are in a state of disequilibrium the educators must guide (not tell) the learners through the organization and restructuring of their understanding.
In order to allow the learner to truly experience scientific research, there will be flexibility to propose another question and set of hypotheses if the data tell a different or more “interesting story.” The lesson is to demonstrate that there is no need to force the data to support or refute something inappropriately. Sometimes the wrong question was asked or the wrong experimental design was executed, but that does not mean that the data are incorrect.

In case the learner can make absolutely no sense of the data, this site is flexible enough to provide the opportunity to change the requested analyses. Immediate updating will give the learner instant feedback in regards to the requested modifications. Plotting a graph a different way, comparing different variables, or collecting different data types may support or refute of the hypotheses. To encourage the learner to solve problems they do not understand, and work through interpretations, they will not be able to change their experimental design. However, they will be able to request more data.

**Results.** This section organizes and compiles the analyses made by the learners so that they can pick out which interpretations will be used to support or refute their hypotheses. This is where the learner pulls together evidence for the discussion and explanations to follow. In these next two subsections, the learners are prompted to apply the knowledge gained and place it in context of their hypotheses and the topic at large.

**Discussion & interpretations.** Tying together the question, hypotheses, and results in this section give learners the opportunity to provide an explanation to the understanding of the problem they proposed, as well as the chance to organize their own understanding of the discoveries they have just made. The Framework section is also revisited to generate thoughts on how their work contributes to the scientific community.

**Manuscript.** This section arranges all of the learners’ entries into one document so that they can review how all their work fits together. The manuscript is updated each time an entry is submitted, thus learners are able to review the manuscript at any point during their research to be aware of how each component of their work relates to one another.
This compilation can serve as a rough first draft of the research paper whether learners plan to turn it in for a school assignment or submit it for on-line publication on this site.

A printer friendly version can be generated via the website to reduce the amount of wasted paper if learners choose to print a draft of their work. They can also email the draft to a colleague for review, or to themselves in order to maintain an electronic version of the work they have created. Directions to “select, copy, and paste” the text is another way to help maintain an electronic version of manuscript. Graphs, tables, and charts can be saved and emailed in PDF format.

Resources Section
Aside from experiences, and a working knowledge of their field, scientists use many tools to aid their research, inspire their curiosity, and further their expertise in their field of interest. Thus some of these tools should be highlighted, and made available to the learners as the DO science on this website.

**Ocean concepts.** These are one-page descriptions of various ocean science concepts that are related to MARS data. Before diving into details about any topic, these one-page descriptions of the concept provide the learners with an overview of how the scientific community understands that phenomenon. This gives them a chance to explore, and compare new and existing knowledge. The intention is to send them into a state of disequilibrium, but having enough resources available that the learners will also be inspired to inquire further. From there, hyperlinks to more in depth literature, either online or in print, gives the learner a starting point to establish background knowledge of the topic of interest.

**Other oceanographic sites.** Hotlinks to oceanographic sites, either technical or educational, gives learners additional resources to doing science. A one-line description of each site offers a glimpse of what to expect at each site.

**On-site equipment.** This is a graphical schematic of all the equipment related to MARS and MOOS (Monterey Ocean Observation System; for more information, go to [http://www.mbari.org/bog/Projects/MOOS/Default.htm](http://www.mbari.org/bog/Projects/MOOS/Default.htm)). Learners will be able to “see”
where pieces of equipment are placed in the ocean, and their spatial relationship with one another. Also, rollovers and hyperlinks lead to more exhaustive descriptions regarding the function and data output of each piece of equipment. This serves as a valuable tool during the Methods and Experiment subsections in the Research Section. As the learners choose equipment and decide upon data to be collected, they are able to review all the devices available to them, and gain an understanding of their use, function, and spatial distribution. For the concrete and transition-to-formal thinkers, this will be invaluable.

**Equipment request.** This feature provides the learners with the opportunity to manipulate and collect their own data, an element that is excluded in the Research section but can be used in conjunction with the learners’ on-line research. Learners, individually or as a group, submit a proposal to use a piece of equipment located on the seafloor node. They need to put forth an on-line equipment request explaining in detail the research project, equipment needed, manipulations proposed, and justification. Just as scientists share limited resources, and need to provide justification in the equipment request, learners will be given the opportunity to participate in this ritual as well.

Philip Sadler and his team of science educators at the Science Education Department of the Harvard-Smithsonian Center for Astrophysics has been designing and managing such a program over the Internet since 1995 via their MicroObservatory on-line telescopes program [http://mo-www.harvard.edu/MicroObservatory/](http://mo-www.harvard.edu/MicroObservatory/), Sadler et al, 2001). Five MicroObservatories make up the network of computer-driven, automated imaging telescopes designed to allow students unprecedented access to the night sky. The service is currently only available to school teachers and students, and requires a proposal to be submitted by the teacher or students. In the end, both students and teachers are given access to five automated telescopes located at the Smithsonian Observatory Visitor’s Center at Mount Hopkins, AZ (two instruments at this location), the Harvard College Observatory in Cambridge, MA, the Smithsonian’s Submillimeter Array site at Mauna Kea, HI, and the Mount Stromlo Observatory at Canberra, New South Wales in Australia.

Activities initiated from these images included simple observation, quantitative studies, student projects, and integration into the curriculum. Control over the telescopes,
and ownership of the images motivate learners to carry out extensive projects. This came as a pleasant surprise to Sadler et al who hypothesized that students might feel distanced from the remotely based instruments on the Internet since they could not directly see the telescope while it moved, thus dissociating the tactile and kinesthetic connection that binds scientists to their instruments. This conclusion challenges the concern regarding learners’ comprehension and abilities discussed above in the Research Section. Involvement in data collection and access to real-time data from the seafloor is an attribute of the MARS Education website that could entice learners as it has at the MicroObservatory site.

An on-line calendar informs the learner of what equipment is available and when so that they can prepare their proposals accordingly. A set of guidelines gives learners an idea of the criteria and specifications of their requests. A panel of researchers at MBARI will review the proposals, and accept or deny requests. A password entry will be sent to the learner with their allotted date and time. The MicroObservatory provides an excellent example of this on-line format and mechanism on their website (http://mo-www.harvard.edu/MicroObservatory/).

**Suggested literature.** An assemblage of the print and on-line literature referenced on this website for further reading and information. This is organized by topics, preferably the same topics as those highlighted in the Ocean Concepts subsection.

**Data Section**

Real-time data of temperature, salinity, oxygen concentration, etc. streaming in at a rate of 1 every nanosecond is more than a budding new scientist needs. In some cases, it may even be more than an experienced scientist needs. The immense quantity of information available may in turn intimidate or overwhelm the learners, and thus lead to dislike or a lack of learning. The data available must be simplified and reduced to daily, weekly, or monthly collections, or some suitable time frame for the proposed question.

Rather than posting tables of raw numbers, the data is organized and presented in a more visual and user-friendly chart and graph format. The opening page greets the
learner with a diagram of the seafloor nodes and cables. This image gives the learner a visual layout of MARS. Rutgers University’s LEO-15 website provides a simple example of this (http://www.imcs.rutgers.edu/mrs/info/leomap.html). However, the model proposed here is slightly more complicated, since there are multiple seafloor nodes. Clicking on a particular node leads to a new browser window displaying charts, graphs, and tables created using data from that node.

While the learner is encouraged to draw their own conclusions regarding the conditions in the ocean based on the posted charts and graphs, general interpretations and examples for each displayed chart, graph, or table give the learner an idea of how to decipher the data. The general examples are important in helping the learners organize their understanding of the information. Although the intention of this website is to encourage the learners to construct their own knowledge and understanding, it is important to provide proper guidance during the “invention” of such understanding. As mentioned earlier, it is a common misconception that students do not need guidance as they construct their understanding. In reality the lack of assistance is usually the source of frustration on the part of the learners.

**Raw data.** Raw numbers for the displayed charts, graphs, and tables are available for copy and paste, or Microsoft Excel download. Thus more experienced learners are able to access the MARS data, and conduct more sophisticated analyses and research off-line.

**Unguided research.** This subsection leads the learners back to the home page of the Data Section. A brief explanation of the resources available will introduce the learners to what is available and how to use them.

**Web cam.** Images from all the nodes will be made available in one window. In this way, learners can make comparisons as they observe the activities at each node.

Publications Section

Social interaction is a critical variable in cognitive development (Wadsworth 1979 and Winn 1997), and in scientific research. Dialogue with other people, be they peers and colleagues or experts and mentors, influence the meaning and knowledge gained from information. Science involves answering questions, making new discoveries, and gaining
a better understanding of the world in which we live. To ensure that this takes place, a good scientist must be familiar with the work that has been done and is being done in their field of interest, and must work with others in the process. Ideas for incredible research, solutions to confusing data, or clarification to challenging concepts can be remedied via discussions, reading publications, and other forms of interaction with peers and experts. Consequently, this section hopes to cultivate the skill of communication and collaboration.

**Request expertise.** MBARI researchers are breaking new ground in ocean science and technology research. Thus they are an incredible resource to those interested in doing science, and contributing to a better understanding of the world’s ocean. Communication with experts in the field is incredibly important because they provide wisdom, ideas, and insight. They can serve as guides through the learning cycle.

This is not a chat room that can be difficult to manage and maintain. Instead, messages will be posted with their respective responses. The messages are organized within topics, rather than posted chronologically or alphabetically. In this way, learners can familiarize themselves with discussions related to their topic of interest in a more organized fashion. The Department of Geology and Geophysics in the School of Ocean, Earth Science, and Technology at the University of Hawai’i has an excellent “Ask-an-Earth-Scientist” (http://imina.soest.hawaii.edu/GG/ASK/) format on-line. The “Ask-an-Earth-Scientist” site greets the visitors with a search engine that allows them to search past questions and replies, making it easy for the visitor to determine whether their question has been answered already. Questions and replies are arranged in general topics, and subdivided into specific categories to reduce unnecessary question submission, and to improve the efficiency of the service that is provided. Cross-referencing within the categories and sub-categories also lessens redundancy. Another exceptional feature is providing hotlinks to other related websites at the bottom of each category. This readily available link to external resources makes the almost endless lists of hotlinks more accessible and useful to the visitors when they need it.

**Peer discussions.** To promote dialogue among peers, a vital element in science, learners can post questions and participate in discussions with one another regarding science
issues and current discoveries. In the spirit of the extended debates between scientists in *Science*, learners are encouraged to post comments and challenge one another’s viewpoints as well as raise questions regarding the latest scientific endeavors.

Once again, this is not a chat room, and only messages will be posted with their respective responses. Just as in the Request Expertise subsection, discussions will be divided into general categories. This organizational structure enables the learner to participate in discussions with their peers in a more efficient and sensible manner. The asynchronous nature of this “bulletin board” discussion design can be a positive attribute for those learners who avoid risk-taking behaviors in the traditional deliberations by allowing learners to prepare prior to participation in an on-line discussion or activity (Downs *et al.*, 1999).

**Submit for publication.** As an incentive to use the MARS data, conduct quality scientific research, and be given proper recognition for their hard work, learners can publish their work on-line at the MARS Education site. This also gives them a complete understanding of the scientific process. The importance of publications is emphasized, as well as its function as a way to communicate with and gain recognition from the scientific community.

Just as any scientist publishing in a peer-reviewed journal, learners will follow a set of publication guidelines and submit their original work to MBARI. Researchers at MBARI review the submission, and publish work that they believe contributes to a better understanding of ocean science. Manuscripts may be submitted electronically at any time, but publications will be posted quarterly or at some regular interval.

**CONCLUSIONS & RECOMMENDATIONS**

Due to the nature of the Internet and the technology available today, certain types of learners are excluded in the first stage of this website. This first version of MARS Education website concentrates primarily on linguistic, logical, and visual learners. However, this initial website is intended to be a starting point for MARS Education. The versatility of the World Wide Web allows activities for more kinesthetic and auditory
learners to be added and incorporated as MARS develops and available technology improves. The structure and format of the site is flexible so that it remains useful regardless of the type of data that streams into its database. The purpose is to guide learners through the scientific process, nurture their natural curiosity, provide oceanographic resources, and make real scientific data available to those interested in doing science whether they live in Monterey, California or Vladivostok, Russia.

Several steps must be taken to ensure success in MARS Education. The most obvious “next step” is the completion of the on-line text components of the website described in detail, specifically the guided research feature in the Research Section, and some of the resources related to it. Since the goal of the website is to provide learners with actual scientific data, and to guide them through the scientific process, the website can begin piloting even before MARS data is collected. Collaboration between the software engineering team and web designers will be necessary to set up the format for the data streams.

Testing out the flow, comprehension, and content of the website with high school and college level learners will be necessary. Their comments and feedback will be invaluable to improve the website’s usability. It is crucial to evaluate the learning that arises from this website to ensure that content is communicated formal thought processes are nurtured. Thus the assessment should be more sophisticated than the typical pre- and post-test measurements. A qualitative research component can prove to be beneficial for determining impacts of the website on the learners’ interest in scientific research undetectable by quantitative measures.

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REFERENCES


