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ABSTRACT

This document contains the following papers on science instruction and technology: "A 3-D Journey in Space: A New Visual Cognitive Adventure" (Yoav Yair, Rachel Mintz, and Shai Litvak); "Using Collaborative Inquiry and Interactive Technologies in an Environmental Science Project for Middle School Teachers: A Description and Analysis" (Patricia Comeaux); "From Instructive to Constructive: A Practical Guide to Implementing Mindtools in the Classroom" (Maggie Irving and Edwin J. George); "Teaching across Collaborative Highways (TEACH)" (Starlin Weaver, Beth Shiner Klein, and Juanita Jo Matkins); "SciLinks: Linking Technology and Scientific Inquiry" (Gregory A. Coverdale); "Teaching Earth and Space Science: A Distance Learning Course for Dade County Florida Teachers" (Paul Ruscher, and others); "Exploring with Computers in Chem Class" (Ron Poirier); "Field-Based Technology in Idaho Middle School Science Classes: An Evaluation of Performance and Attitude Data from Students" (Martin G. Horejsi and Albert W. Strickland); "Technology in the Service of Information Literacy and Writing across the Curriculum: Our Experience" (Reuben A. Rubio, Michael J. Michell, Cheryl Blackwell, John P. Kondelik, and Beth Albery); "Physical Science in the Early Grades: Technology in Action" (Judith A. Duffield, Catherine Skokan, Amy Nicholl, and David Saksek); "Comprehensive Professional Development Reform Efforts: Changing Attitudes and Practices about Pedagogy and Technology for Science Teachers with Diverse Needs" (Stephen Best, Barry Fishman, Ronald Marx, and Jake Foster); "Technology and Field-Based Learning: Efforts To Bring About Change in Schools" (David A. Heflich, Juli K. Dixon, and Aimee L. Govett); "Site-Based Inservice That Works: Using the Internet To Integrate Science and Mathematics Instruction" (Keith A. Wetzel, JoAnn V. Cleland, Ray R. Buss, Peter Rillero, Ron Zambo, and Alice Christie); "A

Net-Course for Physics Teachers Supporting Collaborative Learning and Inquiry" (Rosa Maria Sperandeo-Mineo); "The Web in High School Science Teaching: What Does a Teacher Need To Know" (Raven McCrory Wallace); "A Science Equipment Clearinghouse: Linking Industry to Science Education Reform Efforts" (Adele Kupfer); "The GLOBE Program" (Dave Williams); "High-Performance Computing Technologies, and Pre-Service Teacher Preparation: Is There an Overlap? (Post-Evaluation Thoughts)" (Kris Stewart and Ilya Zaslavsky); and "Visual Imagery for Chemical Conceptualization: Picturing Knowledge with Multimedia" (Malini Ranganath). (Contains 158 references.) (MES)

S C I E N C E

Section Editor:

Linda E. Roach, *Northwestern State University of Louisiana*

The 2000 SITE Annual Meeting Science section offers 20 presentations that encompass a wide range of topics related to use of instructional technology in a variety of classroom settings. Authors provide information about both preservice and professional development projects, literature reviews, and research studies for participants' utilization. Inquiry in teaching science is a common theme across the articles.

Yair, Mintz, and Litvak describe a CD Rom that allows middle school children to manipulate variables in a the Solar System and immediately realize the resulting motion on screen. The mouse becomes a spaceship to navigate a virtual world, thereby utilizing the powerful tool of visualization to teach science.

Comeaux describes, analyzes, and reports extensive results related to a project that uses field-based inquiry experiences in a middle school science class. Using a video conferencing and Internet-based collaborative effort, learners and scholars accomplish increased understanding of environmental concepts.

Irving and George provide a detailed report on a middle school inquiry project. Students use probes and portable computers to collect data in the field, then utilize computers to analyze the data collected.

Distance learning techniques with collaboration across university campuses is the topic of the paper by *Weaver, Klein, and Matkins*. Elementary education methods students are team-taught the methods course across three institutions. Positive outcomes are described, as well as possible problems that might be encountered.

Coverdale also reports on integrating technologies in teacher preparation courses. He adopted a science textbook that includes links to the Internet to teach K-16 preservice teachers. Students triangulate data among observations, web information, and the textbook to glean a deeper understanding of science concepts.

A Masters' program at Florida State University is presented by *Ruscher, Gallard, Cherrier, Hancock, Petrovich, Bisha, Lusher, and Ruscher-Rogers.* Collaboration among the Departments of Meterology, Curriculum & Instruction, Environmental Sciences, and Physics provide an inquiry-based project for both inservice and preservice teachers. Field experiences are provided and the GLOBE program is utilized for further collaboration among scientists. A detailed description of the model is provided.

Poirier describes how he uses instructional technology in his chemistry classes in a variety of ways. He discusses the pros and cons of instructional technology and provides hints about communication among teachers, administrators, and parents.

A project that investigates student gains while using technology, independent of teacher influence is the topic investigated by *Horejsi and Strickland.* They studied how instructional technology affects both the performance and attitudes of middle school earth science students who used probes and laptop computers to collect and analyze data by inquiry methods.

Described by *Rubio, Michell, Blackwell, Kondelik, and Albery*, is a technology class that teacher research using the web and library to create research papers with science content. Much emphasis is placed on the writing process and creation and manipulation of web-based home pages. Linear and non-linear text is discussed.

Duffield, Skokan, Nichol, and Saksek illustrate a professional development project in which teachers use probes to gather data in an inquiry-based learning setting. Data is both collected and processed using technology, then supported by Internet and distance communication with other schools.

Best, Fishman, Marx, and Foster provide information about a professional development program to integrate content based inquiry methodology with technology for a diverse population of middle school teachers. Positive results are attributed to collaboration and continuous support of teachers.

Another professional development project is discussed by *Helflich, Dixon, and Govett.* Inservice teachers are paired with preservice methods students in an elementary setting. This program promotes inquiry learning through the use of laptops and probes to collect data, which is then used in the classroom to create presentations of the experiences.

Site-based inservice is described by *Wetzel, Cleland, Buss, Rillero, Zambo, and Christie*. In this professional development project, teachers use computers in an inquiry-based setting and developed web pages to use in their own classrooms. Teachers then had the opportunity to field test the technology before integrating it into their own classrooms.

Sperandeo-Mineo conducted research in secondary schools in Italy. Qualitative research about distance learning is reported on an experimental model tailored to train teachers to use constructivist methods in their classrooms.

An ethnographic study of three teachers was conducted by *Wallace*. The descriptive results provide insight into how K-12 teachers utilize the Internet in their classrooms.

Kupfer enlightens the reader to a clearinghouse for science teaching materials for secondary school teachers. There are many opportunities for acquiring materials from a variety of sources. Collaboration with industry to train teachers to use the equipment is also described.

A brief description of the GLOBE program is provided by *Williams*, of the GLOBE Training Center. He advocates the use of this NASA based program for professional development.

Another literature review of three programs to integrate technology into environmental education classes is presented by *Huber*. His paper described the congruence between the pedagogical approaches advocated by science education reform groups and three exemplary programs.

Another review of the literature is provided by *Stewart and Zaslavsky*. Two projects are described which addresses the gap between the computing environment and needs of the schools with the awareness of teachers and students about the fast-paced changes.

This year's papers are valuable to a wide-ranged audience of science and technology educators. This section leader believes that anyone interested in instructional technologies in science, whether at the K-12 level, university preservice teacher level or through professional development will find material of interest in this section.

A 3-D Journey in Space: A New Visual Cognitive Adventure

Yoav Yair, Rachel Mintz and Shai Litvak
Center for Educational Technology
Tel-Aviv
Israel
Yoav_y@cet.ac.il

Abstract: This work presents a new 3D model of the solar system with virtual reality (VR) features. It is based on powerful scientific visualization techniques and can be used as an effective aide in astronomy teaching. The learner "enters" a virtual model of the physical world, journeys through it, zooms in or out as he wishes, changes his view point and perspective, as the virtual world continues to "behave" and operate in its usual manner. The continual motion of the planets generates day and night, seasons, eclipses and phases – topics that are customarily hard to grasp, especially at young age. The model allows for a powerful learning experience, and facilitates the mental construction of three-dimensional space, where objects are varied and different, but share common features and obey the same physical principles. The new view helps to overcome the inherent geocentric view and ensures the transition to a scientific, heliocentric view of the solar system.

Introduction

Teaching astronomy at the primary and secondary school levels is a great challenge for science teachers. On the one hand, it is an extremely appealing modern science that fascinates and attracts children. On the other hand, it contains complex subjects in physics, requires an understanding of three-dimensional dynamics and demands advanced cognitive capabilities. To understand the basic astronomical phenomena – day and night, seasons, eclipses, phases of the moon and the motion of planets - one must have the capability of visualizing events and objects as they may appear from different perspectives simultaneously. Children have initial conceptions of celestial objects and phenomena, which are very reminiscent of ancient philosophical ideas and that are probably influenced by erroneous information presented in everyday culture and mass media (Lanciano, 1999) such as science fiction films and TV series. A simple example is the notion that spacecraft can fly faster than the speed of light, as depicted in many scenes in the films "Star Wars" and "Star Trek" . These ideas become deeply rooted beliefs, that are often inconsistent with the accepted scientific view.

Indeed, many researches pointed out that children evoke their own explanations for the easily observed astronomical phenomena, long before they receive any formal education in either Earth sciences or astronomy (Nussbaum and Novak, 1976). Baxter (1989) found that children construct alternative frameworks for explaining astronomical events that become less naive as age progresses. He also found that many pupils leaving school at the age of 16 years were unable to explain correctly ordinary astronomical events. Some of these alternative frameworks continue well into adult age, and are even found in university students (Broughton, 1999). Comins (1993, 1995) identified common misconceptions students have in astronomy and derived a set of origins that account for them. This set includes, among others: factual misinformation, mythical concepts, language imprecision, misinterpreting sensory information and, incomplete understanding of the scientific process and of scientists.

In our modern society, space research – and the implied science of astronomy - has become an integral part of daily life. Space shuttle flight, the latest pictures from the Hubbell Space Telescope (HST) and photographs from weather satellites appear regularly on television and in the newspapers. The Internet is literally flooded with information on scientific discoveries, among which astronomical topics. It is therefore essential to enhance the basic concepts of astronomy at an early age, so that children can grow up to be literate in science and astronomy.

Astronomy Teaching in Israel

In 1994, a curriculum change took place in Israel, introducing astronomy and Earth sciences to the primary and secondary school level study program. Extensive resources were allocated to teacher training programs and to the development of teaching materials. The Center for Educational Technology (CET) in Tel-Aviv, in cooperation with Tel-Aviv University's Science and Technology Education Center (SATEC), developed a new program for teaching astronomy at the middle school level. The program includes three components: a text book with an accompanying teacher's guide, and a multimedia-web hybrid learning environment named "Touch the Sky – Touch the Universe". The latter is a multimedia learning environment dealing with the multiple aspects of space such as location, movement, time and the physical components of objects. "Touch the Sky - Touch the Universe" emphasizes the technology and the power of modern research, and features the various means by which man has chosen to explore space. The learning environment also describes the history of the socio-religious role of astronomy from ancient times until the present day. Stories illuminate the key personalities responsible for the development of the scientific ideas which revolutionized the history of human thought. The learning environment includes a knowledge-base, research assignments and Internet Web site.

The knowledge-base contains 36 subjects in astronomy and space research. The information is arranged under the names of the various objects in the universe: galaxies, gas clouds, stars, planets, comets, meteors and constellations. Within each subject there is a further division of information into categories of common characteristics (for example - size, structure, composition, phenomena etc.) which enables comparisons between objects and the reaching of conclusions about the consistency of the materials and the processes and laws of physics in the universe. Extensive use has been made in the database of video clips and animation. The CD-ROM offers a broad spectrum of active research projects which strengthen the ability of the students to gather information from a variety of sources. Students learn ways to present scientific information and are encouraged to develop the ability to generalize, summarize and draw conclusions. The activities also promote creativity and self-expression: "Postcards I sent from space and "The views from the Spaceship window" are a few examples of the rich possibilities offered by the learning environment.

The "Touch the Sky" Web site (http://www.most-sites.org/space/) can be accessed to obtain updated information in the following areas: the astronomical event of the month, information on astronomical observatories and their activities, research news, lists of scientific periodicals, reading recommendations, FAQ and email connection to experts. The site also serves as the crossroads for surfing to additional sites.

The Virtual Solar System

The novel and powerful component in the "Touch the Sky – Touch the Universe" CD-ROM is a 3D model with virtual reality (VR) features, which is based on powerful scientific visualization techniques. Virtual Reality in this sense is a medium where a user can operate within a realistic representation of 3-dimensional space, in real time. It is a non-immersive experience, which is different from the traditional VR in that it does not entail the use of gloves or masks. By simply clicking on the appropriate icon, the learner "enters" a virtual model of the physical world. The computer mouse becomes a spaceship and enables the user to journey through space, to zoom in or out as he wishes, and to change his view point and perspective. The virtual world continues to "behave" and operate in its usual manner - the planets rotate and revolve continuously, as the program continuously computes their location and the location of the observer with respect to them. The model includes the sun, planets, moons, asteroids and comets, revolving and rotating in their orbits against the constant background of the Milky Way, the stars and constellations. Although the relative sizes and distances of the objects were shrunk and scaled, the Keplerian motion was kept unchanged and at the true relative rates. High-resolution NASA images were used to construct the objects, and their numerical data was calibrated with great accuracy. The user can navigate in space, "fly" above and below the ecliptic plane, approach any object and view it from many angles. The numerical data and orbital parameters, as well as other information, are displayed when a specific object is touched. The continual motion of the planets generates day and night, seasons, eclipses and phases naturally in this 3D-VR, and these can be easily explored.

There are 4 modes of observations which the user can choose from: (a) The Free-Mode: no object is chosen and a free flight in space is enabled. (b) Sun-in-Site view: the chosen object is shown together with the sun, from a vantage point. This position illustrates the respective distance and order of the planet from the sun. (c) Planetary view: the planet (or moon, asteroid, comet) is shown in the center of the screen, and the user is "locked" onto it as if travelling in tandem in its orbit. He can zoom in and out and position himself wherever he likes, but the planet always remains at the center, rotating in its nominal rate. This view is useful for a detailed study of atmospheric and surface features, and for astronomical phenomena such as day-and-night, seasons, and phases. (d) Planeto-centric view: this option positions the observer as a geo- (planeto-)centric satellite, rotating at the same rate as the object he observes. The effect is that the object seems to be "frozen" at the center, and the entire "world" rotates around him. Although disconcerting at first, this view is extremely useful in overcoming the basic difficulty of compromising the inherent geocentric view which children possess (Lanciano, 1999) with the correct Copernican model. The user has an option in which he can change the speed of the entire system, by accelerating or slowing the rotation and revolution rates. This is a strong exploratory tool which enables to investigate how basic phenomena would change as a result of this modification. "What if" questions are a strong tool for elucidating complex astronomical phenomena (Comins, 1999). The present model allows a direct study of questions like "what if the Earth rotated faster", where the consequences are apparent immediately on the computer screen.

Darken (1996) showed that a representation of spatial coordinates is essential for orientation in large-scale virtual environments. The lose of orientation and "vertigo" feeling which often accompanies learning in a virtual-reality environment is minimized by the display of a traditional, two-dimensional dynamic map of the solar system. A camera symbol represents the location and observation point of the user with respect to the object and to the entire solar system. This map helps to navigate and orient the user, and facilitates an easier learning experience. It also helps to overcome the sense of bewilderment which is sometimes induced by the fact that there are objects (such as the planet Uranus) that rotate in an unfamiliar manner. Upon entering the new virtual representation of space, the user has to project himself into this "reality" and to adopt to new looking points, which is by no means an easy cognitive task, especially at young ages. A set of structured inquiries has been added to the learning environment, which aim to orient and teach the student various aspects of astronmy. These activities navigate the user to specific observations, and ask guided questions which deal with the basic observations. For example, the user is positioned above the Moon's orbital plane with both Earth and the Sun in view, and is asked to note the changing angle between the illuminated part of the moon and the Earth, and to relate his observations to the phases. Another example is the identification of the sun as the only source of light in the solar system, by noting the dark and illuminated sides (night and day) of all the planets.

Scientific Literacy and Visualization

The use of computer-generated images and of other visual sources of information in present-day scientific research is generally referred to as ***scientific visualization***. Scientific visualization provides a way of observing natural phenomena that, perhaps due to their size, duration, or location, are difficult or impossible to observe directly. In the realm of astronomy, data sent back by the HST and by other space probes are transformed into images that are enhanced, edited, and analyzed to reveal important new details about our neighbors in space. These scientific visualization tools and techniques are helping scientists to gain a better understanding of how our solar system formed and how it continues to evolve and change over time.

The "Touch the Sky, Touch the Universe program" enables students to interact directly with various forms of multimedia that simulate primary resources used by practicing scientists. Journeys through the virtual simulations of the solar system and the Milky Way help students bridge the gap between the concrete world of nature and the abstract realm of concepts and models. As students examine images, manipulate three-dimensional models, and participate in these virtual simulations, they enhance their understanding of scientific concepts and processes. Students are not simply passive recipients of prepackaged multimedia content. In "Touch the Sky, Touch the Universe", students can use a variety of navigational tools to view, navigate, and analyze a realistic three-dimensional representation of outer space. The included research activities challenge students to keenly observe and interpret the events as they unfold before their eyes during their VR "flight" in space. Students' search for understanding should prompt repeated experimentation with the 3-D simulations and consultation of other information sources in the program. Students should also try to put their observations into the context of their own experience to help them understand the information presented in the program.

Such learning activities provide students with a more intuitive understanding of astronomy and contribute to the development of essential visual literacy and information-processing skills. Many contemporary students are quite adept at processing and understanding visual information as a result of their experience with television, films, and computers. As they become more confident in their ability to constructively interact with the VR elements in the program, students should increasingly use these new technologies as a medium for sharing information and discussing ideas and conclusions.

Summary

The new model holds substantial didactical advantages that can be used as an effective aide in astronomy teaching:

➀ It allows for a powerful learning experience. Space and astronomy have always captured the human imagination, and children are naturally drawn to space science. The new model enables students to explore space as if flying in their own spaceship. they decides by themselves where to go, what to watch and from what distance and angle.

➀ It facilitates the mental construction of three-dimensional space, where objects are in constant motion. The new view is remarkably different from the traditional two-dimensional representation of celestial objects. Complex planetary motions are made simple when observing, for example, the Earth rotating as it revolves around the sun.

➀ It enables the learner to discover the relation between distance, motion and time. The user can explore the physical laws governing the universe by observing planetary motions, and to deduce their uniformity ("Day and night occur on other planets, too").

➀ It offers a tool that helps to overcome the inherent geocentric view of the world, thus ensuring the transition to a scientific, heliocentric view of the solar system.

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Using Collaborative Inquiry and Interactive Technologies in an Environmental Science Project for Middle School Teachers: A Description and Analysis

Patricia Comeaux
Department of Communication Studies
University of North Carolina-Wilmington
United States
Comeauxp@uncwil.edu

Abstract: Scholarly literature in teacher education and science education advocates collaboration as an essential component of their educational goals/programs. The video conferencing network and the Internet are dynamic tools that support collaboration among learners and scholars. This paper describes and analyzes a project, *Students As Scientists*: Pollution Prevention Through Education (SAS) that uses collaboration as its' central educational goal and focus and uses interactive technologies to accomplish that collaborative goal.

Introduction

What does teacher education, environmental science education and interactive technologies (video conferencing network and the Internet) have in common? They all have a strong focus in and potential to create a community of scholars through collaborative endeavors. Scholarly literature in teacher education and science education advocates collaboration as an essential component of their educational goals/programs. The video conferencing network and the Internet are dynamic tools that support collaboration among learners and scholars. This paper describes and analyzes a project, Students As Scientists: Pollution Prevention Through Education (SAS) that uses collaboration as its' central educational goal and focus and uses interactive technologies to accomplish that collaborative goal.

Collaborative learning scholars emphasize the interdependence of the learners and the communal nature in their construction of knowledge. (Bruffee, 1993; and Johnson, Johnson, & Smith, 1991). Bruffee (1993) describes a university education as "an enterprise engaged in promoting change" and as such "we construct and maintain knowledge not by examining the world but by negotiating with one another in communities of knowledgeable peers. Similarly, collaborative learning assumes that learning occurs among persons, not between persons and things (p. 9). Thus, in these pedagogical models, knowledge emerges from the interaction between and among instructors and students as they engage in problem solving, real world (authentic or contextualized) experiences.

Likewise, environmental science education programs influenced by the National Science Education Standards (National Research Council, 1996) strongly advocate collaborative inquiry in the context of real word problems as the focus of their science classrooms. The vision that the *Standards* advocate and support is one of dynamic collaborative learning communities working within enriched learning environments supported by an educational system that has been overhauled to provide the support those communities will need. Within these learning communities, students will be actively engaged in inquiry-driven, experiential, "hands-on and minds-on," learning activities (see National Research Council, 1996, pp 20-21) directed towards the central goal of "scientific literacy for all students" (pp 2 and 21). In these central tenants and additional supporting details, the goals of the standards-based reform effort appear very congruent with the goals of science education programs.

In sum, it seems clear that collaborative inquiry is strongly advocated by scholars of collaborative learning and science education. This paper examines the collaborative nature of the SAS project and its impact.

Project Description and Goals: Centrality of Collaboration

The "Students as Scientists: Pollution Prevention through Education" http://smec.uncwil.edu/glaxo/sas/index.htm) is a three year teacher training program (in its final year) offered through the Watson School of Education, University of North Carolina-Wilmington for middle school science teachers throughout North Carolina. The specific objectives of this teacher training project are: (1) to update teachers on environmental issues affecting North Carolina, particularly water pollution prevention; (2) to engage teachers in collaborative learning and problem-solving methodologies they can use in their classrooms; (3) to provide teachers with environmental monitoring equipment and training in the use of this equipment, (4) to educate a cadre of teacher leaders who will educate other teachers in their districts; and (5) to teach the teacher leaders to learn to use the World Wide Web and the distance learning network so that, after the institute, they can continue information gathering and networking. The project creates Web Pages (that teachers may use collaboratively; they are be able to download curricular information and environmental monitoring data from the web to use with their classes.

During the summer 1997 workshop teachers from New Hanover County Public Schools conducted environmental monitoring activities on the Cape Fear River. Working with University of North Carolina-Wilmington scientists, they performed water analyses and determined dissolved oxygen and solid levels, salinity, temperature differences, and pollution indicators. Participants graphed their data using spreadsheet software and compared their data to the river monitoring activities of the Cape Fear River Project, a consortium of local industries, environmentalists, and state environmental department experts. Guided by project staff, they learned to locate environmental science resources on the Internet. Discussions focused on presenting the project's activities in lessons that reflected the national and state science education standards. Participants developed lessons that incorporated cooperative learning strategies, hands-on science inquiry, and best practices for the Cape Fear River.

During the following academic year, the teachers and their middle-school students spent one day per week on the Cape Fear River replicating the summer's monitoring activities and recorded their measurements on the project's World Wide Web site. The students learned how to graph their results, use environmental science terminology to describe their activities, and analyze local environmental conditions and water-quality tests performed by the state environmental department.

During the summer 1998, teachers from Clay and Graham County Public Schools and Charlotte Public Schools, as well as additional New Hanover County teachers, attended the workshop. After completing the same objectives as outlined above, these teachers conducted water monitoring activities on waterways in their regions with assistance from Western Carolina University and University of North Carolina-Charlotte scientists and environmental education faculty. Participants and their students enter their data on the project's Web site and compare their results throughout the year. In summer 1999, new teachers from the four school systems participated thus completing the three-year project funded by Glaxo Wellcome foundation.

The "Students as Scientists" project emphasizes hands-on science activities which require higher order thinking and problem-solving skills. The project challenges teachers to learn to use their surrounding physical environments and real problems as teaching tools. This expertise allows teachers to better implement the new State Science Curriculum (1996) and help their students understand the nature of science.

The WWW provides a forum for the presentation of environmental education concepts. "Students as Scientists" created a number of interactive web pages where teachers track the project's development and growth, and participate by using interactive forms for the posting of data to the project's home page. Thus middle school science teachers and their students compare and contrast data collected by participating schools and by university scientists throughout the state of North Carolina. In addition, these students develop interpretive skills and begin to understand the fundamental scientific processes that shape and control water basins. With these field experiences, students become involved in "real" environmental science, impact implications and, ultimately, the social and political issues that affect their community's water resources. Furthermore, the WWW component includes modules of information that can be downloaded by teachers for integration into the curriculum and for working collaboratively with other teachers in the project. Thus, it will be possible for teachers around the world to share "Students as

Research Methods

As a communication education specialist, I have evaluated a number of education and technology grants. Patterning my research design after similar evaluative projects, I designed a program of evaluation to study the effectiveness and impact of the SAS project. The evaluation purposes were (1) to determine the effectiveness and the impact of the project; and (2) to secure information for project program changes that would improve the initial design and future projects.

To evaluate the effectiveness of the program design, I used a qualitative evaluation methodology advocated by Michael Quinn Patton (1990). As Patton explains: "When one examines and judges accomplishments and effectiveness, one is engaged in evaluation. When this examination of effectiveness is conducted systematically and empirically through careful data collection and thoughtful analysis, one is engaged in evaluation research" (p. 11). I also followed the naturalistic inquiry approach (Lincoln and Guba, 1985) and used inductive analysis (LeCompte & Preissle, 1993; Lincoln & Guba, 1985) to search for themes and patterns emerging from the data.

Data Collection and Analysis

Data was collected from a variety of sources to ensure completeness and thoroughness. Because the project is presently in its third year, this paper will focus on the analysis of data from the first two years of the project: 1997 and 1998. During the first year of the project (1997), all participants were middle school science teachers from the coastal site in North Carolina (Wilmington) and they completed a written open ended survey at the end of the institute regarding their responses to the summer institute and their plans on how to implement the project. During the second year of the project, middle school science teachers and university scientists from two other geographical sites (piedmont and mountains) participated in the project with a new group of participants at the Wilmington site. Participants at each site completed an evaluative questionnaire at the end of the summer institute. In addition, the 1997 coastal site participants and the 1998 participants from all three sites were mailed a set of open-ended questions to survey their response to the project, the use of the Internet, and their challenges of implementing the project and its impact on their teaching and their students. To provide more descriptive and detailed data, participants at the Wilmington site were interviewed and audio-taped in focus groups (3 groups of 6 each) three times throughout the 1998-99 academic year. The first taped interviews occurred at the end of the summer institute and focused on their responses to the institute and their implementation plans for using the water testing kits with their students and their curriculum. The second focus group interviews occurred during the "Comeback Session" on Saturday, October 23, 1998. At this time the focus groups discussed their successes and difficulties with their implementation plans. In addition, they shared ideas and suggestions for future implementation of the project. The final taped interview occurred the following spring with only one of the focus groups during a "Student Symposium Session" in which the "student scientists" presented their findings to each other in small groups.

The transcripts (from the interviews) and the open-ended surveys were read using inductive analysis to discover the emerging themes (Lincoln & Guba, 1985 and Patton, 1990). After comparing the themes (discovered from the interviews and the surveys), the data was re-read using a "clustering" strategy suggested by Miles and Huberman (1994, p. 248-249) to categorize the themes. Next, the themes were color coded to search for the "emerging patterns" in them (LeCompte & Preissle, 1993, p. 237).

For the purpose of verifying the credibility of the data, I followed Lincoln and Guba's (1985) suggestions for establishing "trustworthiness" of qualitative data (p. 301). Consequently, I used the following criteria from Lincoln and Guba (1985) to establish credibility of the data:

1) <u>triangulation</u>: by seeking perceptions of the experience from "multiple sources", by using different "data collection modes" through the written surveys, interviews, and observations, (p. 305-307);
2) <u>member checking</u>: by asking the interview respondents to attest to the accuracy of the data and its portrayal to verify the data as "adequate representation of their own . . . realities" (p. 384); and
3) <u>peer debriefing</u>: by sharing my findings and analysis with the project director (Richard Huber) and with other informed education researchers

who served as "disinterested peers" for the purpose of "exploring aspects of the inquiry" and keeping the interpretations "honest" (p. 308).

Collaborative Nature of the SAS Project: Findings and Discussion

Using analytic induction, this paper will focus on the one of the prevalent themes emerging from the data: collaboration. The theme is discussed in light of the goals of the program.

The major focus or goal of the project is inherent in the title *Students as Scientists*. As the project director explained, "it is important to help these teachers move from textbook science to doing science so that they and their students can understand more clearly what scientists do" (Huber, 1998). The heart of the project aimed at modeling the collection of data about the environment from local water sources and sharing that data with others throughout the state. Thus the very collaborative and public nature of science was emphasized.

The project modeled what scientists do in several ways. One of the most noteworthy was the collaborative nature of the summer workshops, which lasted from 8:30 to 4:30 for two weeks. Each site was responsible for engaging a local scientist to discuss environmental issues indigenous to their particular region. The video conferencing distance learning network enabled participants from each of the 3 sites to interact with the presenters and with each other during these sessions. Since the participant's would be posting and sharing their data from the water-testing project with others throughout the state, these initial presentations and discussions were necessary to lay the foundation for understanding the inquiry nature of science. Participants noted in both the interviews and the surveys how valuable they found this information particularly in light of environmental issues. As one participant elaborated:

> I thought it was interesting to learn about our area's health and our water health and to discover ways to implement the project. This project is extremely useful, not only to our students but also to our families, especially our children. We got a lot of history of the region and the river, how it's changed, how can we monitor it and what we can do in the future to preserve it. I think that's the best thing I got out of the summer institute (8th grade science teacher).

The above testimony was corroborated in other interviews and surveys as the teachers felt they received a wealth of information and resources to use in their classrooms. They were particularly grateful to meet and make connections with individuals in their community who "might be willing to come out to the school and talk with my students." The centerpiece of the summer institute was the water-testing kit provided to each teacher participant. Teachers were favorably impressed with and appreciative of the kits. As one teacher detailed:

> What struck me is there's this big drive now to make science inter-relate. You've got the interdisciplinary type studies going on and not just with science and English or with science and math, but within all the sciences. It amazed me how much biology and earth science and environmental science and chemistry are all related and can be related through this water testing kit. You're teaching your state objectives but you're also teaching all the other sciences and history and students will be learning to write and communicate and they will learn about how to use the Internet for this project (9th grade chemistry teacher).

As is the nature of any project of this magnitude, teacher participants had varying degree of success with it. That the project was a success was noted from the descriptions from teachers as their students "became" scientists. As one participant noted:

> I'm currently showing pictures of youngsters who are actually involved in the water quality testing. I guess I've never seen a group of young children so involved in a task. They approach the task with, I think, a great deal of intellectual prowess. I was amazed at how serious they took the project and got genuinely involved in it. As you can see in these pictures, they worked. They all are doing tests. They're all busy. They wear goggles and they wear gloves and feel like scientists and they act like scientists. They indeed were young scientists in the truest sense of the word. I was impressed, and I think the pictures

demonstrate the quality of the work they were doing at that time (5th grade teacher).

In sum, the teacher participants found that the summer institute provided them with the information and resources they needed to implement and model inquiry science into their classrooms.

Interactive Technologies as Collaborative Tools: Findings and Discussion

As the teachers explained, the televised distance learning sites proved valuable to be able to interact with university scientists and community environmentalists across the state. The participants felt that these individuals were well selected and they were impressed with their knowledge, expertise and willingness to answer questions. However, the distance learning network has its limitations. Teachers spoke of the difficulty of "sitting for a two hour session" and "having more empathy for what their students

Without exception teachers, upon completion of the summer institute, were committed and enthusiastic about using the Internet to connect their students with other students and to implement the vision of *Students as Scientists*. With such positive feedback and a commitment from the teachers, the project staff were confident and looked forward to monitoring the projects web page for student data. By November of each year it became apparent that the dynamic interactions between sites was not going to take place and in fact very few teachers were sending data to the web page. This was a huge disappointment for the staff and caused us to seek out the answer to why such a low participation rate given the enthusiasm at the end of the summer and their apparent commitment to develop this community of scholars. However, several of the teachers indicated problems were that they:

- Transferred to another discipline and no longer teaching science
- Had difficulty getting on the Internet or having access to an computer
- Did not trust the student results and were leery of posting erroneous data
- Something had come up and they had not yet had a chance to initiate the project
- Were delayed and distracted by the hurricanes in Southeastern North Carolina

Furthermore, by the spring of each year only 20-30 % of the teachers were actively engaged in the posting of data. An analysis of the interviews and surveys indicated a high degree of satisfaction with the project and yet the vision of a dynamic exchange of data over the Internet had not occurred. Some possible explanations are:

- Teachers did not value and envision the public nature of science as viewed by the project director.
- Teachers were locked into the traditional view of their classroom being confined and defined by the classroom walls.
- Teachers still view the workshop as a resounding success because they were able to use information from the workshop in their classes.

It is highly possible that the vision and value of students acting as scientists by sharing their data on the Internet were not communicated effectively from the project director to the teacher participants. Or if it was, this public nature of science an alien idea to teachers that they could not appreciate it. Most likely the type of science most teachers have previously experienced did <u>not</u> involve data sharing or collaboration with other classes or institutions across the state.

Conclusion

Students as Scientist project by all accounts has successfully introduced middle school science teachers throughout the state of North Carolina to the possibilities of the collaborative nature of inquiry driven science. Although the use of the Internet has not been as successful for data sharing as the project director envisioned, the project has encouraged many teachers to ask for more technology equipment and support. That a university program would lead the way in the public schools for the inclusion of the use of technology in science education was the vision of the project director. Now, armed with the water-testing kits and collaborative inquiry methodologies, science teachers are requesting interactive technologies to assist them in their classrooms.

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From Instructive to Constructive: A Practical Guide to Implementing Mindtools in the Classroom

Maggie Irving
EdTech2000 Cohort
Florida Gulf Coast University
United States
Mmirving@eagle.fgcu.edu

Dr. Edwin J. George
Assistant Professor of Educational Technology
Florida Gulf Coast University
United States
ejgeorge@fgcu.edu

Abstract: Making the transition from an instructive classroom to a constructive learning environment is difficult for the best teachers, and seemingly impossible for beginning teachers to manage. This paper presents techniques that were used for converting existing science units into constructivist experiences through the use of computer-based Mindtools (Jonassen, 1999) as the unifying principle. Students remain at the center of their own learning, even as direct instruction is added to the environment.

Introduction

There exists in American education a wide disparity of technological resources among schools. We have spent 30 years dismantling a race based, two-tiered educational system in which selected schools had the best texts, teachers, and laboratories; only to replace it with a technology based, multi-tiered system in which chosen schools have the best teachers, technology and training available. Where the post-Sputnik science education reforms saw resources poured into predominantly white, middle-class schools, today's reforms are pouring resources into educational institutions with the greatest access to financing. This leaves many of America's schoolchildren with inadequate access to technology, and aids in creating a new underclass in our country, the technologically disenfranchised. According to the 1998 Journal of Educational Statistics, 75% of elementary students had access computers in the classroom, and only 24% of the classes had Internet access. In addition, the level of minority enrollment correlated with low access levels. Before any meaningful implementation of nationwide science or technology standards can occur, a common base must be established within the scientific instructional community.

Jonassen (1996) has presented us with just such a common base in Mindtools. By utilizing computers in constructivist settings and incorporating common and inexpensive programs, Jonassen provides us with the ability to establish a minimum standard of technological integration for all students. Using computers to support constructive practice is cyclical in nature. Becker and Ravitz (1999) have shown that increased computer use leads to increase constructivist practice. With national standards and certifications, magnet and voucher schools, it is more important than ever to establish certain fundamental uses of technology that are accessible to all students and consistent with the latest research in learning theory.

How can new teachers integrate technology with constructivist principles? It has been established that students in constructivist science classes have outperformed their counterparts in traditional classes in all areas measured. (Lord, 1999) However, it is impractical, if not impossible, for most new teachers to design a thoroughly constructivist course for a variety of reasons. One component faced by many teachers is fear that these methods don't seem like "real" teaching. In a recent issue of Learning and Leading with Technology, Sprague & Dede (1999) reflect on the difficulty one teacher faced:

> A high school teacher was designing a project on finances for her students.... She had read about constructivist theory... and had seen it modeled in her university courses. However, when it came time to implement this approach, she was reluctant to allow students to be in charge of their learning. She said, "I don't see that as teaching. The noise level was very loud, and I was nervous when my principal walked in. What will he think about my teaching with all that noise? I just felt I was not doing my job. I know I should teach that way but it is not my style." (p. 7)

The same article, however, tries to ease this fear by illustrating how one teacher was able to demonstrate how effective the constructivist approach was to her normally "traditional" principal:

> When he sat in on [a parent-teacher] conference, Principal Helmquist was confronted with a new model of teaching, one that centered on the needs and interests of the student. He saw that [the teacher] was able to provide a richer assessment of [the student's] abilities, one that went beyond just his low-level skills and knowledge. He saw that students' learning... went further than [the 8th grade social studies] content area, including language arts and science as well." (p. 16)

The purpose of this paper is to provide new teachers with a guide for developing and integrating technology into a constructivist setting. I am pragmatic in my approach, setting aside for now discussions of various constructivist "flavors", in order to present a realistic plan for action that is usable by both new and in-service teachers. While this model was implemented in a middle school science classroom, it is easily adaptable to any subject.

Designing the Unit

Choosing a Topic

First, a topic must be selected that lends itself readily to inquiry-based teaching. The goal is to be able to provide initial experiences within the domain that can be further built on by the student. The chosen topic should meet the following criteria:

1. Is the instructor well versed in the content of the unit?

The novice teacher will be learning to master a complex environment during this unit. Content proficiency is essential for the project's success. I would suggest that a teacher weak in chemical processes choose a different area for their first attempt. A novice teacher should keep their first foray into constructivist teaching well within their domain of expertise.

2. Can a hands-on, student centered learning environment safely be created with a minimum of effort and expense?

Remember that students may well be learning how to learn in a constructivist setting at the same time that the novice teacher is learning how to teach in a constructivist manner. The tasks designed for the students need to be within their ability to achieve, with guidance from the instructor. Providing a set of acids and bases for students to experiment with would be inappropriate, for example, as an introduction to the study of chemicals. They would be lacking the prior knowledge needed to safely explore the topic. By the same token, a beginning teacher may not have the time necessary to prepare 15 different solutions for 5 different classes. A teacher must consider both the time and materials available for their use.

3. Will the use of computers to represent or process the information gathered during the activities significantly add to the learning of the students?

Jonassen insists that a computer application is used as a Mindtool when it "engages learners in critical thinking about their subject."(p.18) The use of the computer must be more than just a means of presenting information learned; it must be a means of creating new learning. Creating a spreadsheet that will predict the outcome of a given event requires the students to understand both the scientific concept and the mathematical laws that govern it.

This project focused on simple machines. The instructor was very familiar with the subject matter and materials were easy to gather. Students could be given simple, every day objects such as string, wood, pulleys and toy cars to explore how machines work. Spreadsheets would allow students to process their experience and demonstrate the mathematical relationships between force, work, and distance as well as calculating the mechanical advantage of various machines.

Setting the Standards

Once the topic has been established, the teacher needs to determine what standards the students upon completion of the project will meet. These vary from district to district, state to state. But it is important for the novice teacher to realize that standards met are not limited to those within a grade level curriculum. Correlating the simple machine's unit with the local district's standards revealed not only science content and process standards but also many within mathematics and technology as well. Document as many of these as realistically possible. Constructivist learning takes longer than direct instruction, and new teachers will have to justify not "finishing the book" or keeping up with their peers.

New teachers should ensure that all applicable standards have been noted by:

1. *identifying all content areas standards to be addressed*
2. *explaining what process skills will be needed to complete the unit*
3. *examining both the technology and mathematics curriculum guides for relevant standards*
4. *identifying what communications skills and techniques will be used by the students.*

Given the exhortation to save time in the previous section, this may seem like an unnecessary amount of work for the overburdened novice teacher to complete. However, this documentation is essential in gaining both administrative and parental support for the changes that will be implemented in the classroom. Parents will want to know why only two chapters were "covered" during first quarter, and principles will need to be assured that the cooperative classroom is truly producing results.

Establishing Criteria for Success

Detailing the standards and benchmarks achieved also focuses the novice teacher on which areas to assess. Not every skill, process and bit of knowledge can be tested or assessed each unit. While students in this project were manipulating mathematical equations and creating spreadsheets, they were expected to master only certain essential information:

1. *What is a simple machine?*
2. *How do machines alter distance and force to make work "easier"?*
3. *How can the mechanical advantage of a simple machine be predicted?*

For this project, it was decided that students were to be evaluated on this information using a traditional test, as well as the final spreadsheet they produced. Completion of the spreadsheet would be evaluated using a rubric (Jonassen, 1996) which established the standard for success. Additionally, interim performance checks would be conducted to determine how well each student was fulfilling his or her role in the group.

Gaining Administrative Support

Armed with this information, a new teacher should now present their proposal to their mentor or supervising administrator. The quickest way to gain their support is to ask for feedback and suggestions on how to proceed. This may result in long stories of "When I was in the classroom..." however getting the administrator to feel like a part of the project will pay off when it comes time to evaluate the teacher's classroom performance.

One of the biggest hurdles I faced was installing enough computers to meet the needs of my groups. The beauty of Mindtools as envisioned by Jonassen is that the programs used are standard installation on most computers. No further outlay of funds was required from the principal. There are also teachers in every school who would love to see their classroom computers removed, if not destroyed altogether. New teachers can take advantage of this by asking their supervisor for permission to "borrow" unused computers. I managed to gather up several 486 PC's in this manner, powerful enough to meet the students' needs.

Unit Implementation

Cooperative Essentials

One of the biggest challenges facing a novice teacher is the management of cooperative learning situations. It is not enough for the teacher to create heterogeneous groups and assign tasks for them to complete. Analyses of classroom interactions have demonstrated high-status students often dominate discussions in cooperative groups. Conversations rarely reflect deep processing of concepts and procedures. (Bianchini, 1997) A constructivist classroom, centered on the student as learner, depends upon functional communication between students for its success. While in no means a comprehensive list of effective cooperative learning strategies, the following techniques were used with good success during this study. Note this was not the first experience these students have had in cooperative learning. The roles and their responsibilities had been practiced in the classroom many times before.

Create heterogeneous groupings. Rather than looking just to grades, consider a student's ability to organize, communicate, manipulate and lead before assigning them to groups. A group with three natural communicators will be more likely to discuss the upcoming dance than a group with one. Similarly, a group with three natural leaders will be more likely to disintegrate into argument than a group with only one.

Have a role for each member of the group, and responsibilities that go with that role. I prefer groups of four, for the simple reason that if one child is absent, the others can easily absorb their duties. For this activity I chose the roles of Lead Scientist, Recorder, Materials Manager, and Communicator. Teach the students their roles as they are assigned. Clearly explain and demonstrate their duties and the expectations for their success. In the event a class has an uneven number of students, have students negotiate which extra duties they would each assume.

Spend the first day of the activity strictly enforcing the expectations of each role. Students will quickly forget their roles and assume their usual social activities without reminders. During this project, only Communicators were allowed to initiate conversation with me. If any student had a question, they had to phrase it so the communicator understood what was being asked. Then, the communicator would ask me the question, take my response and restate it for the other student and in the process the whole group. This may seem cumbersome at first, but after a period of asking students "Are you the Communicator?" they quickly learn to discuss questions among themselves before calling on the teacher.

Let the students know they are being evaluated on how well they perform their assigned duty within the group. I simply walk around with a clipboard, randomly checking five or six students at a time, marking + or – for each. This is accompanied by constant questioning the first day or so: "Who is the Lead Scientist?" "What should you be doing now if you are the Recorder?" This is done several times through the period, enough so that each student has 2 or 3 marks per class.

Let the students know they will not be penalized for the poor performance of another member of the group. This is perhaps the most common concern I hear from parents regarding cooperative learning. Maintain individual accountability. The goal is for the students to work together in order for them to increase their individual learning.

Avoid stereotypes when grouping students. I asked the groups to select their Materials Managers and Recorders first and their Lead Scientist last. The eager and vocal students often opted for the first jobs, leaving some of the more reticent students as Communicators and Lead Scientists. The Lead Scientists were all given the option of switching jobs with anyone in their group, but surprisingly, all held on to their positions; much to the dismay of some of their more assertive group-mates.

Unit Design

The simple machines unit was divided into 5 phases: *Exploration, Explication, Analysis, Construction and Evaluation.* It was designed to be open and adaptable to the direction of the student's learning.

The Exploration phase provided students with an opportunity to develop an understanding of how simple machines operated. It also provided the teacher with important information regarding the students' level of prior knowledge. Students were given three tasks to complete during this phase. A variety of raw materials were provided in a central location, including wood blocks and planks, weights, pulleys, toys and string. The assignment was to lift an object with a lever. They were asked to modify the lever to make the object more difficult to lift, and again to make it easier to lift. Their observations had to be recorded and diagrammed, with one student presenting the results to the class. This process was repeated with pulleys and inclined planes. A different student was required to present each time.

It is essential during this phase that the teacher resists the temptation to tell the students what to do. Instead, questioning techniques should be used to both assist the students through their reasoning process as well as redirect them when necessary. Some of my students attempted to lift a lever using a pulley to drag an object up a ramp. While they were not on target, they learned a great deal about each machine before I finally asked them to reread their directions. When other students had questions about the machines, I would question them in return regarding what they were doing rather than explaining it myself. Some students had to be coached to look at resources available such as their text and available science databases.

The Explication phase consisted of the presentations by the various groups, and discussions that resulted. Most groups had come to a good understanding of what simple machines do, and developed some intuitive ideas about why they worked. The discussion here focused on the relationship between work, force and distance. They discovered that the object moved less when the work was easier and vice versa. Some teams had gone so far as to take preliminary measurements that helped to support their conclusions. We also took the time at this point to discuss what problems or difficulties the groups had encountered among themselves and how they had solved them. This better prepared them to work together on the more challenging tasks that followed.

The next phase, Analysis, required the students to repeat the initial tasks and quantify the relationships between work, force and distance for each of the machines studied. Again, groups shared their results, this time with the discussion building towards an understanding of calculating work done and mechanical advantage. Direct instruction was necessary here to explain the proper use of scales and other equipment. Most groups had by this time explored the chapter and discovered formulas that related these variables.

The groundwork was now laid for the Construction phase to begin. Jonassen (1996) provides a series of learning activities for teachers to follow when having students use spreadsheets as Mindtools. My students had already had extensive experience with spreadsheets, so it was not necessary for me to follow all of the steps he recommends. The task before the groups now was to create a spreadsheet that could calculate work, force, distance, and mechanical advantage for any given simple machine. Here it was important to have the students plan their spreadsheets before moving to the computers. Once at the computer, most groups began with entering the data they had already collected in the Analysis phase, utilizing the graphing functions to see relationships among the variables. The greatest difficulty was in determining what calculations to embed into the cells. Once that was mastered, groups quickly achieved their goals. Two techniques were particularly helpful at this point. First, I frequently asked groups to change positions and duties while in front of the computer. Each student in the group was thereby assured the experience of working directly with the spreadsheet. Second, Communicators were allowed to consult with Communicators of other groups, to compare their progress and share ideas. Often, the Communicators were not the computer experts in the group. This meant the "experts" had to teach the Communicators the program's design, both reinforcing their own learning and increasing that of the other members of the group.

Assessment took many forms. Presentations at the end of the Exploration and Analysis phases served as informal assessments of student learning, indicating areas that needed additional scaffolding or even direct instruction. Final assessment of the spreadsheet came from the students themselves. Following Jonassen's model (1996) each group prepared a set of 5 "what if" scenarios to be tested on another group's spreadsheet. Students enjoyed trying to pose problems that other spreadsheets could not solve. When spreadsheets failed to function properly, the group was required to troubleshoot and repair the problem. Each spreadsheet was then evaluated using a rubric based on Jonassen's recommendations. A "traditional" test was also administered. Finally, more as celebration than assessment, each group was required to construct a "Rube Goldberg" machine using at least 3 simple machines.

Conclusion

This project focused on simple machines. First, I determined the standards that would need to be met by the lessons, as well as additional technology standards that would be met as well. This was key in obtaining the administrative support I needed. In a school with limited technology resources, I had to demonstrate the effective use of the computers given to me. Presenting this plan to the principal secured enough computers to ensure the project's success. Ten computers formed the core Mindtools of the project. The spreadsheet program was used by the students to create their own simulations of machines.

By carefully planning the sequence of instruction, student-centered experiences were effectively utilized. When formal instruction was required, it was driven by the students own questioning and anchored in their previous experience. By designing their own computer models of machines, the students were required to process their new learning in a deeper and more meaningful way. The use of rubrics allowed for evaluation of the student spreadsheets that took into consideration their accuracy, organization, and level of complexity.

Effective planning and implementation eased the transition from an instructive to a constructive classroom. Computers as Mindtools are an important ingredient in creating a constructivist environment that both challenges the learners and requires higher order processing of new information. These skills are mastered with time. It is important that novice teachers be encouraged and supported in their desire to create constructivist learning environments. It is in the doing that new teachers create their own knowledge and become masters of these techniques.

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TEACHING ACROSS COLLABORATIVE HIGHWAYS (TEACH)

Starlin Weaver, Ph.D.
Salisbury State University, USA
sdweaver@ssu.edu

Beth Shiner Klein, Ed.D.
State University of New York - Cortland, USA
kleine@cortland.edu

Juanita Jo Matkins, Ed.D.
University of Virginia, USA
jjm7k@virginia.edu

Abstract : This article describes the process of using collaborative technologies to team teach elementary science methods courses across 3 different institutions: two small state universities and a large research university. The project was initiated because of the isolation each of the faculty members felt serving as the only educator (or only elementary science educator) at each of their institutions. A description of the project and the Internet-based collaborative technologies at each site is provided. Each of the three faculty members involved in the project share their unique stories of implementation and outcomes as a result of participating in this project.

Introduction

Excellence in elementary science teaching requires teachers that have a strong self-confidence in their ability to learn and teach science processes and content in an inquiry-based manner (Penick 1983). Prior to the availability of collaborative technologies such as video linkages, meeting software and Internet program sharing, college science educators were often isolated in their own colleges and universities. The three elementary science methods course instructors who participated in this two year collaborative project have explored strategies for sharing instruction and resources while adapting the available technologies to the specific needs of elementary science methods course instruction.

The application of modern digital educational technologies in instruction in college and university education programs has been the focus of research during the past decade. The potential for enhancement of collaborations among students and among in-service teachers has been explored in a variety of venues, with applications of telecommunication technologies such as listservs, newsgroups, email, and the World Wide Web (Caggiano-Hatton & Abegg, 1998, Khan & Clement, 1999). A recent study (Hatton & Abegg, 1999) on the effect of use of a telecommunications network on secondary science teachers concluded that teachers in the project shared technology resources and classroom experiences with colleagues. The teachers also reflected upon their teaching practices, such as how they managed technology in their classroom, and how the technology worked for their students.

Collaboration in education classes has been explored and elaborated upon at the University of Virginia and Iowa State University (Heinecke, et al., 1999) by way of emerging "groupware" technologies such as Microsoft NetMeeting software, whiteboards, and full-duplex telephone systems. Initial models involved seminar-sized groups , two-way collaboration, and a course content focused upon technology issues. These collaborations were themselves a transition from the "one-to-many" model common in distance learning; and the new model was characterized as a "several-to-several" model, or "Collaborative Education" (Bull, et al., 1999).

The project described in this paper, Teaching Across Collaborative Highways (TEACH), examines collaboration across three institutions of higher education. Three assistant professors of science education developed a plan to use telecommunication technologies embedded within their elementary science methods courses. During the first semester, students and faculty at a Wisconsin, private 4-year college, St.

Norbert College (SNC), worked with students and faculty at a large research university in Virginia, the University of Virginia (UVa), and with students and faculty at a public Eastern Shore university in Maryland, Salisbury State University (SSU). During the second semester of the project, the professor at St. Norbert moved to The State University of New York at Cortland (SUNY-Cortland) and continued the project. Course enrollments at the three institutions ranged from 15 to 30 students.

The Technology

Planning for the TEACH project began in the summer of 1998, and plans were implemented in the spring and fall of 1999. Technology recommendations were obtained from persons involved with the UVa/Iowa State projects. The chart below (Bull, et al., 1999) describes various options tested by other faculty and recommended for our consideration in the TEACH project.

	Inexpensive (> $500)	Low Cost (> $2,000)	Moderate Cost (> $10,000)
Whiteboard	NetMeeting Software White board (free)	Graphics Tablet ($200)	Electronic Whiteboard ($2,000)
Real-time Audio	NetMeeting Internet Audio (free)	Full-duplex Conference Phone ($300)	Conference Phone with Wireless Mike ($1,000)
Projector	Scan Converter ($300)	LCD Tablet ($1,000)	Projector ($3,000)
Real-time Video		NetMeeting + Video Digitizer ($70) and Video Camera ($150)	NetMeeting + Video Digitizer ($70) and Camera & Tripod ($1000)
Document Camera		Adapted Video Camera (no additional expense)	Video Digitizer + Video Switch ($20) + Document Camera ($1000)
Streaming Audio		SoundBlaster ($60) + Sound Recorder Software (free) + NetShow	SoundBlaster ($60) + Sound Editing Software ($50) + NetShow
Discussion Group		Internet Discussion Group (Collabra);(free)	Internet Discussion Group (Collabra);(free)

Table 1. Designing a Collaborative Education Laboratory (Three Examples)
Note: From " Mining the Internet: Collaborative education," by G. Bull, G. Bull, W. Heinecke, R. Walker, L. Blasi, and J. Willis, Learning and Leading with Technology 26, p. 52. Copyright 1999 by International Society for Technology in Education. Reprinted with permission of the lead author.

During the initial stages of planning it was hoped that collaboration technologies enabling full three-way audio and video interaction, the "Moderate Cost" example detailed in Table 1, would be available to all three classes. It soon became apparent that each institution would have its own answer for the technology requirements of this collaboration. Each instructor had to work through the process of designing the collaboration procedures while considering the technological capabilities of the other institutions. The University of Virginia was the only institution that used a system recognizable within the examples proposed in Table 1. Dr. Klein and Weaver had similar setups that included a USB Logitech digital video camera, laptop computer, speakerphone, and portable projector.

How the Collaboration Worked in TEACH

Though the three instructors discussed a possible collaboration as early as the 1998, actual implementation did not begin until a year later. The three instructors decided on the six research topics that would be assigned to each cross-state group. The six topics, all focusing on elementary school science were: curriculum resource materials, methods of teaching, diversity, state standards, integration of other elementary curricular areas, and alternative assessment.

The spring semester began with Virginia and Wisconsin starting classes at the same time and Maryland starting 2 weeks later. Three individual collaborative sessions between Virginia and Wisconsin were later followed by state team presentations at the individual sites. During the timeline of the project, differences in the semester schedule for each institution, as indicated on Table 2, complicated the student email collaborations across the institutions.

January	February	March	April	May
13-17 Planning meeting at AETS conference	1 SSU class begins	5 Individual team papers due for each institution	1-14 No UVa science methods classes	14 SSU class ends
20 UVa and SNC classes begin	20 UVa and SNC classes begin	12-26 Collaborative papers due	1-26 SSU team presentations	
	10 First UVa/SNC Internet collaboration	12-31 No UVa science methods classes	6-9 SNC team presentations	
	10-17 E-mail introductions for 3 schools	14-31 SSU team presentations	9 SNC class ends	
	17 Second UVa/SNC Internet collaboration		16-30 UVa team presentations	
	24 Third UVa/SNC Internet collaboration		30 UVa class ends	

Table 2. TEACH Collaborative Timeline for Semester 1

June - August	September	October	November	December
6/1-6/3 Reflection on 1st semester; refinement of 2nd semester project	3 SSU class begins	1 1st live collaborative session with SUNY-Cortland and UVa	2 Optional night seminar	1-14 All team presentations
7/21, 8/13 & 8/31conference calls to plan for 2nd semester project	30 UVa and SUNY-Cortland classes begin	5 Optional night seminar	9 Optional night seminar	14 Final Collaborative session
	13-17 Introduction to project	12 Optional night seminar	16 Optional night seminar	
	15 - Register on Blackboard.com, complete online survey and introduce team member via discussion board	20 2nd live collaborative session with SUNY-Cortland and SSU	17 3rd live collaborative session with SUNY-Cortland and SSU	
	21 Optional night seminar	22 2nd live collaborative session with SUNY-Cortland and UVa	19 3rd live collaborative session with SUNY-Cortland and UVa	
	29 1st live collaborative session with SUNY-Cortland and SSU	25 Individual State papers due	22 Collaborative state papers due	
		26 Optional night seminar		

Table 3. TEACH Collaborative Timeline for Semester 2

Initially, the students were introduced to the project via their instructor. Each faculty member gave a brief description of the six science education topic areas: standards, diversity issues, assessment, curriculum resources, teaching methods, and integration across content areas, for students to investigate; and the students selected the topic of most interest and created the state and cross-state teams. The students assigned themselves to one of six groups by placing their name on a sign-up sheet under the topic of interest. Each state team had a counterpart team at each of the other two locations. These three state teams formed the cross-state teams. For example, the New York group investigating state science standards would also work with the Virginia and Maryland groups that were also investigating state science standards. Each cross-team group was required to work together to develop a question (or questions) on their topic and then conduct an investigation at a local and state level. Teams accomplished this in a variety of ways including: classroom teacher interviews, principal interviews, education faculty interviews, reviewing state and local documents, and reviewing journal articles. Virtually the same process was used during the second semester. The topics were modified and one school was different but all else remained unchanged.

The Live Collaborative Sessions

Since the groups from Virginia and Wisconsin were able to arrange for the use of collaborative technology and a common time to conduct collaborative lessons in real-time over the Internet, they planned three live Internet-based collaborative class sessions during the first semester. Each of the sessions contained a PowerPoint presentation for part of the presentation so that copies of the PowerPoint materials in either HTML or native PowerPoint format and any supporting materials could later be shared with the Maryland group. During the second semester, three live Internet-based collaborative sessions were planned as well.

For the second phase of the project, class schedules only allowed fpr collaboration between schools at a time: SSU/SUNY-Cortland abd UVa/SUNY-Cortland Dr. Klein (SUNY-Cortland) split her class into two separate groups. One group would meet online with Dr. Weaver's (SSU) class on Wednesday during a collaborative week. The other half of her class would meet with Dr. Matkins (UVa) on Friday of the collaborative week. Approximately 45 minutes of live collaborative teaching was possible during each session.

During semester one, the three collaborative sessions included an introductory session, a session that focused on gender issues in science education, and one that focused on alternative assessment in science education. The introductory session included an overview of the project and a review of team responsibilities. This session, which included a PowerPoint presentation, was facilitated by both instructors. During semester 2, the introduction was done at each individual institution by each professor with no live collaboration. For both the first and second phases a session on gender issue and alternative assessment was conducted.

Dr. Matkins (UVa) led the gender issues session, which focused on her research about the lives of six women scientists. It included a reader's theater-style presentation of case studies. Six students, three from each location, played the part of the six women scientists in this interactive session. Following the case study presentation, the instructor facilitated a discussion, using a PowerPoint discussion outline, about gender issues in science education.

The session on alternative assessment led by Dr. Klein (Phase 1 - St. Norbert, Phase 2 SUNY-Cortland). Students were asked, via a listserv posting, to read a section of an online resource about alternative assessment. In this session college students reviewed samples of answers to an open-ended question created by fifth grade students. Students at each location created scoring criteria to evaluate the answers and shared their approach to the process and their results using the collaborative technology. This was followed by a discussion, using a PowerPoint discussion outline, on alternative assessment strategies for use in elementary science teaching.

During semester 2, Dr. Weaver (SSU) conducted a session that focused on using children's literature as a catalyst to begin the inquiry process in elementary school science. Once again a PowerPoint Presentation was created to emphasize key points. Students were introduced to the topic and instructed to use the science processes to design an investigation. Students were also provided with a rationale for using literature to teach science. During the collaborative session between SUNY-Cortland and SSU, Internet connection problems prevented a successful collaboration. However, in the session with SSU and UVa successful collaboration occurred.

Student Research Teams

Student teams in each state were required to develop two documents. One was a short paper on the selected issue and the ways in which that issue was addressed in their state. The second document was a summary paper developed by the cross-state teams on the same issue topic. All papers were intended for posting on the TEACH web site. Instructors established a series of due dates for each stage of the project. During the initial semester, variations in due dates were unavoidable because of differences in school schedules and in class duration. The Wisconsin class did not meet for the last third of the semester, the Virginia class met sporadically during the mid-point of the project due to prior arrangements with a social studies colleague, and the Maryland institution held spring break during the most intense document-sharing flurry of the project. These differences in institution and class schedules added to the potential for difficulties and frustration of the students as they were trying to collaborate on their cross-state summary papers. Many of the problems associated with different calendars were eliminated during the second semester. Dates were more closely synchronized as delineated in Table 3.

During the first semester, the student cross-state teams communicated primarily via email, listserv, and chat rooms. The listserv was created and set up by the faculty coordinators to initiate student communication and to allow the coordinators to monitor communication. During the second semester a class site was established on Blackboard.com. to facilitate further communication. This site hosted a discussion board as well as other features that enhanced communication between instructors and students at all three sites. Many of the students decided to communicate on their own directly via email and also by setting up chat room communication. Students at all three locations experienced email difficulties such as problems with sending attachments, and with sending messages to the whole group when a more narrow audience was intended. This worked itself out as faculty and students coached other students using a "just-in-time training" model.

Conclusion

The TEACH project effected change in the faculty involved in the project. Faculty involved in the project, Drs. Matkins, Klein, and Weaver, developed more sophisticated problem-solving skills as the collaboration progressed. They worked with three variations of technology, and guided their students through the team collaborations. PowerPoint presentations lent themselves to NetMeeting sharing, so faculty developed PowerPoint presentations. A common site for references and class notes was needed, so a faculty member accessed her university's class web site and established a class web page for student and faculty access. This type of sharing was further enhanced during the second semester via the Blackboard.com site.

The three faculty members became more confident and fluent in ways to use technology for instruction and collaboration. They learned to move smoothly from a question and answer portion of the class to a PowerPoint presentation and then on to use of a Netscape-accessed web site – all focusing upon the topic of the day. An aspect of the problem-solving strategies developed was the development of multiple "fall-back" technologies as the semester progressed. Faculty guided the students through a succession of telecommunication strategies, from listserv to email, then fax to phone. When one option failed, another was found. Frustration due to technology glitches and the unfulfilled assurances of technology support staff was often coupled with the TEACH team's exhortations to each other for patience.

Even though the audio connection during the live sessions could have been better, the audio, such as it was, proved essential to the live collaboration. The speakerphones at Maryland and New York and the full-duplex phone at Virginia could be depended upon if everything else failed. Faculty would maintain the class discussions through the use of the speakerphone until the connection was re-established. While other systems were being rebooted and brought back on screen, the class could continue to talk and listen to each other.

In taking on this project, faculty accepted a myriad of challenges with management of the project. Initially, each of the faculty members was on a different semester schedule, and only one of the three faculty members had a three-credit full semester course. One faculty member taught science methods in an integrated course with mathematics, and the another taught science methods in an integrated course with social studies. It was necessary to negotiate not only with each other, but also with other faculty at the university. Table 2 illustrates the variations in start time, spring break, and last day of class. For the collaboration to occur, school must be in session at each collaborative site. Also to facilitate synchronous collaboration, classes must meet at the same time. The changes that occurred during the second semester allowed for these necessary components. Time zone changes must be accounted for, as these faculty discovered in their first (abortive) attempt at a conference call. One reality of video and audio collaboration is the need for real-time coordination; and variations in class schedules and class meeting times must be accounted for in planning for the semester's collaboration.

Though student collaboration was the intent of the project, purposeful faculty collaboration served to diminish the sense of isolation of the faculty involved. Each was either the only science educator or the only elementary science educator at their institution, and each had the responsibility of delivering a quality course that had the potential to effect change in a mostly traditional audience of mainly young, white females.

An important aspect of faculty outcomes must be seen in terms of its potential effect upon students; that is, the modeling throughout this project by female faculty of relevant problem-solving with technology. A recent AAUW study (Online) cited the differences between girls and boys in choice of computer classes. Girls are more likely to choose clerical-type classes (e.g., word processing), and boys are more likely to choose advanced classes (e.g., graphics design). By participating in TEACH, the females in the class not only developed technology strategies to meet their collaboration assignments, but they also observed their professors working through challenges with advanced technology. Students even helped faculty with the use and adaptation of the technologies employed.

The TEACH project served as an initial step in preparing teachers to access and use technology for collaboration with colleagues across geographical and philosophical boundaries. Both elementary science education faculty and elementary education students reported a diminution of a sense of isolation from other educators. Faculty and student interactions revolved around science reform topics: diversity issues, standards-based education, assessment, teaching methods, integration of subjects, and curriculum resources. Authentic, purposeful assignments were the motivation and the vehicle for collaborative examination of science education reform topics. It is through such projects that teachers have the possibility of developing professional attitudes, practices, and habits that will enable them to be leaders in science education reform.

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SciLinks: Linking Technology and Scientific Inquiry

Gregory A. Coverdale, Ph.D.
Department of Behavioral Sciences and Education
Penn State Harrisburg
United States
gcoverdale@earthlink.net

Abstract: Because of the ever-expanding emphasis on technology integration in today's schools, and because of technology standards established by NCATE, it has become more important than ever that preservice teachers graduate their programs with a high level of technological literacy. Currently however, technology training for preservice teachers is generally inadequate. This paper will establish a rationale for technology integration in teacher preparation courses, and describe a new technology-rich science textbook that enables preservice teachers to access the Internet more easily via a program called SciLinks.

Introduction

In his classic treatise on education, *Schoolteacher: A Sociological Study*, Dan C. Lortie (1975) described teaching as an occupation with limited mediated entry. Beginning teachers are immediately responsible for all classroom interactions and are socialized into the profession in a "learn by doing" approach. Novice teachers rely heavily on their apprenticeship of observation experience; that is, they look at teaching through their experience of having been a student (Lortie 1975). In his seminal study, Lortie (1975) found that teachers viewed teaching as characterized by anxiety and isolation, and as a private rather than a shared experience. Thus, socialization into teaching is largely a self-socialization process and teachers tend not to adopt a practice unless it fits with their established way of doing things. Since most preservice teachers lack any significant apprenticeship of observation in the area of technology, they are ill-prepared to think about technology as a tool in their own teacher preparation and later practice.

The above view of teaching is closely juxtaposed with many classrooms of today if one considers issues of technology integration across K-16 curricula. Despite an almost fanatic enthusiasm about technology in popular culture, many American classrooms still lack an adequate approach to technology integration. Thus, one current view of technology integration in preservice teacher training is characterized as follows: despite the abundance of technology in schools across the country, we seem to "live in the best of times, and in the worst of times" (Rogers 1996). The best of times viewpoint is widely represented by those who purport children of today as net-savvy, techno-kids who devour a cornucopia of emerging technologies in their schooling and entertainment worlds. Tapscott (1998) describes these youth as the *Net Generation*. The "worst of times" scenario is described by the literature on actual teacher practice, which indicates the inadequacies of teacher preparation for technology integration (NCATE 1997; Rosenthal 1999).

Clearly, the literature describes a digital divide in today's schools. Because many practicing teachers are ill-equipped to narrow this divide (Cuban 1993; 1997; Rogers 1996; Viadero 1997; and Stoll, 1995) technology training has become paramount in teacher preparation programs. How well are today's preservice teachers being prepared to integrate and utilize information technology? Some education schools are on the "vanguard" (NCATE 1997 in Rosenthal 1999, p. 22) of preparing teachers for technology integration across their curricula. However, most colleges of education are currently inadequate in their technology training programs. Thus, most preservice teachers enter their professional semester with limited views of technology use. This is not surprising since only two states, Vermont and North Carolina, require any evidence of student proficiencies in integrating technology into their teaching experience (Rosenthal 1999).

Those tech-savvy preservice teachers who do integrate information technology into their teaching via a variety of emerging technologies, are able to diminish Lortie's notion of teachers working in isolation because their curricula and colleagues become global in scope.

This paper will first explore the rationale for integrating instructional technology in teacher preparation programs. Next, the paper will describe a new type of technology-rich textbook that helps science teachers enrich and extend their curricula through utilizing embedded Internet links called SciLinks. Finally, the paper will examine specific examples of SciLinks that preservice teachers used in response to an environmental education scenario presented in their coursework.

Rationale

The National Council for Accreditation of Teacher Education (NCATE) has developed strong recommendations for strengthening technology integration in teacher education programs. NCATE's (1997) report, *Technology and the New Professional Teacher: Preparing for the 21st Century Classroom*, establishes a strong rationale for increased technology use in teacher preparation programs. This rationale is based on two assertions: (1) that technology is not just 'a tool,' but that it has significantly changed the nature of academic work; and (2) that teachers need to gain technological expertise in order to utilize emerging technologies to promote better learning (NCATE 1997).

The International Society for Technology in Education (ISTE) continues to develop and refine its National Educational Technology Standards for students which when fully implemented, will facilitate school improvement vis-à-vis technology integration (ISTE 1998). Similar to the national *Benchmarks for Science Literacy* (AAAS 1993), the ISTE standards outline what students in grades preK-12 need to know and be able to do in order to demonstrate technological literacy.

The National Science Teachers Association (NSTA), in conjunction with Holt, Rinehart and Winston Publishers, is developing an innovative, practical approach to assist students and teachers in meeting goals and standards established by NCATE, and ISTE. Holt, Rinehart and Winston has produced a series of science textbooks that blend two of the major paradigms in today's classrooms; textbooks and telecommunications (Editor, 1999). These new textbooks promote technology integration by embedding URLs called SciLinks into the textbooks. SciLinks are found in the textbook margins and enable students and teachers to enrich text material and major scientific concepts by linking directly to extensive and "instructionally rich" (Editor 1999, p.5) Internet resources. "SciLinks represents an opportunity to create new pathways to learners, new opportunities for professional growth among teachers, and new modes of engagement for parents (Editor 1999, p.5). The specifics of SciLinks will be described later in this paper.

In addition to technology Standards established by academe, the need for greater technological literacy in America's populace is outlined in detail by several scholars in the business world (Davenport 1997; Tapscott 1998; Dertouzos 1997; Lewis 2000; Gates 1999; Judson and Kelly 1999; and Bronson 1999). The following quote illustrates the central position of information technology to the business world, and by inference, to the education world:

> I don't see information technology as a stand-alone system. I see it as a great facilitator. And maybe most important, it's a reason to keep asking yourself the question-why, why,why (Paul O'Neill, Chairman & CEO of Alcoa, in Gates 1999, p. 295).

What does information technology facilitate? Simply put, its integration across K-16 curricula promotes a new, inquiry-based, collaborative way of learning (NCATE 1997; Author 1999; Bruce and Levin 1999; and Molebash and Milman 1999). In facilitating this integration, SciLinks may provide the necessary assistance to teachers that is missing in many approaches to technology integration. Many K-16 educators find technology difficult to use and too time consuming. SciLinks is a new curriculum tool that may provide educators the boost they need in order to use technology in new, creative ways.

> ...What teachers actually need is in-depth, sustained assistance as they work to integrate computer use into the curriculum and confront the tension between traditional methods of instruction and new pedagogic methods that make extensive use of technology (Panel on Education Technology 1997 in Schmidt, et al. 1999, p. 1469).

Course Participants and Program

In the Fall 1999 semester, 49 preservice teachers at Penn State University at Harrisburg utilized Holt, Rinehart and Winston's text *Environmental Science* (Arms 2000) in their science methods course. This text includes SciLinks Internet resources and was used primarily as a reference tool to support an inquiry-based examination of environment and ecology issues. These issues were organized around Pennsylvania's soon-to-be-adopted Environment and Ecology Standards. Students worked in collaborative research groups and utilized SciLinks to respond to scenarios such as the following:

> Camp Catherine and 1,000 surrounding acres are being cleared to make way for a new, single-family housing development. The development will require new roads and infrastructure, sewage and water lines, and communication infrastructure. The acreage to be developed currently includes agricultural fields and pastures, mixed forest, the Swatara Creek corridor, and extensive wetlands. Use SciLinks and other references to explore the impact that development will have on this natural area (Coverdale 1999).

Students utilized SciLinks, other Internet sources, and conventional written reports to research this scenario. Their findings were compiled into poster projects, PowerPoint presentations, and oral presentations. The students' findings were presented to teachers and students in two inner-city elementary schools. The issues raised by students' research were then the focus of Penn State Harrisburg's first Environmental Town Meeting, an interactive forum with a panel composed of experts from several Pennsylvania agencies and governmental departments.

SciLinks – A Description

To use SciLinks, students accessed the SciLinks web site at www.sciLinks.org. They registered as either "Student" or "Teacher," and entered the SciLinks access code found in the textbook margins. This linked students to science content and links to other topics related to specific topics. The list of related URLs has been screened by science educators for accuracy and age-appropriate content and pedagogy (Editor 1999). This screening process by NSTA ensures the URLs represent sound science and the database is continually updated to ensure sites are still active and appropriate. Below, I describe two specific SciLinks that students used to examine the scenario above.

Example 1

TOPIC: ecosystem factors
GO TO: www.scilinks.org
KEYWORD: HE035

Most students chose to research the ecosystems and wildlife habitats found at the Camp Catherine study site. Since the class had attended three field trips to this site throughout the semester, they had collected on-site data on habitats, water quality indicators in the Swatara Creek, and conducted a brief wetland study. Students used the SciLinks feature in their text to research various aspects of the scenario. Below is a brief description of SciLinks KEYWORD HE035 - ecosystem factors.

Entering HE035 into the SciLinks database links students to five URLs that provide background information on ecosystems. One specific URL is titled: *The Chesapeake Bay: Abiotic and Biotic Factors*. This site was particularly helpful to students' research because Camp Catherine and the Swatara Creek lie within the Susquehanna River watershed, all of which drains into the Chesapeake Bay.

Students reported the most useful menu for researching factors affecting the Chesapeake Bay watershed was found from within SciLinks HW035 at: clab.cecil.cc.md.us/faculty/Biology/Chesapeake/cb.html. The following links were provided in table form:

Introduction	The Chesapeake Bay Ecosystem
Submerged Aquatic Vegetation	Trophic Levels
Abiotic Components	Problems With The Chesapeake
Chesapeake Bay Geography	History of Chesapeake Bay
The Watershed	Excessive Sediment In The Bay
Food and Consumption	Common Life & Endangered Species

From these links, students focused their research on *The Watershed, Abiotic Factors, Excessive Sediment in the Bay*, and *Problems With The Chesapeake*. Because students had conducted field study at Camp Catherine, they utilized SciLinks to provide background information and specific science content about factors affecting the Susquehanna River watershed and hence the ecological health of the Bay. Much of the information found at SciLinks HE035 related directly to the Camp Catherine research scenario. For example, as students pondered the fate of the Camp Catherine wetlands, they discovered in SciLinks HE035 that even though wetlands comprise a small percentage of total land area, they provide habitat to a large percentage of unique and even endangered species. Students also discovered the major threat to wetland habitats: drainage for farmland and construction of housing developments.

The *Sediments* link confirmed student hypotheses about the effects of development at Camp Catherine: the Susquehanna tributaries would become more clogged with sediments that ultimately degrade the Bay, and increased runoff from development would contribute to Bay degradation due to heavy increases of fertilizers, oil runoff, pesticides, and possibly sewage runoff.

Finally, students learned through SciLinks HE035 that by destroying the Swatara Creek buffer zones to develop a housing community, a large portion of the Susquehanna watershed and the Bay would be degraded. However, students also learned that if the development *weren't* built, maintaining the status quo of Camp Catherine would not be enough to improve or *restore* the Bay.

Thus, students were able to triangulate their research data by comparing information from their field study at Camp Catherine, the textbook and other printed sources, and SciLinks sites provided within their Environmental Science textbook.

Example 2

TOPIC:	population problems
GO TO:	www.sciLinks.org
KEYWORD:	HE342

Several student groups felt that issues related to population growth fueled development and urban sprawl and thus examined SciLinks related to population issues. Below is a brief description of SciLinks HE342, population problems.

When students entered HE342 into the SciLinks database, they found four URLs dealing with population issues. Two sites contained information about U.S. and world population statistics. Important global environmental and development trends were depicted in maps, graphs, and diagrams. One URL was a link to the U.S. Census Bureau and was interactive in that it allowed students to analyze census data and predict the rate of the U.S. population growth.

Another Census Bureau site found at www.census.gov/www/index.html contained extensive information under the major headings of People, Housing, Business, Geography, and News. The Geography link directed students to dozens of related links including Geographic Information System data, geographic statistics, maps, charts, and even employment opportunities. Students used this site to research population statistics, land area, and the population density of Dauphin County, Pennsylvania where Camp Catherine is located. Several student groups also used this link to locate a list *of State Data Centers*, which provided a wealth of population and land use information about Pennsylvania.

Conclusion

Unless preservice students are better prepared to integrate technology across their curricula, the paradigm of under-utilized modern computers collecting dust in teachers' classrooms will continue. In order to improve teacher education for preservice students vis-a-via technology, teacher educators must do a better job of modeling technology integration. NCATE has provided a strong mandate to teacher education programs and will continue to be an influential force in forging more technology integration into teacher preparation.

Formal data on the utilization of the SciLinks program were not collected, as this was a pilot experience with this textbook. However, several informal interviews with students indicated that they enjoyed using this textbook, primarily because of the SciLinks feature. Many students stated that they realized the importance of technology integration but that when they prepared for class or wrote their own lessons, they were often inhibited by the time-consuming nature of searching the Internet for relevant material. SciLinks, because it was embedded in the text, was easier to use and saved students time as they researched several environmental issues. Students highly recommended that I adopt the text again.

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TEACHING EARTH AND SPACE SCIENCE: A DISTANCE LEARNING COURSE FOR DADE COUNTY FLORIDA TEACHERS

Paul Ruscher
Department of Meteorology, Florida State University
United States
Paul.Ruscher@fsu.edu

Alejandro Gallard[1], Jennifer Cherrier[2], Elizabeth Hancock[1], Fred Petrovich[3], Zandra Cerpa Bisha[1], William Lusher[4], Kimberly Ruscher-Rogers[4]

Abstract: This paper describes a new program of study for inservice teachers in Miami/Dade County Florida, for the purpose of developing more teachers interested in teaching middle school science. At the end of this interactive/distance learning program, teachers will have gone from an elementary/early childhood specialty to middle school science certification, helping to meet a critical shortage of teachers in this area. The community of teachers is dominated by females and the students they teach consist of the most heterogeneous population in the state, with many minority groups represented. This ongoing course is still evolving and the teachers are responding very favorably to this approach of combining instruction in pedagogy with scientific methods and ideas.

Introduction

In 1999, The Florida State University (FSU) established a Distance Learning Master's in Science Education Program, for teachers in Dade County Public Schools. Students enrolled in this program take a minimum of 33 semester hours, which include 21 hours of science education courses and 12 hours of science content (Florida State University Department of Curriculum and Instruction 1999). All courses of this program adhere to the following goals:

- Improve the science content knowledge of science teachers
- Improve the science pedagogical knowledge of science teachers
- Improve the learning of science in elementary and middle schools; and
- Assist science teachers in understanding issues underlying reform efforts in science education

The program is rich in the use of educational technology, requiring teachers to be active Internet learners, constantly upgrading their level of sophistication to include processing of scientific data, preparation of reseearch reports, and publishing reports on the World Wide Web (WWW). Field trips and occasional lectures are used to reinforce the department's desire to instill value to the implementation of constructivist thinking as teachers reinvent the way they teach, in addition to developing further competencies in new subject areas.

All courses are geared to the Miami-Dade Competency Based Curriculum as closely as possible. In August of 1999, a new course was established at FSU for this program, Teaching Earth and Space Science, for the inservice teachers. The complete list of courses is shown in Appendix A.

A New Course: Teaching Earth and Space Science

Teaching Earth and Space Science is a 3-credit course currently available only to the 120 students in the Miami/Dade County Public Schools Master's Degree in Science Education Program. The focus of the course is on how to teach earth and space science in middle school and in all courses in which earth and space science content is taught (e.g., general science, social studies, physical science, and physics), including elementary-level classes. Science teachers who enroll in this course will know how to teach earth and space science such that their students are able to:

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[1] Department of Curriculum and Instruction, Florida State University, United States
[2] Environmental Sciences Institute, Florida A&M University, United States
[3] Department of Physics, Florida State University, United States
[4] also at Department of Meteorology, Florida State University, United States

- Use scientific principles and processes appropriately in making personal decisions
- Experience the richness and excitement of knowing about and understanding the natural world
- Engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- Understand complex scientific issues that relate to environment and environmental policy

Earth and Space Science includes the traditional discipline categories of astronomy, geology, meteorology and oceanography. The fundamental concepts underlying the content standards of the National Science Education Standards (National Research Council 1996) are utilized to organize the course subject matter that is the focus of this pedagogical content course. Coursework organization which crosses traditional discipline boundaries assists teachers in developing interdisciplinary perspectives as well as helps students recognize the relevance of earth and space science in their daily lives.

This course examines earth and space science subject matter in a historical context and employs the variety of activities that can be used to promote learning of students in elementary and middle school grade levels. Students explore the subject matter knowledge of given topics and the historical development of those ideas while also investigating the alternative frameworks and misunderstandings usually brought with them to the process of learning. Such an approach has been utilized in the outreach programs in meteorology at FSU throughout the decade, beginning with the direct readout weather satellite program known as EXPLORES! (Ruscher et al. 1993).

Course Design

As with much of the Dade County Public Schools Masters' Program, Teaching Earth and Space Science is an on-line course. The course website is used by students, teaching assistants and instructors in all aspects of course presentation. Students can:

- Read announcements from teaching assistants and instructors
- View the syllabus
- Obtain course documents, such as handouts
- Submit assignments through a "Digital DropBox;"
- Take quizzes and surveys
- Communicate with other students through email, virtual chats and threaded discussion boards
- Access on-line learning materials such as text, audio and video files
- Dialog with dialog journal partners and develop personal almanacs of real-time earth and space science datasets

For the first semester (Fall 1999), students used an earth science textbook (Press and Siever 1998), an on-line meteorology text (University of Illinois 1999), a set of readings on ocean ecosystems (Cherrier 1999), astronomy resources such as *Cosmos* (Sagan 1983), as well as articles from scientific journals (Scientific American 1998) in their learning. In addition to these activities, students met with instructors face-to-face five times. At the onset of the semester, an instructor orients the students to the course format and online software. During the course of the semester, the students meet with instructors once during the teaching of each content area. During these meetings, students discuss homework assignments, participate in field activities and attend lectures.

Numerous field experiences are also incorporated into the course as part of the face-to-face meetings in Miami. The purpose of these experiences is to encourage teachers to gain some familiarity with their natural environment as well as extracurriculuar resources which can allow them to believe in their ability to use these resources in their own teaching. With the cooperation of numerous agencies and individuals, we have been able to participate in field experiences that provide teachers with realistic examples of how complex scientific issues are dealt with in the real world. Field experiences carried out for Fall 1999, the first semester of the course, included:

- National Weather Service Forecast Office, Miami
- National Hurricane Center, Miami
- Federal Aviation Administration Air Traffic Control Center and Center Weather Service Unit, Miami International Airport
- Atlantic Oceanographic and Meteorological Laboratory, Virginia Key
- Marjory Stoneman Douglas Biscayne Nature Center
- Broward Community College Planetarium
- Night Sky Watch in the Everglades

Among the locations, the new Marjory Stoneman Douglas center provided opportunities to integrate the various aspects of earth sciences rather well. Although originally picked as a site to carry out a beach walk (Figure 1), the site also afforded an exposed fossil coral reef (Figure 2), which facilitated discussions of climate change, geological processes, and meteorological processes (we were forced to evacuate the reef during a heavy rain squall, on a day in which only a 10% chance of precipitation was forecast).

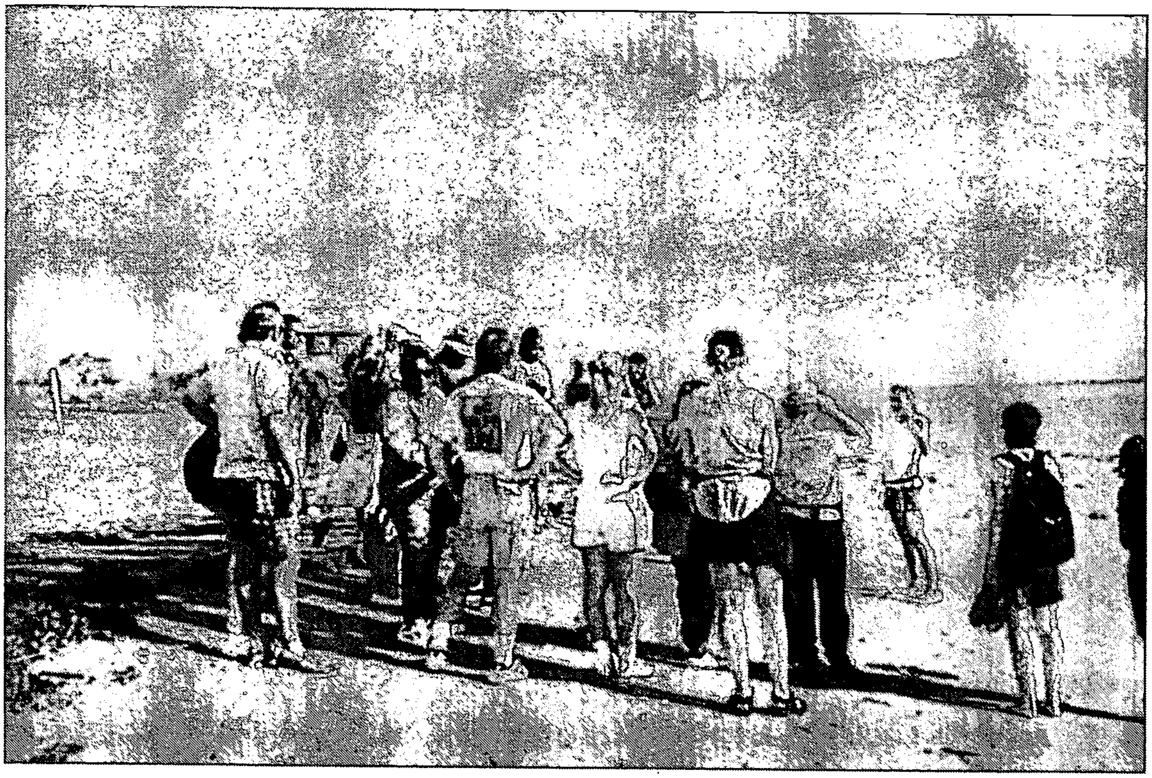

Figure 1 Teachers are guided on a beach walk of Marjory Stoneman Douglas Biscayne Nature Center in Dade County. In addition to being exposed to marine ecosystems and habitats, a variety of species were collected and studied, and meteorological and geological processes were discussed. Several of our teachers indicated they had brought their students out to this location previously, but had never realized the richness that the center offered for a wide array of earth science topics.

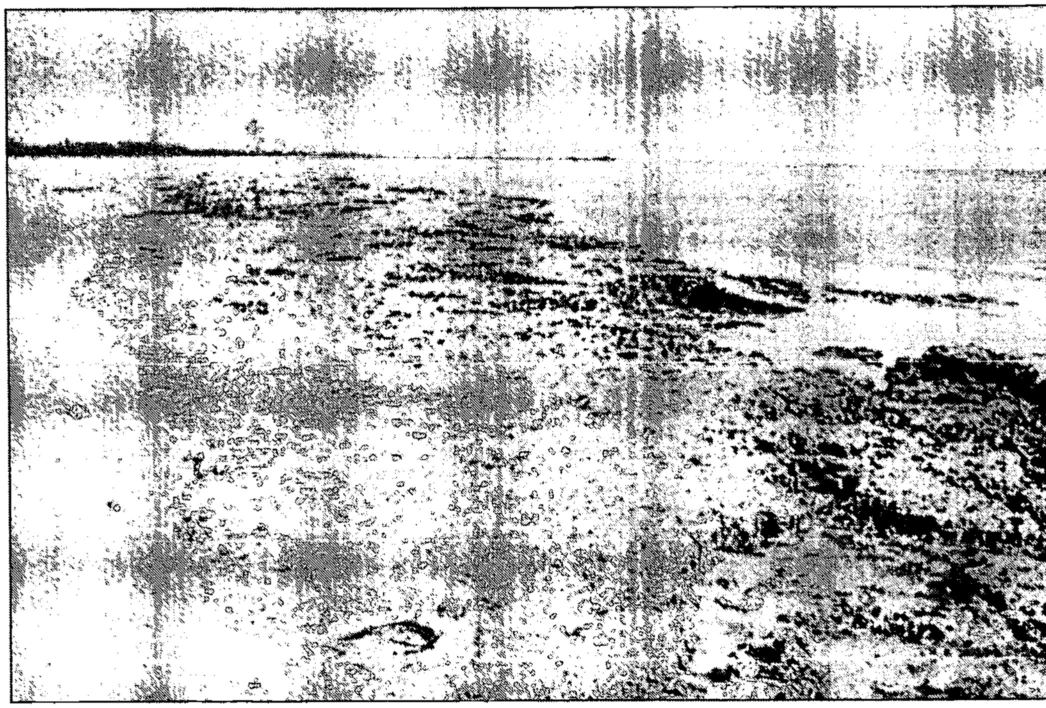

Figure 2. At the end of the beach walk discussed previously, an exposed fossilized coral reef is present. In addition to tide pools, discussions of coral bleaching, limestone formations in other parts of the county, and climate change were facilitated before heavy precipitation occurred.

Course Assignments

Students complete three major assignments in one semester. The first is a term paper, based on one of the four core subject areas. This project is done individually, and reviewed by an instructor and at least two peers. The next assignment is the creation of a WWW site, which is a follow-up to the term paper. Students create their web sites in groups, and are required to include graphics, text and links. These web sites are meant to be meaningful to educators seeking information on earth and space science teaching. The next activity is also conducted with a partner; students create lesson plans for a week of earth science classroom activities. These plans are on a topic different from the web and paper topics. The plans do reflect the content covered in the course.

There are other assignments, done on a smaller scale in the course. Each student is assigned a dialogue journal partner. These journal pairs are required to communicate weekly in their journals. Also, students create almanacs of astronomical, geological, hydrological, oceanographic and atmospheric data. These data are obtained via on-line and newspaper resources. Also, students submit homework problems via the course web site and also while visiting with teachers. Formative and summartive assessments are used to collect data on the effectiveness of communication and learning. Most of the teachers are practicing elementary school teachers and have had little formal training in science classes, so we try to incorporate active investigations of scientific topics of interest. Some of the primary integrating topics used in the Fall were Hurricanes and the El Niño/Southern Oscillation phenomena (University of Illinois 1999). A recent report providing evidence for the success of this type of approach is given in Kielborn and Gilmer (1999).

Future Plans

This course will be taught throughout the year 2000 for Dade County teachers, and beginning in the Fall of 2000 it will be taught on campus in Tallahassee for preservice as well as inservice teachers. This course will be offered annually thereafter on campus for both inservice and preservice teachers in FSU's Colleges of Education and Arts & Sciences. One of the challenges facing instructors will be the recreation of field experiences that are done in an organized manner at a level consistent with the Dade County teachers, but would be difficult to reproduce for the benefit of teachers in other physical locations. To replace the intensive field experiences that are only available in Miami, Tallahassee teachers will visit the State of Florida Emergency Operations Center, the National Weather Service office in Tallahassee, and the Florida Geological Survey, as well as local science and natural history museums and field sites (sink hole, sandy beach, estuary). In addition, extensive use of the GLOBE program's teacher's guide

(GLOBE 1997) and suggested activities will be made, and all preservice teachers will become certified GLOBE teachers, enabling them to bring substantial field experience in taking valid scientific observations with them. Since 1994, the GLOBE program (http://www.globe.gov/) has been providing teachers at all levels in primary and secondary schools worldwide opportunities to train students in the collection of data that scientists can use. It is hoped that this type of training can augment or replace field experiences for those teachers who take such a class, in a locale where intensive field experiences at government facilities are not possible.

For the 2000 offerings, we will also incorporate more video clips and utilize more point-to-point video conferencing. One of the significant shortcomings for the first course offering was the limitation on interactivity. Only during the visits by faculty to Miami did the teachers feel like they were as actively engaged as they would have liked. To some extent, some of the web-based development and labs they used also engaged them actively. These traditional students still felt a lack of direct teacher-student interaction; the interactions through electronic mail were insufficient to capture the spirit of a traditional teacher-student exchange. Further evaluations will be shared at the conference, once data from Fall 1999 has been collected and analyzed.

Although the course web site is restricted to registered teachers and students, a mirror of it will be online in January 2000 at http://www.met.fsu.edu/Classes/SCE5635/, and it will be demonstrated during the presentation (Figure 3).

Acknowledgements

This work is supported by grants from the National Science Foundation Urban Systemic Initiative and Geosciences Directorate (GEO 980193) to Florida State University. Support is also acknowledged from the Departments of Curriculum & Instruction and Meteorology, in the Colleges of Education and Arts & Sciences, respectively. We also gratefully acknowledge the staff at each of the centers we have visited during our Fall 1999 session for the outstanding job done.

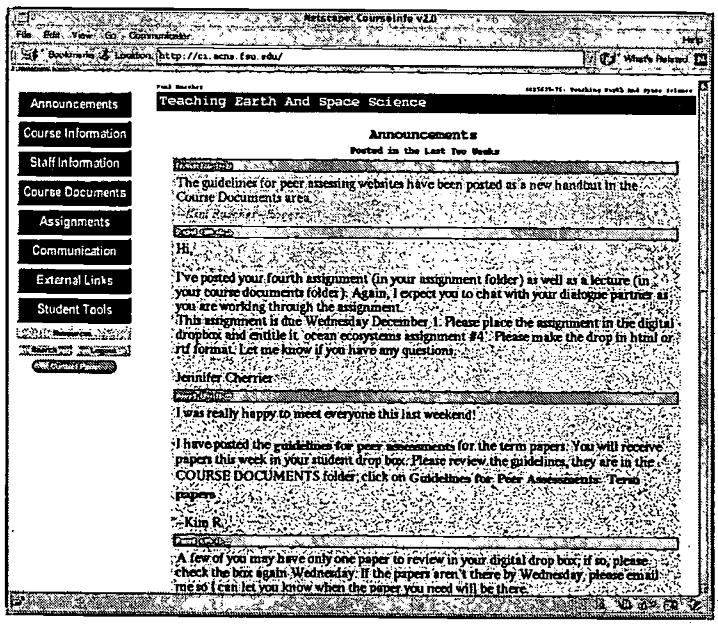

Figure 3. Course web site as seen by registered students and faculty.

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Appendix A:
The FSU/Dade County Graduate Science Education Program

First Summer 1999 – direct instruction in Miami for 4 weeks, strong online component

- SCE 5635r Florida Ecosystems (3 semester hours)
- SCE 5920r Colloquium (1) Technology, use of the web.
- SCE 5340 Teaching and Learning Science (3)

Fall 1999, Spring 2000, Fall 2000 – students rotate through these 3 courses in groups of 20 (2 sections per term) – completely online with some faculty-directed field experiences and lessons

- SCE 5740 Research Methods in Science Education (3)
- PHY 5940 Physics Teaching (3)
- SCE 5635r Teaching Earth and Space Science (3)

Second Summer 2000 – direct instruction

- SCE 5140 Curriculum in Science Education (3)
- SCE 5920r Colloquium (1) Current trends in science teaching.
- SCE 5635r Marine Biology (3)

Spring 2001

- SCE 5623 Conceptual Learning in Middle School Science (3)

Third Summer 2001 – direct instruction

- SCE 5695 Science Education in Developing Countries (3)
- SCE 5715 Conceptual Learning in Elementary School Science (3)
- SCE 8966 Master's Comprehensive Examination (1) *or*
- SCE 8968 Specialist Comprehensive Examination (1)

Exploring With Computers in Chem Class

Ron Poirier
Science Department
Toll Gate High School
Warwick, Rhode Island
poirierr@ride.ri.net

Abstract: Since 1997 the RITTI program has provided 25% of all public school teachers in the state of Rhode Island with a laptop computer and two weeks of training in its use in the classroom. This paper is an attempt to chart the impact of this program on the classroom practices of four science teachers with particular attention being paid to teachers of chemistry. The author will also document his experiences in incorporating this technology into his own chemistry classes.

Introduction

The Rhode Island Teacher Training Initiative (RITTI) began back in the summer of 1997 as a privately funded program to train public school teachers in the use of computers and software in the classroom. Over the course of three summers, 25% of all public school teachers (approximately 3000) were trained over a two week period. This training consisted of lessons in the basic care of computers; the use of various pieces of software including Office '97, Netscape, and Eudora; and skills such as basic web page design, the use of mailing lists as sources of information, presentation software in class, the use of image and audio processing, the use of search engines, and projection techniques. As a climax to the two week period, each teacher was to have generated a standards based classroom unit that would be used in the next year in his/her classes. These projects can be found and downloaded from www.ed.uri.edu/rif99/. As a part of this program, each teacher was issued a new Toshiba or Macintosh laptop (participants' choice). These participants went back to their classrooms with experience, enthusiasm, and equipment that would enable them to infuse in their students a spirit of excitement and inquiry. The hope was that the teachers would generate an enthusiasm for the use of computers in the classroom that would be contagious and would help the level of technology to achieve a "critical mass", making this new technology a self-sustaining and perhaps ever expanding component of the educational scenery.

During the summer of 1998, I was a trainer at the Woonsocket, Rhode Island training site. I saw first hand the enthusiasm generated among the participants of this program. Last summer I was chosen to be one of 12 RITTI Fellows statewide who were charged with studying the impact of this program and the influence of technology on the learning experience of our students. For my study I chose to research the field of high school chemistry and physics education. This included a search on the Internet of the results of studies on the effectiveness of Instructional Technology in the classroom, a study of the projects written by previous RITTI participants, and interviews of those participants. This research led to some interesting findings. In a study from Washington State (The Gates Foundation Teacher Leadership Project Evaluation Report – July 1, 1999), only 27% of high school science teachers indicated that student learning had moderately or substantially increased because of (computer) technology. In searching high school science classroom web pages, I found examples of sites that ranged in utility from "How can I teach without this?" to "Not much of an improvement over a textbook and bulletin board". For various reasons RITTI participants responding to my questionnaire gave mixed results in their success at integrating computer technology into their classes. One teacher in particular impressed me with the extraordinary changes he has made in his methods and with the subsequent increase in interest on the part of his students.

Explorations

Can education take place without the use of Instructional Technology? Absolutely. Can education improve with the use of Instructional Technology? Once again, the answer is a definite yes. The essential question becomes "How can education improve through the use of Instructional Technology?"

One of the frustrations encountered in exploring the ways in which instructional technology can be used to improve education is the polarization of opinions and of research outcomes relating to the effectiveness of classroom use of Instructional Technology. The following is a list of changes in the relationship between teacher and student that accompany the introduction of Instructional Technology in the classroom as reported in a 1998 T.H.E. report:

1. Technology increases student motivation, and motivated students are more receptive, more engaged, and more likely to learn.

2. Technology promotes cooperation and collaboration among students, and good teachers can capitalize on these opportunities. Cooperative learning approaches with technology give students with different talents a chance to excel.

3. In classrooms with computers, conversations between teachers and students and among students themselves become deeper and more probing.

4. Technology use encourages teacher-as-facilitator approaches.

5. Technology promotes a "balance of power" between the teacher and his or her students.

6. With technological tools, students show more persistence in solving problems.

7. Technology encourages varied methods of assessment.

8. Despite all the challenges of a one-computer/one Internet-connection classroom, even this classroom environment enables good teachers to work effectively with diverse students.

9. Technology fosters increased and improved oral and written communication.

10. Technology enables opportunities for more depth of understanding, but the breadth of the curriculum is still problematic.

11. Technology provides increased opportunities for thematic, interdisciplinary explorations; teachers can use these interdisciplinary connections to further engage and excite students.

12. Technology makes classroom activities "feel" more real-world and relevant, and students often take these activities more seriously.

(McGrath 1998)

As a counterpoint, the following teachers find Instructional Technology lacking when it comes to helping students to understand the function of mechanical devices:

> -"Listen to Tom Henning, a physics teacher at Thurgood Marshall, the San Francisco technology high school. Henning has a graduate degree in engineering, and helped to found a Silicon Valley company that manufactures electronic navigation equipment. 'My bias is the physical reality,' Henning told me, as we sat outside a shop where he was helping students to rebuild an old motorcycle. 'I'm no technophobe. I can program computers.' What worries Henning is that computers at best engage only two senses, hearing and sight -- and only two-dimensional sight at that. 'Even if they're doing three-dimensional computer modeling, that's still a two-D replica of a three-D world. If you took a kid who grew up on Nintendo, he's not going to have the necessary skills. He

needs to have done it first with Tinkertoys or clay, or carved it out of balsa wood.' As David Elkind, a professor of child development at Tufts University, puts it, 'A dean of the University of Iowa's school of engineering used to say the best engineers were the farm boys, because they knew how machinery really worked.'" (Oppenheimer 1997)

In addition, some evidence exists to show that the incorporation of technology in the classroom actually lowers some assessment scores:

> "Increasingly, schools are encouraging students to use computers in their writing. As a result, it is likely that increasing numbers of students are growing accustomed to writing on computers. Nevertheless, large scale assessments of writing, at state, national and even international levels, are attempting to estimate students' writing skills by having them use paper-and-pencil. Our results, if generalizable, suggest that for students accustomed to writing on computer for only a year or two, such estimates of student writing abilities based on responses written by hand may be substantial underestimates of their abilities to write when using a computer." (Russell & Haney 1997)

Some of my colleagues feel a bit negative about the prospects of fostering the use of Instructional Technology in the classroom. Implementing projects involving the use of Instructional Technology involves a great deal of effort on the part of teachers and there is a constant struggle to avoid slipping on those comfortable old sneakers of worksheets and quizzes that are so convenient from a preparation perspective. This struggle also involves working to overcome the institutional inertia mentioned by Vin Doyle in a recent monograph by Roland Barth - "It seems that when the status quo is threatened by anything new, an immediate systemic defense mechanism comes to life. Even when people appear willing to try something new, they eventually revert to the status quo." (Barth 1999).

Despite the caveats expressed above, Instructional Technology has been growing over the years. Part of the reason is the way communication has changed among the stakeholders in children's education. More and more schools are replacing the repository of paper called the teacher's mailbox with e-mail. This has the advantage of minimizing both the handling of physical paperwork and the mountain of "important documents" on the teacher's desk. It also saves much time that would otherwise be spent by an increasingly frazzled clerk on "stuffing duty." In addition, some of the matters that we consider to be crucial to discuss in departmental meetings are conducted via e-mail. This has the effect of reducing the amount of time spent in group meetings that could be spent more fruitfully on topics such as using new software, generating meaningful inquiry topics, incorporating research projects into the curriculum (or the content of the curriculum itself), etc.

Communication among colleagues within a building is also facilitated in this manner. It is much easier to send an e-mail note to a fellow teacher regarding the usage and placement of stage lights for a particular production for example than to try to track down which corridor that teacher is assigned to on that period during that day in order to get the same information. We can all think of dozens of instances where interruptions occur in our daily routine just to deal with minor points that could be dispatched more efficiently through the use of the technology that we have available to us.

Communication with students is enhanced with the current technology. Students are using computers to e-mail their teachers for clarifications on assignments. They are also using web pages to gather materials (as enrichment activities or as missed assignments when they are out because of illness or field trips). Teachers are noticing a trend among students to keep in touch over vacations and after graduation via e-mail. We know that as teachers we often establish relationships with students that reach far beyond the school year. I treasure the short notes I get from graduates from years ago just saying hello and asking how things are. This trend has accelerated since the beginning of e-mail

Communication with parents has shown a marked increase in the past few years. In order to inquire about a student's performance in class a parent had to call the school, leave a message for a call-back, and wait. The teacher would do his/her best to call back, usually speaking with at best an answering machine but usually getting no answer. This might be followed with an evening call (making the teacher about as popular as a telemarketer) or worse, a morning call involving the attempt to communicate with a barely conscious newly-awakened parent or one who is hurriedly trying to get ready for a new day. Contrast this with a teacher getting a short e-mail inquiring about a student's performance. This is answered at leisure and with all material available. The prompt response is usually followed by an equally prompt thank-you on the part of the parent. Feedback is maximized, response time is minimized, overall stress is minimized. Again, this does not replace personal conferences or face-to-face contact, but it does ensure that developing situations can be defused quickly and perhaps with less need for interruption in the parents' daily routine.

Distance learning is a concept that has developed over the years to include much more than the early "You too can learn to be an artist at Matchbook Cover University – just draw the pirate shown...
to televideo courses whose daily presence on PBS is a source of no cost audits for those of us who want to learn a bit more about physics, chemistry, finance, statistics, or a smorgasbord of other offerings. Some of the RITTI Fellows participated in a distance learning course on the use of the web in the classroom. Granted the structure of the course and its content left a bit to be desired, but the idea is one which will surely catch on. Providence College offers 6 distance learning courses on topics ranging from creative writing to world religions.

Connection to the world wide web has enabled students to do original research in ways never before possible. My original view of this was limited to seeing the Internet as a library accessible to each student in every classroom. The students can at a moment's notice look up historical figures, such as Johannes Kepler, or report on famous controversies in the history of science (the Newton/Liebnitz controversy, the Darwin/Wallace issue, the discovery of oxygen by Priestley/Lavoisier/Scheele, etc.). My vision has expanded to include projects done by students across the country, across the world, and across cultural boundaries. Many students participated in the Monarch butterfly watch, which traced the migration of the Monarchs across the continent. Many students participated in a study of the development of tulips. This helped them to see the differences in climate and weather patterns over broad areas of the country. A rural North Carolina second grade class is developing a set of pen pals in a second grade class on a Navajo reservation in northern New Mexico. These sorts of projects and many, many others are being conducted world wide.

The nature of professional development is changing as well through the introduction of technology in education. A case in point is the RITTI Fellowship. The research for material in this paper was done largely over the Internet. This effort was made much easier by my membership in mailing lists such as the RA-CIA list (RA Curriculum, Instruction, and Assessment). The RITTI participants were expected to create a lesson that would involve the use of technology and would improve learning on the part of their students. The following paragraphs explore the work that some RITTI science teachers have developed. All the projects mentioned can be accessed via the RITTI site mentioned in the introduction of this paper.

Gerry Aissis created a learning environment in which students learned the mathematics and mechanism behind inheritance by studying the characteristics of superheroes that were listed online and by assigning genetic properties to those characteristics. The students then had to predict the characteristics of the offspring of various combinations of superheroes. This is a creative application of information technology in gathering information for a dramatization of an important biological topic. Gerry has found that his use of Instructional Technology has increased dramatically since the RITTI program. He reports that he wants to expand his project next year to include Pokemon characters.

Bob Springer created a great graphic representation on the reason chemical equations must be balanced by presenting animated graphics. The atomic-molecular model for chemical reaction seems to come alive in a way that would be impossible using textbook images. Bob says "I felt it (this project) enhanced the lesson and the visuals help the students connect better with the concepts."

Howard Lancaster is using the Internet to have his students gather information about the elements and the trends for certain properties in rows and columns. This is done as one activity out of four in a "round robin" fashion. He says he has a frustration with a shortage of equipment (hence the round robin format) but he feels that he is doing what he can with what he has. This unit has been improved and upgraded since 1998. Mr. Lancaster says that he has "... tried to use technology to encourage more peer instruction by forming small work groups to complete computer tutorial programs, internet searches for specific chemical information, and worksheet activities."

Gerald Lafontaine was a participant of RITTI-97 (the pilot year). He began his work by incorporating a computer station as a part of his Forensics class. This worked out well since at the time there was only one connection to the Internet possible in his classroom. The computer station was the place where students went to access the Forensics Web Page to access links to sites with forensic information about ongoing cases in the real world. This use has expanded (along with increased access to the Internet) to include his chemistry classes as well as Forensics. The depth of use on the part of his students has increased as well. These students can visit links that are topic specific. They can take practice tests, find review notes, and more. He has documented a marked increase in numbers of users at his site in the day or two before a test is given. Mr. Lafontaine remarks on the impact of Instructional Technology on his classroom experience:

> "My teaching has become more varied and interesting. For example, at first PowerPoint presentations were used simply as slide shows for note taking. Now I use them for reinforcement and enhancement of topics. The Internet links that I researched serve as a source of additional information that is not covered in the textbook. It added a more practical side to the topics covered. Using the testing program (Harris Test) gave students the opportunity to better prepare for tests. The pretests I wrote were great for preparing students for a test situation. I use Excel for grades. Students are now aware on a weekly basis of how well they are doing in class. By using a CD-reWriter, I was able to organize all my coursework on one CD. By adding to this every year, one can build a tremendous library of lessons and ideas to be used in the classroom. Using Web Whacker and a CD-reWriter, I captured some web sites in General Science and placed them on CD's."

Mr. Lafontaine's web page - http://hometown.aol.com/risa3025/FirstContact/firstcontact2.html - is a continually evolving source of information for his students. He uses his interests and his humor to introduce students to this site and to keep them coming back.

My own experiences are similar to those above. I started using a station or two in the classroom for Internet use. PowerPoint became the method of choice for presenting lecture notes. Word processors made the task of generating worksheets and quizzes a bit easier. As the facilities at the school have improved, so has the variety of uses of this technology.

When I began to introduce Instructional Technology on a larger scale and to a greater depth to my classes I felt that somehow the curriculum would be too restrictive to allow me the flexibility I needed to experiment with new techniques. The Performance Standards were something I would use to rate pre-existing activities or worksheets. (Let's see, that old periodic table worksheet addresses standards S1a and S1b). As I studied the triad of course curriculum, Instructional Technology, and New Standards, I came to see that properly applied they complement one another. As an example I recently tried working in a way that made much more sense from a planning standpoint. I began with the section in my curriculum that called for addressing chemical change. I went online and found an activity which (with modification) would introduce science standards S1b, S1c, S5b, S5d, S5f, and S7b. In this activity the students heated a sample of $Cu(NO_3)_2$ which released a reddish brown gas and formed a black ash as a residue. Heating the black ash in the presence of HNO_3 caused a reappearance of the original $Cu(NO_3)_2$ in solution. I had the students develop a rational explanation of the composition of the black ash and reddish brown gas. The students were allowed to use the Internet to find the properties of different substances, as well as other references (such as the CRC Handbook of Chemistry and Physics). As small groups they had to write down their conclusions and the reasoning they used to reach those conclusions. The students used a rubric to self assess their reports. After discussion of their findings, I used the same rubric to assess their work. I could tell from their reports that they were learning to think like chemists. This activity was the type of educational experience that I want my students to have more frequently.

I have been assigning more research topics for the students, and I have created a web page to help my students and their parents understand what is happening in our chemistry class (http://come.to/Poirier).

This web page contains a practice test on the current topic, links to other chemistry sites and a "Parents Corner," an open letter to parents describing the activities in class for the next two weeks and inviting them to e-mail me concerning their children. To introduce the students to this site I included pages on social activities (dances, concerts, etc.) and schedules for athletic events which are in season. Like Mr. Lafontaine, I have seen an increase in traffic at the web site on the days before tests. I have been using Rasmole (a program which allows students to view a variety of molecular models in various formats and in three dimensions) to show the students similarities in shapes of molecules. We will explore the relationship between structure and function in molecules in the not too distant future. Students use the Internet to do research. One valuable lesson my students learned this year was that the Internet was not the panacea that they might have thought. I created an assignment that was based on six products or processes that were used over 2000 years ago. The students were first to gather information on how these were related to chemistry and then to create a report for the class. The topics included manufacture of jewelry, dyes, ceramics, metals from ores, perfumes, and paints, as well as research on the process of mummification. The students seemed to enjoy not only the research, but also reporting their findings to the class. The one group that did not succeed was the group that was researching the production of ceramics. They could get no information via search engines on how the process originated or on the chemistry of ceramic manufacture. They did get an answer, but from a chance conversation over dinner with an artist and ceramics teacher from Pennsylvania. This is reminiscent of the "Old Way/Net Way" feature in Yahoo! Magazine. I encourage students to find and evaluate chemistry web sites that would help us in learning chemistry. With the growth in the number of students with Internet access at home (around 80% for my students), this is one approach for a teacher to have a multitude of eyes searching for more and better sources of information and ideas on the use of Instructional Technology in the chemistry classroom.

Conclusions

Instructional Technology has been with us for a while now. We can see that it can become a useful educational tool. With it learning can become more interesting and more challenging. It is important to realize that there are educational experiences that are best learned through the use of "tinkertoys and farm equipment". It is also important to realize that Instructional Technology (especially computers and the Internet) provides the students with opportunities that simply cannot be duplicated in any other way. Properly used it will lead to more and better learning on the part of the students. We, as professional educators, have to be willing to put in the extra effort which is required to produce an educational experience which is much more rewarding for our students.

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Field-Based Technology in Idaho Middle School Science Classes: An Evaluation of Performance and Attitude Data from Students

Dr. Martin G. Horejsi
College of Education
Idaho State University, Pocatello, Idaho, U.S.A.
martinh@isu.edu

Dr. Albert W. Strickland
College of Education
Idaho State University, Pocatello, Idaho, U.S.A.
strialbe@isu.edu

Abstract: This project collected student performance data on the use of portable computers and probeware in a pair of eighth grade earth science classrooms. Data addressing the subject-matter performance and attitudes of the students was collected before and after the technology integration. A unique opportunity was available to investigate the change in student performance due to a technology integration effort, and independent of the teacher's influence, was possible. Statistical comparisons were made between a treatment group and a similar control group class working with the same subject matter, and with the same teacher. Four earth science classes from two teachers were examined. This investigation suggests that the addition of certain technologies to an existing earth science curriculum will increase the performance of students on a subject-matter assessment. While much of the literature is limited to the speculation of an educational improvement due to certain technologies, this study offers significant findings based on research.

Introduction

The results of this investigation suggest that the addition of certain technologies to an existing earth science curriculum will increase the performance on a subject-matter assessment. With much of the current literature focused upon the speculation of an educational improvement due to certain technologies this study sought out research-based findings on the issue.

The most likely reason for a small body of statistical research in the area of technology integration efforts may be due to the inability of school districts to allow unequal distribution of technology resources within the same curriculum, grade, and teacher, however, the unique opportunity to investigate student performance and attitude change independent of the teacher's influence on the class was available for this study. Since each teacher had one experimental group class and one control group class, the influences of the teacher on that same teacher's control group and experimental group are the same.

A study by Campoy (1992) suggests a possible explanation for the lack of experimental research in educational technology, even in the face of the persistent view that technology can improve learning. Campoy states that teachers and administrators often have little understanding of the role of technology in the teaching/learning process. Furthermore, he states, teachers and administrators do not identify reasonable expectations for the use of the technology.

Tarwater (1992) continues this line of thought with the observation that the lack of reasonable expectations from teachers may be related to the teacher's own ineffective use of technology. The ineffective application of the technology may also be the reason that Paolucci (1998) found that a majority of the articles addressed technology applications, development, and implementation, but did not report findings on the use of technology that included student achievement data. Many articles in education journals offer advice and suggestions of how to integrate technology into the science classroom. However, very few research studies focused upon the measurable effects of the integration efforts.

In order to increase student learning in a predictable and efficient manner, research is needed. The successful integration and effective application of technology into the science curriculum requires more than good intentions. Formal research that tests a theoretical framework is imperative if technology integration efforts are to provide achievement gains that are reproducible and consistent. This study proposes to explore the relationship between a specific classroom technology integration effort and its direct impact upon student performance and attitude. Specifically, the study will attempt to ascertain if the use of probeware technology will impact student achievement and attitudes in science. Using a set of additional technologies applied in middle school earth science classes, performance data on subject matter performance and attitudes were collected and analyzed. The additional technologies include portable computers, probeware, digital cameras, Internet, and multimedia development software. These technologies are referred to as additional technologies because they go beyond the standard technology setup (personal computer, printer, and utility software packages) found in many school classrooms.

Data collection regarding technology use is important to the educator for many reasons. If further technology integration is anticipated, the foundation for the future integration should be based upon research. Ferdig and Weiland (1998) stress this point with, "There is a plain, one might say urgent need for a more complete approach to research on technology integration" (p. 1334).

Lowery (1997) describes upper elementary science students as good observers who are now ready to learn about cause and effect, and how to record data describing their relationships. Unfortunately, as reported by Bybee (1993) there are many reports offering reasons why the American public has lost confidence in our current science and technology education programs.

Treatment

The training of the teachers and students took place throughout the year as more technologies were incorporated into the science classes. In all cases, the teachers were trained in the use of the specific technology prior to the training of the students. Additionally, the students were trained exclusively by their teacher. While this researcher did observe some of the student training and student use of the technologies, the teachers were responsible for all the student training, and classroom management of the technologies.

The teachers participating in the project were given several hours of training on the use and troubleshooting of the probeware. Previous technology training unrelated to this project gave the teachers the necessary skills to operate the other pieces of additional technology implementation of the project required. Once the teachers participating in the project received training and the additional technologies, they began training the students in the experimental group how to use the equipment. The anticipated progress of the project is outlined the timeline. The timeline offered the teachers a sequence in which to introduce the additional technologies to the students in addition to the steps taken to evaluate the progress of the project.

The teachers began the project with the use of eight portable computers. The portable computers operated in a similar manner to the desktop models the students already had access to in the classroom, but the probeware was new to the students.

One particular probe was used by the students to learn the operation of the computer/probe interface. The probe was called an exercise heartrate. The exercise heartrate monitor allowed the student to measure and graph their own heartrate over time while doing various activities. While this probe was used extensively at first, it was not the focus of data collection for the project. Instead, it was just used for training purposes.

When each teacher believed the students understood the operation of the portable computer, and the exercise heartrate probe, each introduced the other probes available to the students for scientific data collection. At that point, the students practiced using the probes both inside the classroom, and outside the school. The teachers even had some of the students practice using the portable computers inside a dark closet to simulate using the equipment in a cave like what they might find at the Craters of the Moon area.

While most of the activities applied the additional technologies in the classroom, outdoor activities did supplement the indoor work. The most ambitious of the outdoor activities involved two fieldtrips to Craters of the Moon National Monument in south central Idaho. The first trip took place in late September, shortly after the teachers and student received the additional technologies. Since the additional technology was new to the students, taking digital images with the cameras dominated the outdoor activities. The captured images provided a large amount of material to work with once back in the classroom.

The second fieldtrip to the Craters of the Moon area occurred near the end of May. A late snowfall kept much of the Craters of the Moon area closed to the public until the middle of May. During the second trip to the area, students used the portable computers and probes to take temperature and light measurements in several caves; including lowering a 100-foot temperature probe into a volcanic cone to measure the drop in temperature per meter of depth. Hundreds of digital pictures were taken using the digital cameras. The students wrote detailed notes about all the pictures they took, as well as their methods of data collection using the probes.

Data Collection Method

The data collected during the first year of the implementation of the project included the geology pretest and posttest raw scores of the students in the experimental groups. A survey addressing technology attitudes was administered to the students in the experimental group both prior to the treatment and following the treatment. A geology posttest was also given to one additional class under the two teachers who are participating in the project. The additional student performance on the geology posttest served as the control group in the posttest-only control group experimental design.

Two different multiple choice tests were given to the treatment groups. The two measures each consisted of a 45-item multiple-choice test covering two constructs: Construct 1 addressed igneous geology and, Construct 2 addressed general earth science and biology. Woven into the constructs were questions addressing the interpretation of data, and the reasons for observed change. To insure a similar representation of constructs, each test had approximately half the questions representing each construct. The reliability of the geology test instruments was established through a Guttman Split-half analysis. The reliability coefficient of 0.73 was generated using the general geology pretest and posttest scores from the experimental groups of both teachers 1 and 2.

Results

A question of primary focus of this project was to see if a change in student performance on a geology knowledge assessment could be attributed to the inclusion of additional technologies into the existing curriculum. One set came from the groups of students who received the treatment of the additional technologies (the experimental group), and the other set of scores are from students of the same teacher in the same subject, except they did not receive the additional technologies (the control group).

The results of the ANOVA comparing pre-treatment and post-treatment change in attitude about technology indicates that no significant change took place due to the treatment. An F value of 0.1415 was found which is in excess of our alpha of .05. Therefore, the researcher failed to reject our null hypothesis that the introduction of additional technologies into the earth science curriculum will not significantly affect the student's attitudes about technology.

The survey data provided by the students offers some interesting results. In one case, a treatment group reported a lower desire for more technology even though prior to the treatment, they reported the highest desire to have more technology in the classroom. This result could be an indication of a point of saturation where the students prefer to use the existing technology instead of gaining more technology. The finding may also show that the continued introduction of new technology into the classroom may not continue to improve student performance, thus indicating a point of diminishing returns. If further research supports this line of reasoning, it may provide scientific data on which to pattern a timeline for technology integration.

Summary

The purpose of this study was twofold. First, the potential influence of additional technologies on the student performance on general science measures was examined using a posttest-only control group experimental design. Secondly, the influence of additional technologies on the attitude of students toward the use of technology in school was explored. Following a statistical analysis of the data collected by the project, the following results were found. Finding 1: The comparison of posttest data from the experimental group and the control group on the multiple choice geology instrument did yield a significant increase in performance of the experimental group following the use of the additional technologies by the experimental group. Due to this result, the researcher rejected the null hypothesis and concluded that the additional technologies significantly improved student performance on a subject-matter test. Finding 2: The attitudes of students about the role of technology in education did not significantly change following the inclusion of additional technologies into the existing curriculum. Due to this result, the researcher failed to reject the null hypothesis that the additional technologies will not significantly affect the student's attitude about the role of technology in education.

Conclusion

Based upon the results of this study, it is clear that, in certain applications of technology, student performance will be higher than if the technology was absent. As was mentioned above, most of the literature regarding technology integration does not address the effects of the technology, but rather the application or types of technology used.

The research base addressing technology in the classroom needs to encompass both the commonly found technologies and the more advanced classroom and field-based technologies. It is imperative that more research be done to explore the impact of educational technology. Without data collection during technology integration efforts, each effort becomes an isolated experiment with no contribution to the body of educational research. It is hoped that this study will be joined by others to continue building the body of research necessary to successfully and effectively integrate the powerful tools of technology into the classroom.

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Technology in the Service of Information Literacy and Writing Across the Curriculum: Our Experience

Reuben A. Rubio, Michael J. Michell
Education Department
Albion College
USA
rarubio@albion.edu, mmichell@albion.edu

Cheryl Blackwell, John P. Kondelik
Stockwell-Mudd Libraries
Albion College
USA
cblackwell@albion.edu, jkondelik@albion.edu

Beth Albery
English and Elementary Education
Albion College
USA
balbery@albion.edu

Abstract: To ensure that future generations are information literate, we must help future educators develop a clear understanding of how to do research, how to write a sound research paper, and how to translate it into quality hypertext. Our goal was to help the students see this as an authentic, long-term process, where their development was of considerable interest to us. We implemented a phased approach, based on the Information Search Process Model, to help them. We employed joint intervention from faculty and librarians, with milestones embedded in the assessment process. This allowed us to view, encourage, and guide their development.

Duckworth (1987) asks the thoughtful question, "what is the role of teaching, if knowledge is constructed by each individual?" (p. 112). Her answer is that the teacher should seek to put the students in contact with the *real* phenomena to be studied, and should ask the students to explain the sense they are making of it rather than telling them what it should be. As reflective practitioners with a constructivist approach to teaching and learning (Brooks & Brooks, 1996), this question and the family of answers that result are always in our minds as we shape and reshape our individual teacher preparation curricula. Recently, a group of us – faculty in the teacher preparation program and reference and information librarians – began considering how to address our unique but shared academic concerns about our students:

> Have you ever desired to teach your students how to craft a thoughtful research paper, one which is not just thrown together a day or two before it's due and never given another thought after having been graded and returned?
>
> Do you believe that the web can be a useful tool in doing research, but that most of the references your students provide from web sources are junk?
>
> How can we help our students construct good hypertext?

What follows is the short tale of our experience in addressing these concerns in the arena of an elementary education course for second-year students. We see both success and room for growth in our experiences, but more importantly we hope to encourage all who allow Duckworth's questions and answers to pervade their teaching to strive for a better way of utilizing technology in the service of information literacy and writing across the curriculum.

Multiple Imperatives

One of the major and growing concerns of academic librarians has to do with the issue of information literacy. The extraordinary growth of Internet (Web) based information resources over the last several years brought this clearly into focus for librarians. Faculty and students frequently lack the needed skills in evaluating the quality of information found on the Web. The situation for the typical student today is one in which the range of information resources available is so rich that even the simplest search of the Web will produce results that appear, on the surface at least, adequate to the students' needs of the moment. They often assume that all information is of equal value whether it is on the web or in print, but if it is on the web, it must be the latest and best information. By contrast, faculty often assume that if the information source is on the web, it is of no value and students should avoid using it for any assignment.

We are troubled to consider the outcome of a stereotypical research paper assignment. It takes the form of a teacher or professor revealing the assignment early in the semester, making it due late in the semester, and leaving the students to their own devices to figure out how to complete it. Even students with a well developed notion of how to approach the task will be sorely tempted to begin the project in earnest only a day or two before the due date, racing through normally time-intensive processes such as topic selection and research. The lack of true ownership of the assignment is indicated by the lack of attention given to it after it has been graded and returned. This stands in stark contrast to the thoughtfulness and iteration embedded in successful writing process models used in elementary teaching, such as that described by Graves (1983). There, one finds student topic selection mediated by the teacher, multiple drafts of papers, conferences between students and teachers while the work is in progress, and publication of student work. If this is considered ideal practice for training young writers, it is no less ideal for college students in a teacher preparation program, students who will one day attempt to guide young writers.

Hull (1989) describes heuristics that an instructor can keep in mind when structuring an assignment, principles that undergird effective writing instruction. They assume a constructivist approach to learning, and are similar in flavor to the ideas of Duckworth. Writing should be seen as a process, suggesting that students should view the writing task as authentic within a particular context. A writing assignment for pre-service teachers would mirror a professional writing task by allowing the students to make a contribution to a body of knowledge. Writing should also be treated as a process rather than an art – accessible and understandable, but the result of guided practice. Any teacher who creates a writing assignment should be prepared to help the students learn to write, and should not assume that they "should learn it somewhere else." Finally, the writing process is a connectionist process that is complex and social. Since writing emanates from the history and experiences of the writer, some latitude for this diversity must be incorporated into the task.

Given their historical placement, both Graves and Hull probably envisioned a traditional, linear artifact as the outcome of the writing processes they describe. However, near the forefront of the revolution of academic technology is the routine employment of non-linear writing such as hypertext. More alarmingly, this routine employment is being encouraged in the absence of scholarly study and debate. Popular books such as "HTML for Dummies" may address the mechanics of writing hypertext, but bypass the reflective process that is needed to make it *good*. Murray (1997) notes that some genres of non-linear writing predate and coincide with the ascent of hypertext and hypermedia into the educational consciousness, but suggests that hypertext and hypermedia are in their infancy as studied forms, with far greater potential than actualized value. More importantly, she asks that the study begin in earnest, which brings us to this work.

The Information Search Process Model

The ISPM is a "six-stage model of the information search process developed from the thoughts, actions and feelings most commonly encountered in the experience" (Kulthau, 1988, p.232). The model is summarized in Table I. It incorporates concepts from theories by Taylor, Belkin, McFayden and Paisley. It was developed, tested, and refined with information from interviews, questionnaires, time lines, and journals gathered from high school students.

There are very few models that discuss information seeking behavior, and this is the only one that offers a holistic approach combining affective, cognitive, and behavioral elements (Kuhlthau, 1985).

Stages	**Actions**	**Analytical Strategies**	**Feelings**
Research Assignment	Considering possibilities	Brainstorming; Discussing	Uncertainty; Apprehension
Topic Selection	Finding Background Sources	Evaluating & predicting outcomes	Confusion: Optimism after topic selected
Prefocus Exploration	Skimming & taking notes	Identifying possible foci	Confusion; Frustration; Doubt
Focus Formulation	Reading notes	Choosing or combining ideas	Confidence' optimism
Information Collection	Comprehensive library searching; Taking notes	Summarizing; Possibly redefining	Confidence or Intimidation
Feelings	Filling gaps in information	Organizing sources; Analyzing adequacy	Relief; Satisfaction or Disappointment

Table I: A summary of the Information Source Process Model

Most information seeking guidelines tend to be very product-driven – how to take notes, compile a bibliography, etc. The ISPM breaks new ground because it identifies and legitimizes the researcher's feelings throughout the research process. For example, students learn that it is *normal* to feel stressed-out, confused and overwhelmed in Stage 3, *Prefocus Exploration*, and Stage 4, Focus *Formulation* (Kuhlthau, 1985). When students are introduced to the model, they are relieved to discover that their feelings of anxiety, fear, indecisiveness and apprehension are part of the information search process.

Once they realize the business of conducting research is somewhat predictable and not random and haphazard, they are more responsive to developing information skills and strategies. They can see the long-term value in acquiring skills that will help them locate information and help them cope with the tumultuous emotions associated with the research process. For example, they may learn how to realistically budget their time and not procrastinate or they may learn how to use reference sources to explore and formulate a topic focus.

The African American Scientists Website (http://educate.albion.edu/art/aframsci)

The description of this project from the course syllabus reads as follows:

> The class will develop a self-contained web site that will elaborate upon the personal stories and scientific research of specific Black Americans or Africans. "Science" may encompass the traditional disciplines of biology, chemistry, mathematics, physics, and geology, as well as second-tier subjects such as engineering, medicine, architecture, computer science, and astronomy/cosmology. We do not want to create the compilation of still shots and short biographical sketches that are prevalent on "Black History Month" posters. Instead, we want an integrated sketch of the person – the story of their life and how they ended up doing what they did, the context of their times, a description of their research contribution in science and the ramifications of that research, and what happened to the person since then. The person chosen can be contemporary or historical. An event or issue that is of interest can influence your choice of a person.

Linear

Early in the semester, we provided the students with an introduction to the ISPM. We asked the students to comment on it, and to talk about their previous experiences with research papers. We then spent some time in class allowing the students to brainstorm or sample possible choices of scientists to research, and receive feedback from each other on their thinking. Next, we introduced reference sources that provide background information on African

Americans and scientists such as encyclopedias and biographical sources, along with some basic topic-refining techniques. Shortly after this session, the students turned in a research proposal with an annotated bibliography. They were asked to include sources that turned up a "blind alley" as well, so they would understand by way of a grade that all of their exploration at this point was of value. This sequence of sessions and assignments moved us through the first four stages of the model.

The next session involved the presentation of in-depth reference sources such as online databases and specialized reference sources, along with other information sources like listservs, interviews, etc. We also discussed guidelines for evaluating sources. It was here that we spoke with the class about the pros and cons of using commercial web search engines for research. On one hand, there is apparent ease and a wealth of ready information from searching the web, especially when one sees hundred or thousands of hits from a search. Web sources also can provide up-to-the-minute information on a topic, and increase the likelihood of first person contact or sources. However, web search engines have uniformly weak filters and do not always turn up information from reputable sources. We told the students that web sites are at best self-indexed with ad hoc keywords, and at worse may show up as a "hit" because an errant word on the page happened to match one of the keys. Together we discussed some strategies for Boolean searches, and we noted the relative strengths and weaknesses of specific search engines. We spoke about how to decipher URLs in order to determine the origins of the page creator. We also talked about how to assess the quality of information on a web site by looking for modification dates, author names and contact information, bibliographies or reference lists, or reviews about the information from other sites.

This was followed by a fourth session in the library, where the students used class time to perform research under the supervision of the two faculty and the librarian. This allowed us the chance to model information research and problem-solve with them. We held conferences with the students to assess their progress, and gave them hints about locations for other sources. Through these efforts, the students made use of "alternative" ways of accessing material that they had generally not used before -- interlibrary loan, searching the collections of large, state universities nearby, and personal email and telephone contact with the scientists.

The efforts we made to scaffold students' research not only helped them as writers of informational text, but it helped the faculty facilitate and be responsive to students' needs, questions, and suggestions. For instance, we planned to provide students with thorough feedback and suggestions for improvement on their rough drafts. We did this to help the students achieve the highest quality final linear paper and subsequent web version. Our intentions were to be as supportive as possible. In the syllabus the components were weighted as BLAND POINTS for the rough draft and BLANK POINTS for the final draft. Several students voiced concern about the point distribution. Upon consideration of this the faculty realized that such a distribution undermined one of the key motivations behind responding to the rough drafts so thoroughly ^ to help students work toward improvement. So the faculty responded to the students' concern, and made the change in weighting. And the efforts to provide extensive feedback and return the drafts within a week proved to be of considerable help in improving the final written work of students.

Non-linear

Now that the students had a thoughtfully written linear text, we began the process of creating a non-linear piece. The process of constructing hypertext or hypermedia begins with an assessment of three simple questions: 1) What do I want my reader to know right now?, 2) What do I want my reader to know next?, and 3) How can I use the tools of pictures, sound, video, animations, and time-dependence to convey my message more effectively? The first question defines the *lexia* (Murray, 1997), the amount of information that is appropriate for viewing on a single screen. While no studied rules exist for the upper limit of the lexia, our experience is that roughly 600 words of straight text can reside on 1.5 "screens." This was used as the upper bound. We suggested that the students start by breaking up their linear texts into lexias, and that they respect the upper bound by a wide margin throughout the translation process. In fact, this starting point was identified as another project milestone for the students, providing a window through which we could view the translation process. We guided them through the mechanics of conversion to Hypertext Markup Language (HTML) using the "save as HTML" option. Most students then used a basic HTML editor to further refine their pages.

The second question defines the selection of links to further information that are delineated in each lexia. We proposed two navigation schemes for each student to consider. The first is a *subway* model that gives the reader a

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well-defined path through the document. This is the easiest transition form between linear and non-linear text because it presents information in a time-dependent order that is determined and controlled by the author. The second is a *web* model, with multiple entry points to different lexias. This provides a true non-linear experience for the reader, who determines what to read and when. It was the responsibility of the students to construct screens that were vigilant in reminding the reader where they had been and where they could proceed next.

The richness of links across each student texts presented itself early in the process. While reading the rough drafts, we noted that different places or themes were common to several of the stories about the scientists. Some of these were facile, such as career choices or institutions of employment. However, some were profound; for example, one student wrote a brief description of the south side of Chicago, the home of one of the scientists. Others wrote about hospitals where the medical doctors they wrote about had practiced or pioneered innovative practices. We alerted the students to these commonalities, and provided class time for them to speak to each other about their subjects. The result was that some students created lexias from their papers that were linked in appropriate places from lexias created by other students. This epiphany is what turned a collection of texts into a communal, unified web site with far more communicative power than the sum of its parts.

Each student was asked to include at least two pertinent media items in their set of pages. The term "pertinent" was meant to focus them on the last of the three questions. The term was presented to the students to mean that the media should directly support or advance the story, conveying a meaning that words by themselves could not do. A majority of the students asked for guidance about the pertinence of items they had selected, and for the most part their instincts were reliable. We also showed them how to copy graphics from other web sites or scan them. Finally, but not insignificantly, we asked that they scrupulously abide by copyright laws, citing the source of each graphic that they obtained elsewhere.

It was anticipated that the students would pass through three phases in their use of media such as colors, graphics, audio, video, and animations. The first phase, from which everyone would probably graduate, shows a bare-bones screen with color absent or quite simple. The second phase, which occurs after one learns a few "tricks," results in all manner of gaudiness with respect to colors, backgrounds, and animations. Not everyone was expected to graduate from this phase, even though we made the usual suggestions about a high contrast of color and focus between background and foreground, minimizing the number of different text colors, and the distraction value of blinking.

A Student's Voice

As a student who had absolutely no experience with webpage design before this class, I was certainly a bit anxious when I heard that our final project was going to be to create an entire website. However, as I went through the step-by-step process, the project turned out to be an incredibly valuable learning experience.

In doing my initial research I explored the lives of many African American scientists. I chose Mae Jemison, a female astronaut. I now began really focusing my research on the life of Mae Jemison. I tried to extend my research beyond a simple documentation of her personal life as I also examined her role as a minority woman in science, a male dominated field. I finally compiled the results of my research efforts to first compose a preliminary draft of my research paper and later a final draft where I enhanced certain sections of my paper by developing them more thoroughly. I also added a new section in my final research paper upon making personal contact with one of Jemison's co-workers at Dartmouth.

Converting my research paper into a webpage was the most exciting part of the process. I created a short summary of Jemison's life and accomplishments to include on my individual Mae Jemison homepage. I then chose main sections of my research paper to create additional webpages that focused on more specific aspects of Jemison's life and her role in science. These sections became links that could be accessed from my homepage. After each student in the class finished putting together their own pages about the scientists they chose, the class worked together to create our collaborative website. We created committees to work on the homepage, organize the main index, and link related pages together within our site.

The best part about the project was that we were not given step-by-step instructions on how to organize our information and create our webpages. I spent many hours exploring on my own and making many changes to my own pages before I considered them "ready" to be a part of the final website. I am now using the skills that I acquired in this class to help maintain the website at the elementary school where I am student teaching. This experience was definitely a valuable experience as I also intend to maintain a class website in my own classroom next year.

Reflection

In the end all participants – faculty, librarians, students – were surprisingly pleased with what they had learned and produced. There were moments, particularly before the rough draft was due and during the first days of HTML conversion, in which students were vocally resistant to the relevance of the project and the amount of effort it required. However, it was clear at the end of the term (and has since become increasingly so), that students feel great pride in what they accomplished as writers, as thoughtful and creative users of technology, as young professionals trying to find ways to integrate substantive multiculturalism into the teaching of science, social studies, and language arts.

The Dialectic of Science and Culture (http://educate.albion.edu/art/dialectic)

One year later, we decided to implement the same basic project for the course, but with a different focus and some changes in the methodology. In response to feedback from the students that we had underestimated their overall understanding of the research process, we scaled back the number of class sessions with the librarian. We had been pleased with the sense of community and committee work that the previous class had developed, so we also decided to be proactive in fostering a sense of community. Our hope was that this class would be able to work even more cooperatively, and produce an even more cohesive project.

We also changed the focus of the project, as follows:

> The class will develop a self-contained web site that will explore the dialectic (discourse; interaction) between science and culture. You will define and elaborate upon a particular topic/issue/question concerning this dialectic for any context which is outside the contemporary mainstream Western tradition of science in the United States. Through this project we are asking you to thoughtfully consider what multiculturalism has to do with teaching science; we are asking you to consider how people around the world, both historical and current, have employed "the sciences" to make sense of and better their world. We ask that you not narrowly define "science" with respect to method and tradition that characterizes science in our own society in the present.

Though we accomplished our goal of cultivating a stronger learning community, the faculty discovered upon reflection that the topic choice was too great a challenge for students to conceptualize questions or topics that they were truly invested in and few were successful in making the "dialectical" links between culture and science. As a result, students felt less ownership of the topics and their efforts on the website were more going through the motions than the investment we saw the first time.

Future Directions

Our colleague Sean Pollack of the Great Lakes Colleges Association has suggested that an important future direction for this project is the incorporation of an image analysis component. Graphical images, as well as audio and video, communicate a message more precisely than text because of minimal signal degradation and less individual interpretation on the part of the recipient (Rosmiszoski, 1986; Salomon, 1984). However, precision does not imply effectiveness. A message that is not accurate about what the author means to say can be sent through a medium, and if the medium can precisely transmit that message, the result is that this inaccurate meaning becomes fixed in the mind of the recipient. Thus, an important ability for future educators in an age where hypertext and hypermedia are routinely employed is a more complete understanding of how to interpret the messages conveyed in images and other media, and to teach others to do the same.

These pilot classes provided our opportunity to test this approach to acquiring information literacy in a collaborative environment, and provide evidence of the learning with a web-based artifact. Such an approach may be of great value to teacher preparation programs and academic libraries in that it provides an opportunity for librarians and classroom teachers to work together to understand the best possible use of information technologies.

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Physical Science in the Early Grades: Technology in Action

Judith A. Duffield
University of Colorado at Denver
USA

Catherine Skokan
Colorado School of Mines
USA

Amy Nicholl
Windsor Elementary School
USA

David Saksek
Montrose High School
USA

Abstract: The Colorado School of Mines presented an intensive two week program that delivered physical science content to upgrade teachers' science skills at the elementary level. The objectives of the workshop were to: (a) upgrade physical science material understanding, (b) provide teachers experience in a technology-driven delivery of instruction, (c) promote collaboration of teachers between schools and grade levels, (d) provide teachers with a repertoire of teaching strategies, activities and lesson plans for teaching physical science, (e) provide laboratory and demonstration equipment, (f) provide teachers with hands-on experiences in problem solving, and (g) provide teachers with a sustained experience for continuous improvement. The topics of motion, heat, light, electricity, magnetism, and sound were investigated. Technological skills including probeware, the internet, compressed video, and computer usage were employed to augment these content areas. Thirty teachers successfully completed this program with significant gains in knowledge of physical science principles.

Often science learning in elementary schools is limited to very basic observations and concepts. This is often due to limited expectations for what young children can understand and to a lack of teacher understanding of scientific concepts. Science texts are generally written two reading levels below grade level in order to ensure that the students will be able to understand what they read. This does not mean that students are incapable of understanding more complex ideas, it just means that teachers need to be careful about how the information is presented. As long as it is presented in a way that students can understand, complex concepts are not out of their reach.

Technology has the potential for increasing the concepts that children can understand by allowing them to collect and process data more easily, safely, and accurately (Rudolph & Preston 1995). Tools like probes, calculator-based labs (CBLs), calculators, databases and spreadsheets allow children to collect and analyze data that would be beyond their capabilities if they had to do it by hand. Teachers can also benefit from technology by using it to communicate with others who are teaching similar concepts.

In order to address the problem of a lack of teacher understanding of scientific concepts and explore the ways in which technology can be used to aid in developing scientific concepts in elementary school children, a two-week workshop was designed. The objectives of the workshop were to: (a) upgrade physical science material understanding, (b) provide teachers experience in a technology-driven delivery of instruction, (c) promote collaboration of teachers between schools and grade levels, (d) provide teachers with a repertoire of teaching strategies, activities and lesson plans for teaching physical science, (e) provide laboratory and demonstration equipment, (f) provide teachers with hands-on experiences in problem solving, and (g) provide teachers with a sustained experience for continuous improvement.

The workshop was developed and delivered by university and K-12 teachers in two distant sites on opposite sides of the state. At each site, fifteen teachers and one or two instructors explored concepts in physical science, using hands-on activities to understand the concepts, gaining knowledge through these activities, reference texts and web sites. The teachers spent time each day exploring web sites relating to the concepts they were studying and interacting with those at the other class site through a course web site. Up to two hours each day were spent online with the other site using a video link. This time was used for sharing what those at each site had learned that day, making plans for the next day, and sharing group presentations that exemplified the concepts being studied. This time was also used for a guest speaker on assessment.

An Example Unit: Heat

One concept which was discussed was "heat". The preliminary reading assignment covered two chapters from the course text (Hewitt 1998): Temperature, Heat and Expansion, and Heat Transfer. The day opened with a discussion of terminology. For example, we clarified the difference between heat and temperature. Then the teachers were divided into teams of three. Each team received a 3 x 5 card which presented a question about heat. On one card was the question: Will hot water cool faster in a black container or a silver container? The question came directly from the pre-test and had been incorrectly answered by many teachers. The team investigated the cooling of hot water in two tin cans. One can was painted black while the other remained silver in color. Temperatures were taken at regular time intervals using the CBL system's temperature probe. Temperatures were also taken with a laboratory thermometer and numerical values were compared. The results were then plotted using a spreadsheet. The information gained included: accuracy in measurements (both time and temperature), repeatability and reliability (by taking parallel measurements with thermometers), use of spreadsheets and graphics, as well as the concept of emission and absorption of radiant heat. Next, web sites related to heat, such as the Utah Link (http://www.uen.org/utahlink/lp_res/TRB004.html), were investigated.

After lunch, results of the morning experiments and computer connections were shared with the other campus via the video connection. Finally, we returned to the classroom for a discussion of how the information learned about heat could be useful. In reviewing the results of the experiment with the silver and black cans, some questions were raised: Would one want to build a white house or a dark house in Colorado? What color of car might you want to own in Arizona? At the end of the day, teachers concluded with journal entries on the day's experiences.

Method

Students

The workshop was intended for elementary school teachers, mainly 3rd grade and below. The actual participants ranged from kindergarten through eighth grade. Most were classroom teachers, but a few others were resource teachers, retired teachers, or on leave. The came from districts across the state, including urban, suburban, and rural. Test scores on a pretest of the science concepts to be covered averaged 54%, indicating a lack of understanding of basic physical science concepts.

Instruments

An attitude survey questionnaire was developed to evaluate the last six objectives (b-g). A fifteen-item, seven-point Likert-type scale was used to assess the participants' perceptions of how much they learned about science, technology, problem solving, teaching science, and working cooperatively. It also asked for their overall feelings about the course and the instructors. The questionnaire included seven open-ended questions covering the same topics.

A pretest/posttest was developed by the course instructors to assess the first objective, physical science subject matter understandings. It contains 59 items, including 10 true/false, 48 multiple choice, and one short answer, dealing with the six concepts covered in the workshop (motion, heat, sound, electricity, magnetism, and light).

Procedure

The workshop was held for two weeks in June. The class met for six and a half hours a day (including an hour for lunch). The mornings were divided between lecture, demonstrations, hands-on activities, and time in the computer lab. The afternoon included two hours for the online video connection between the two sites and closing activities. The pretest was given on the morning of the first day and the posttest was given on the morning of the last day. The attitude questionnaire was given to the participants on the afternoon of the last day. In addition, the evaluator spent 18 hours at CSM observing a variety of activities during six days over the course of the workshop. This included observations of each type of activity, the guest speaker on assessment, and a full day of activities. The evaluator also reviewed the workshop web site and other course materials.

Results and Discussion

The data were collected as planned. The pretest and posttest scores were compared using a t-test. The attitude questionnaire responses were tabulated and the frequency of scores determined. The open-ended question responses were analyzed by content. Notes taken during the observations and web site postings were also analyzed by content.

Science Understandings

The mean score on the pretest of physical science subject matter understandings was 32 out of 59 or 54% (SD = 6.6). The posttest results averaged 49 or 83% (SD = 4.3), indicating a significant increase in understanding of physical science concepts ($p < .001$). The first two items of the questionnaire dealt with how much the participants felt they had learned about physics and about conducting classroom physics activities. Item 1 asked, "How much information about the subject matter of physics did you learn during the course?", with 1 indicating "nothing" and 7 indicating "a lot." All of the participants responded 5 or higher, with 70% selecting 7. Item 2 asked, "How much did you learn about conducting physics demonstrations, and designing and conducting physics labs, during the course?" All of the participants responded 4 or above with 53% selecting 7. This objective to increase understanding of physical science understanding seems to have been met, both in the test score gains and the students' perceptions.

Promote Collaboration and Technology Use

The participants actively used the course web site during the course. The intention of this site was that the teachers would continue to use it during the school year to seek assistance with projects they were working on and to share successes. So far, this has not happened. The teachers are communicating via email instead, even to respond to messages posted on the web site. It is still early in the school year, so that may change as the teachers begin to use the lessons in their classrooms.

Teachers from twelve districts participated in the workshop. They interacted daily via the course web site and over the video link. The majority of the web site interactions were of a personal nature, such as introductions and sharing interests. All of the teachers explored the Internet for related science web sites. Those they found that were appropriate for elementary students and related to the state content standards were shared with the others in the course via the course web site.

The video connection between the sites proved to be a challenge. The connection remained stable most of the time, but there were several instances where the signal was cut off. The participants found that the two second delay made it difficult to have true real time interactions. This was particularly noticeable with the guest speaker. The participants at the site with the speaker were able to ask questions right away, while those at the other site had to wait until the participants at the first site had finished before they could get a word in.

Presentations from one site to the other worked particularly well. The teachers at one site were already familiar with their fellow teachers' presentations, so those from the other site were able to ask questions without being interrupted as often. The interactions between the instructors followed a similar pattern. They were able to establish a dialog that made their conversation feel fairly natural, even with the delays.

Probably the most important aspect to the video connection was the way it allowed the participants to quickly get to know each other. Personalities surfaced on the first day as they introduced themselves to each other. Many commented during the first week of the course that they felt they knew the teachers at the other site. If the only connection they had had was through the course web site, it is unlikely that they would have gotten to know each other as well. Seven teachers mentioned that the time spent on the video link was worthwhile. For example: "I also enjoyed the interchange with the class in Golden." "It is good to see more experiments from Grand Junction to expand on our concepts." "Distance learning was excellent!" Six teachers suggested having less time for the video link and five suggested moving the video link time to the morning "while we're all alert. After lunch, the hands on activities and demonstrations will help keep us engaged."

All of the teachers had direct experience with several forms of technology, but there is room for improvement. While the comments in the second part of the questionnaire indicated that the teachers enjoyed using the technology that was part of the course, one teacher questioned the degree to which the experience was technology-driven, calling the use "sparse." Technology was being used throughout the workshop, but many of the experiments and activities used non-electronic technologies, such as cans with wind-up motors and thermometers. A balance between electronic and non-electronic technologies seems appropriate, due to the nature of hands-on experience with real objects needed at the elementary level and given the concerns of some teachers as to the expense and lack of availability of the electronic technologies in their schools.

Several of the teachers requested more of a particular tool. Three requested more time to use the experiments they found on the Internet. Two wanted to do more with CBLs. One teacher wanted to learn to use graphing calculators and one wanted to see more on using the computer in ways other than the Internet. One wanted to see more applications that were appropriate for younger children.

Problem Solving

Items 6, 7 and 8 in the first part of the questionnaire dealt with problem solving. Item 6 asked, "How much did the course teach you personally about problem solving skills and techniques?" The responses were mostly rated 4 and above, with the mode at 6 (30%), indicating that all but 10% felt that they had learned some to a lot about problem solving skills and techniques. Item 7 asked, "How much did the course teach you about teaching problem solving skills and techniques to students?" Seventy-seven percent of the teachers rated this item a 5 or 6, with 93% rating it at a 4 or above. Most of the teachers felt that they had learned some to a lot about teaching problem solving to their students. Item 8 asked, "How useful do you think the material covered on problem solving techniques will be for you in your teaching?" Of the three, this item received the strongest positive response. Sixty percent of the teachers rated this item a 6, with 97% rating it 4 and above. This indicates that the teachers felt that the materials will be somewhat to very useful in the classroom.

Based on observation and a review of the course materials, problem solving was embedded in all of the course activities. The demonstrations and experiments required the teachers to pose questions, search for solutions, and discuss their findings. Unfortunately, this was not made as clear as it could have been, as the following data show.

Item 5 in the second part of the questionnaire asked, "Did you find the problem solving material helpful? Why or why not? Could it have been changed in any way that would have made it more helpful?" In response to this item, seven teachers said that no problem solving instruction had occurred, even though several of them mentioned problems solving activities in their responses. For example:

- We talked together and solved problems with demonstrations. Problem solving techniques were not covered in this course.
- No instruction on problem solving – We were in problem solving mode…
  I don't think we did a lot of the problem solving – We did solve problems on experiments and shared ideas on using in the classroom.

Eighteen teachers recognized that the problem solving instruction had occurred. Their comments included: "The problem solving activities helped us develop an understanding of concepts and helped us think about what we were observing." "Problem solving material was very helpful. It helped me to see better ways to approach problem solving with my students." and "So many ideas and techniques in problem solving – gives me a lot of confidence in my ability to present material that I never have used before." More specific connections need to be made for some of the teachers to become aware that problem solving is taking place.

Conclusions

Overall, the teachers were satisfied with the workshop. They felt they were more able to teach science and that they better understood science concepts. The knowledge test indicated that their knowledge of science has increased. Though there is room for improvement, the workshop objectives were met. When planning for future workshops, the following changes are recommended:

- Require the participants to work in different groups and make the groups consist of at least three members. This will provide the participants with opportunities to get to know each other better and facilitate future interactions.
- Be more overt in the use of instructional and problem solving strategies. Debrief after each activity, not just about the science learned, but about the strategies used.
- Embed assessment within the activities, as was done with problem solving. A short review of assessment with opportunities to develop and use authentic assessments would be more effective than a guest speaker.
- Extend the workshop to meet the same number of hours, but spaced out over three or four weeks. This will allow more time for independent work and reflection between sessions.
- Two topics were not covered in sufficient depth: Circular motion and electromagnetism. We recommend that a one-week advanced physical science class be given to cover these topics.
- On the technology side, we recommend that the one-week advanced class cover the technology of creating a web page for each participant. This would enable both students and other teachers to see experiments in physical science and add a further connection to discuss physical science issues.

Finally, although the class was advertised for elementary school teachers, there were four participants who taught at the 7th and 8th grade levels. There appears to be a need for a similar class for the middle school teacher as well as for elementary school teachers. In future planning, this will be discussed.

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Comprehensive Professional Development Reform Efforts: Changing Attitudes and Practices about Pedagogy and Technology for Science Teachers with Diverse Needs.

Stephen Best
Center for Learning Technologies in Urban Schools
University of Michigan
United States
sdbest@umich.edu

Barry Fishman
Center for Learning Technologies in Urban Schools
University of Michigan
United States
fishman@umich.edu

Ronald Marx
Center for Learning Technologies in Urban Schools
University of Michigan
United States
ronmarx@umich.edu

Jake Foster
Center for Learning Technologies in Urban Schools
University of Michigan
United States
fosterjg@umich.edu

Abstract: This paper examines a professional development program within a large urban school system, along with a framework of the pedagogical concerns to be addressed by the program. As a part of the Center for Learning Technologies in Urban Schools (LeTUS), the University of Michigan and Detroit Public Schools have partnered to develop and implement a systemic educational reform program geared toward changing the practices of middle school science educators to include the integration of technology into the enactment of the curriculum and a transition to student-centered inquiry and investigation. To do so, the professional development program focuses on changing teachers' knowledge, beliefs, and attitudes regarding pedagogy, learning, and science. Initial findings of the impact of the program suggest a significant positive impact in changing said beliefs. This paper discusses elements of the program, and suggests recommendations for future study.

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Introduction

The past several decades of research and development in science education reform have yielded many innovative curricula, tools, and ideas. One area, however, that has seen less overall progress is the development of new frameworks for professional development of science teachers (Marx, Freeman, Krajcik & Blumenfeld, 1997b). The staff development literature rarely addresses science education directly, and in turn the science education literature has not until recently addressed issues of professional development at any length. Tobin, Tippins, and Gallard (1994) devote considerable attention to teacher development in science, pointing to two practices as successful: connecting to teachers' existing knowledge and providing a supportive environment for change over time. In addition, Richardson (1996) states that a chief objective of professional development should be to foster changes in teachers' knowledge, beliefs, and attitudes (K/B/A), which show a strong correlation to changes in their classroom practices.

We have been working in collaboration with an urban school district to reform science education to be inquiry-oriented and make use of pervasive educational technology by creating professional development opportunities that will address the needs of a diverse population of teachers. There are challenges unique to urban environments, including high teacher mobility rates, erratic content-area and technology specific preparation for teachers (with many teachers teaching out of their specialization), a lack of a substantial and "teacher friendly" technology base in many schools and classrooms, and high poverty among students. These challenges (and others) must be addressed by professional development if reform efforts are to become successful for individual teachers and students, scaleable to the needs of the whole school and district, and sustainable in both individual classrooms and the system as a whole.

Theoretical Underpinnings

The professional development framework described in this paper is rooted in a larger theoretical frame called CERA (Marx, Blumenfeld, Krajcik & Soloway, 1997a; Marx et al., 1997b), which stands for Collaborative construction of understanding; Enactment of new practices in classrooms; Reflection on practice; and Adaptation of materials and practices. CERA provides the general backdrop for our collaboration with the school district and with teachers in all activities, including professional development.

Collaboration

Collaboration involves teachers, principals. and university researchers working together to inform, critique, and support each other (Lieberman 1992), with group members sharing both work and thinking. Support may come from other teachers who provide useful feedback about changes being implemented (Fountain & Evans, 1994; Nelson, 1986) and suggestions about enactment of the technology-centered curriculum. Support may also emanate from a research partnership with a university, allowing teachers and researchers to develop models of change together (Goodlad, 1993; Knight, Wiseman, & Smith, 1992; Stoddart, 1993) as well as provide feedback on use of experimental technologies. Support may take place through dialogue with administrators, particularly school principals (Greene, 1992; Leithwood, 1992) in matters involving administrative concerns regarding technology access and curriculum enactment.

Enactment

Collaborative conversations serve as a stimulus for change, but, by themselves, are not enough to promote teachers' learning. Experience and accompanying reflection are also essential. Teachers must try complex innovations such as those suggested by research (Krajcik et al. 1994; Roupp, Gal, Drayton & Pfister, 1993) and policy (Project 2061, 1993) before they understand the innovations' full implications. Enactment involves planning for innovation and conducting new practices in classrooms. We use the term enactment to emphasize that the process is generative and constructive. Rather than merely applying a set of predefined prescriptions, teachers attempt to establish practices which take into account their own, individual classroom situation, based upon reflection and practice.

Reflection

The element of reflection and its role in professional practice is the subject of Schön's (1983) seminal work. We share Schön's view that teachers must reflect on teaching to extract the knowledge that leads to improved student learning. Experience educates via reflection. Reflection involves both private acts, such as the reviewing of videotapes of classroom implementations, the use of new multimedia tools (Krajcik, Soloway, Marx, Blumenfeld, Bos & Ladewski 1995), and the use of reflective journals and other artifacts of classroom practice, and public acts, such as the opportunity to discuss their work with peers and university researchers.

Adaptation

Finally, and perhaps most importantly, new approaches to education often require an explicit tailoring of instruction to the local contexts in which it takes place. Thus, enactments will look different in various classrooms. In particular, adaptations often occur after teachers have been given the opportunity to reflect on their enactments. Adaptation with respect to the use of technologies in the classroom is of particular interest, as individual teachers must respond to administrative and technological differences which are not likely to be addressed for individual circumstances within a professional development program.

The implicit goal for the design of our professional development activities is to provide opportunities for teachers to enhance their knowledge, beliefs, and attitudes (K/B/A) about science content, science teaching, and technology use. Changes in teachers' K/B/A result from a variety of conceptual change mechanisms that are mediated by cognitive, social, and contextual components. Cognitive mechanisms include the intelligibility and feasibility of the innovation. For instance, an innovative software program may not become intelligible to a teacher until he/she gets to see how another teacher uses it. Teachers may not feel that using technology is feasible for a variety of reasons, including their attitudes toward technology, their self-efficacy for using technology, and combinations of underdeveloped content knowledge or pedagogical knowledge with respect to the technology or science content. Social mechanisms include support for risk taking among teachers, or simple exchanges of information among colleagues, such as a teacher being more inclined to try to use a new technology in the classroom if they see that people they trust have tried it with success. This may lead both to increased feelings of self-efficacy ("If he can do it, I can do

in attitudes toward the technology. Contextual mechanisms are factors related to the settings in which the innovation is to be carried out, such as availability of resources and understanding by administrators of the teachers' goals and practices and the bureaucratic barriers limiting these practices.

Context

This professional development program was one of the programs developed by the University of Michigan and Detroit Public Schools as members of the Center for Learning Technologies in Urban Schools. The Center is an NSF funded partnership between those institutions, Northwestern University, and the Chicago Public Schools with a mission of developing educational programs using pervasive technologies. This particular effort was aimed at changing practices of middle school science educators throughout the large district. Programs were piloted in two schools at first, reaching ten schools in the second year. In this third year, more than 45 teachers and administrators from 18 schools participated in the program.

At the outset of the program, a series of goals were established and communicated to all individuals involved in the program, which would become the benchmark for success in the program. Our implicit goals for professional development are complemented by a set of five explicit goals, which are communicated to all teachers as part of regular professional development activities. These goals are: (a) to become active participants in a science teaching community; (b) to learn how to enact and adapt inquiry-oriented, standards-based science curricula that employ new forms of pedagogy, learning technologies, content, and assessments; (c) to understand how constructivism forms the basis for inquiry-based science; (d) to develop strategies for managing change in the broader context of your school and district; and (e) to actively participate in the evaluation and adaptation of curriculum and technology.

Implementation and Findings

Professional development for systemic educational reform (focusing on understanding and enactment of inquiry-based science curricula with embedded technology use) within a massive urban school district requires a variety of elements in order to accommodate the diverse needs of the teachers within the system. These elements include more traditional development activities such as summer and weekend workshops (with non-traditional, model based activities during the workshops) with other, less-traditional events such as in-class support by curricular, pedagogical and technological experts. All of these elements of professional development are centered around the use of educative curricula, which are intended to provide opportunities for student learning through inquiry and technology use while providing teachers with activities and other constructs to enhance their understanding of content, pedagogy, and technology through active reflection. This allows for individual teachers to center on their own goals and strategies within the classroom, while being a part of a massive development program.

Initial findings regarding the impact of the professional development programs center on information gathered from the summer workshop element of the program. The summer workshop functioned as the kickoff activity for teachers involved in the program, in that it provided the orientation to the program and the underlying pedagogical concepts promoted by the Center. Teachers were introduced to inquiry-based, technology centered curricula by enacting their own investigation of the concepts inherent in the curricula they would be teaching in the following academic year. While participating in the inquiry projects, teachers were constantly encouraged to reflect upon their activities from a learner's perspective, and develop and share strategies for the teaching of these concepts during the school year. Teachers also participated in other work sessions, focusing on understanding the underlying content and pedagogy of the educative curricula, forming a community with other colleagues in the program, and developing a strategic plan for local enactment of the curricula. All of these sessions were videotaped for subsequent analysis to document both the actual activities of the workshop as well as teacher actions and responses during the sessions.

Daily reflection surveys asked summer workshop participants to reflect on the day's activities and the impact which that might have on their teaching practice, as well as the explicit goals of the professional development program. Our analysis thus far gives credence to the professional development framework we are using to support the systemic reform of science teachers in the Detroit Public Schools. Teacher commentary in workshop reflections showed evidence that all of the major change mechanisms we posited were necessary to foster their development. Furthermore, the quantitative feedback from teachers on the workshop indicated that the goals we explicitly stated for the work session were important to them. The lowest rating was 4.62 (on a 5-point scale), assigned to the goal of becoming active participants in the evaluation and adaptation of curriculum and technology. The highest rating was 4.85, on the goal of understanding how constructivism forms the basis for inquiry-based science. Teachers also felt that the work sessions as designed were useful in helping them achieve the five goals. The lowest rating was 4.66, for helping teachers develop strategies to manage change in their local school contexts. The highest rating was 4.79, for helping teachers to become active participants in a science teaching community.

Saturday workshops held throughout the school year provide another element of the professional development program, similar in nature to the summer workshop, but held periodically through the school year to provide a construct for teachers to reflect on practice during the enactment of the educative curricula. These workshops group teachers and administrators working with four distinct curricula together in the mornings to discuss general concepts and strategies of constructivist pedagogy focusing on technology integration and inquiry based science. In the afternoons, teachers collect in smaller groups to discuss issues relevant to the implementation of their particular curricula, which are divided by grade level and district standards. These events have yet to be fully enacted as of this writing, and, as a result, have not been thoroughly analyzed regarding the impact upon teacher attitudes, knowledge, or practice.

We do not claim that these in-service workshops, by themselves, can create lasting change in support of systemic reform. They are two of the pieces of a comprehensive approach to professional development represented by the CERA model. Another very important aspect of this program is the use of in-class support personnel who assist the teachers with the enactment of the curriculum, and encourage reflection on practice. These individuals are prepared by training and immersion in the curricula and with the technological tools. All support personnel are experienced teachers with an understanding of the underlying pedagogical concepts of the program.

Initial findings of the practices and observations of the support personnel based upon field notes indicate that these individuals participate in four basic activities; cognitive/pedagogical understanding support, in-class teaching assistance, technology related assistance, and logistical or documentation activities. Based upon these findings, a survey instrument has been developed and piloted to examine the teacher's perceived need for elements of these areas, though collection of this data has not been completed at the time of this writing.

As mentioned earlier, all of these activities are centered upon the use of an "educative" curriculum unit, designed to provide opportunities for enactment of the desired practices within a content-focused framework. These curriculum units provide a guided set of activities to engage students in the learning of science content focusing on a contextualized driving question. They are designed to remove the teacher from the role of "keeper and communicator of knowledge" to a facilitator of student learning through an inquiry and investigation process, which utilizes a variety of technological tools to help students understand relationships of the content concepts. They provide a number of opportunities for teachers to personally reflect upon the enactment of the curriculum, and engaging questions to help redirect the personal pedagogy of the teacher. They also provide the context for the professional development program to help teachers examine different practices and their impact on student learning.

While findings of these curriculum units are not discussed here, informal observation reveals the impact, both positive and negative upon teacher practice. Successful enactment of the curricula allows the teachers to become familiar with the content, pedagogy, and technological tools encouraged in the program. Teachers use the materials to provide learning opportunities for students which also allow the teachers to gain experience in the enactment of an inquiry based pedagogy, and in the infusion of technological tools designed to aid in student cognition regarding the concepts and relationships of the content. The reflective questions and commentary within the written curriculum documents, when teamed with other forms of support, help the teacher understand the educational impacts of their practices on students, and focus on the changes in student learning, motivation, and content focus encouraged by the curricula.

Difficulties in the enactment come, for the most part, from challenges regarding organization, time management, and a diverse and dynamic student population. These challenges have forced some teachers to cut short elements of the curricula, as administrative and personal pressure encourages teachers to move on to more familiar practices. Such enactment seems to encourage the use of the pedagogy and technologies as interspersed "activities" and "techniques" rather than an underlying change in philosophy of teaching and learning to a more constructivist approach. Such challenges highlight the need for more comprehensive integration of all of the forms of support for teachers, as well as additional needs for addressing administrative buy-in and professional development for individuals in decision-making positions.

But, the challenges for enactment do not stop there. A number of other issues face educators in a variety of ways regarding the use of the curricula and adoption of these goals and practices. Some of the teachers struggle with content knowledge and its accompanying pedagogy. Over one third of the science teachers involved in the program have no strong science background, and so part of the professional development must address basic scientific concepts for these individuals. Many teachers who feel less proficient with the content often find themselves so tied to the activities listed in the curricula that they limit the adaptation necessary to gear the curricula to their students' specific needs and abilities. Others let their insecurities get the better of them, straying away from the design and focus of the curricula.

Perhaps the greatest barrier to enactment does not exist within the teacher, but rather within the school. Implementation of a curricula with pervasive technology use requires knowledge of and access to the technological tools utilized within the curricula. Problems with these technologies abound within the program. Some teachers have little or no access to facilities with appropriate technology within their school, either because the school as a whole is limited in these tools (though the Center made this an inherent element in the selection of schools to be involved in the program), or because these tools are used for other educational programs. The software for these curricula are specialized and require a variety of specialized hardware and software requirements, which are often limited within some schools. And, while the software has been tested in a variety of circumstances, the tools created for this program are specialized tools for these curricula, and are continuously under development. Analysis of all of these barriers will take place in a variety of stages, including analysis of videotaped class sessions, field note forms from teachers and support personnel alike, notes from administrative meetings, and interviews and surveys of teachers and students involved in the project.

Conclusions

As a result of the dynamic interplay of collaboration, enactment, reflection, and adaptation, teachers' visions of innovative instruction are enriched. To provide this interplay for a large group of individual teachers within the context of a large urban school district is a challenge of the professional development program which supports these teachers. Yet, the interplay is necessary for real change, both in teachers' beliefs and practices, to occur.

To enact such a professional development program for such a diverse group of teachers requires far more than traditional in-service style approaches. A diverse population of teachers has diverse needs from a professional develop program, ranging from support to understand base philosophies and practices to assistance in understanding content concepts to knowing that there are other educators facing similar issues and that ideas and strategies can be garnered from a community of teachers. The professional development program described within this paper is an attempt at such a program, and initial findings show examples of the successes and challenges of such a program in changing teachers' knowledge, beliefs, and attitudes regarding their students' learning and their own practice as educators.

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Technology And Field-Based Learning: Efforts To Bring About Change In Schools

David A. Heflich
Department of Curriculum and Instruction
University of Nevada, Las Vegas
United States
dheflich@ccmail.nevada.edu

Juli K. Dixon
Department of Curriculum and Instruction
University of Nevada, Las Vegas
United States
dixonj1@nevada.edu

Aimee L.Govett
Department of Curriculum and Instruction
University of Nevada, Las Vegas
United States
govett@ccmail.nevada.edu

Abstract: Authentic learning is often considered to be hands-on and experiential in nature. This paper describes research that was conducted with an educational methodology designed to provide students with an authentic learning experience in a field-based setting with the help of computer technology. Furthermore it presents efforts to expand the use of the methodology in an elementary school through efforts to provide faculty in the school and undergraduates who will be engaged in their student teaching practicum in the school with the same access to the methodology through engaging them in field-based learning. Plans for exploring the effects of the professional development are also discussed.

Introduction

Around the country, numerous efforts are underway to learning opportunities for students through authentic and meaningful inquiry. Such endeavors provide contexts for students to 1) think critically, explore phenomena, and solve relevant problems; 2) plan and conduct investigations in relevant settings; 3) gather and collect information to construct reasonable explanations and solutions; 4) engage in discourse about their ideas, explorations, and conclusions; and 5) use technological tools to assist in their investigation and communication efforts (International Society of Technology in Education, 1991). In order to continue this reform movement, inservice teachers, and ultimately preservice teachers also need to be exposed to such contexts and also have the opportunity to learn through inquiry. The projects reported here focused on the use of tools of science, mathematics, and technology by preservice and inservice teachers to engage in scientific inquiry through the investigation and communication of phenomena in field-based settings.

Computer technology is a tool that supports authentic learning experiences in field-based settings as well as in the classroom. It allows students to collect and record information in the form of numerical data, written field notes, drawings, and digital images while in the field. Technology helps to connect the field-based experiences to the classroom learning by providing ways for students to easily and professionally display and analyze the data that they collect in the field and to communicate their findings so that peers can share in their newfound understandings. As students work in relevant field-based settings, they use and develop skills necessary for scientific work such as formatting significant questions; developing methods of exploration; carrying out studies; and engaging in discussion with others about their discoveries.

Technology supports the processes of wondering, exploring, and discovering which are central to the scientific process. Through these authentic learning opportunities students construct their own understandings about the world around them.

In addition, teacher education programs are doing an inadequate job of preparing preservice teachers to teach with technology. Too often preservice teachers' exposure to computer technology in their preparation program is limited to a single required survey course (Strudler, Heflich, & Anderson, 2000). Efforts to integrate technology into methods of teaching and applying that to student learning are sorely lacking. The projects described herein are one attempt to more fully integrate the use of computer-based technology in methods of teaching mathematics and science.

Integrating Technology, Science, and Mathematics in Field-based Learning

The project reported here falls in two phases. The first was a Dwight D. Eisenhower Professional Development Program supported effort to integrate field-based inquiry into a preservice science methods class and with inservice professional development offered to faculty at two elementary schools in an urban, southwestern school district (Heflich, Dixon, & Davis, 1999). Our goal in working with both preservice and inservice teachers was to influence the way technology was used in elementary education. An additional goal was to explore the integration of mathematics, science, and computer technology through the use of field-based teachning methodolgies. The project utilized field trips to a variety of natural areas within the community, using traditional data collection tools, as well as temperature probes connected to Apple Computer Corporations eMate computers. Each of the interventions followed the same model:

- A discussion of the inquiry process as a means of looking at natural phenomena in the world;
- An introduction to the data collection tools, including the computers, and opportunities to practice with them;
- Trips to a site in the field in which they were introduced to field-based inquiry methods throught games, engaged in observational exercises, delineated a study site, and, working in groups, collected data;
- Space to organize the data collected in terms of the inquiry driven questions they had asked;
- An introduction to story boarding techniques as a way of planning ways of presenting their questions, data, and conclusions to the larger group;
- Working with slide show software to create presentations;
- And, presenting their results to the group as a whole (Heflich, Dixon, & Davis, 1999).

The project successfully exposed both preservice and inservice teachers to field-based methods of scientific and mathematical inquiry through the use of computer technology. Teachers in the participating elementary schools expanded on their use of the methodology and introduced it to others in their schools, but preservice teachers had less success in influencing the practice of their colleagues once hired by schoolsin the district. By this last measure the project was less than fully successful.

On-Campus Professional Development School

Some of the teachers involved in the Eisenhower-funded professional development grant work at a school that was in the process of becoming a collaborative program of the College of Education (COE) and the Local School District (LSD) to create a Professional Development School (PDS) on the university campus. The goal of the PDS is to improve the clinical preparation of educators (Robinson & Darling-Hammond, 1994). Central to the planning for the PDS was relocating the school to the university campus, adjacent to a privately funded professional development center containing a computer laboratory, offices, two classrooms, and a large activity room, all amply provided with computers, projection systems, and smart whiteboards. In addition, the COE developed a teacher education cohort of twenty-two students who work intimately with teachers at the school and with program faculty in an integrated approach to teacher education which offers them the opportunity to learn both in the university and elementary classroom. (Myerson, Gallavan, Girogis, Heflich, Putney, Ramirez, & Regin, 1999).

In fall, 1999, the PDS cohort was engaged in their last semester of coursework prior to entering their semester-long student teaching internship at the school. Their coursework during fall semester included advanced literacy methods, mathematics methods, science methods, and a field-based practicum at the school that was supported by a seminar in which students were expected to reflect on their experiences as teachers. One of the authors was responsible for teaching science methods; another was responsible for running the seminar. The latter proposed to use the seminar to expand cohort students' concept of the use of computer-based technology in teaching and learning, building upon the experiences of some of the PDS teachers All of the students had previously taken a required survey of computers in education. Within that course students learned to design and develop slide show presentations. Therefore cohort members possessed some of the ability that had been stressed within the professional development provided to PDS teachers. Working with the cohort in the seminar, exposing cohort members to the same field-based, technology- infused methodology to which teachers working at the PDS had been exposed provides the opportunity to explore the possiblity of changes in teaching methodologies that may result.

Working in the field with the PDS cohort

The cohort convened on an autumn morning at the Desert Demonstration Garden, the same local used for providing professional development to the PDS teachers and a site within walking distance of the PDS. They were joined by two of the authors, their teachers in Science Methods and in Seminar. Cohort members were divided into four working groups. Each group had with them:

- Apple eMate computers with temperature probes;
- Measuring tapes;
- Ph kits;
- 10m of rope;
- And, digital cameras

Groups decided on a site which they bounded with the rope. They spent time observing the site and reflecting upon and discussing what it was within the site that interested them and why. Group members then began utilizing their tools to record the data needed to answer their question. Temperature data of all sorts (water, air, sunlight, shade, reflections, body, etc.) were recorded with probes and the eMates. The eMates also served as a vehicle for recording questions, making sketches of objects in the area, and serving as a repository for the data collected from the probes, measuring tapes, and ph kits. Digital cameras were used to take pictures of the site, objects within the site, and the activities in which group members were engaged.

These data were taken back to a computer laboratory and uploaded onto desktop computer systems. Group members met with one another, revisited their questions, catalogued the resources they had gathered for a presentation, and began the process of developing storyboards that recounted their experience. Students were given the freedom to develop their slide show in the program of their choice. Among those chosen were ClarisWorks, PowerPoint, and KidPix Studio. Groups received technical support from faculty when they encountered problems, but otherwise worked on the slide shows independently for five hours over two weeks, before presenting them to the group as a whole. Examples from student presentations are included in the attachements.

Where do we go from here: changing educational practice.

Changing educational practice in schools is not simply a matter of having a good idea, sharing it with others, and waiting for it to develop. An investment needs to be made in the process. It needs to be pushed and shaped by those who are willing to commit the time to try to realize it. Fullan (1993) points out that institutional change is inherently personal. Therefore any consideration of change must be broadly based, a group of individuals who share a common vision of how to change their practice as educators.

The plan for change in the PDS involves integrating technology into methods of teaching science and mathematics through field-based experiences. The actors involved include the two teachers at each grade level, who have previously been exposed to the methodology during the Eisenhower-funded professional development project described by Heflich, Dixon, & Davis, 1999, PDS interns in the school, now student teachers who have been exposed to the same methodology, a technology coordinator who serves the role of a change agent (Fullan, 1993) committed to seeing the methodology succeed, and a coordinating group containing members equally invested in changing the way technology and teaching occur in the school. Efforts are underway to match teachers with experience in the methodology and interns who have had the same experience. In addition, a series of workshops, supported by Project THREAD (Technology helping to restructure educational access and delivery) ,a federally funded imitative described in Strudler, Heflich, & Anderson (2000), will work with teachers in the school to more fully integrate technology into teaching and learning. Follow-up support will be provided to the teachers by the technology coordinator, Project THREAD, and university faculty.

Five classes, one at each grade level, will take a trip to the Desert Demonstration Garden on the university campus, about one quarter of a mile away. Support will be given to the teacher and the intern helping students ask questions about what they see in the environment, and teaching them how to measure things and keep records of their measurements. The older children will use eMates to collect data. Once the data is collected, we will introduce children to slideshow software, and work with them as they prepare presentations. Other classes at the various grade levels will be invited to student presentations of their experience.

The plans descripted here are part of the larger agenda of Project THREAD which is designed to better prepare preservice teachers to work with technology in teaching and learning. Teachers working in the PDS have a clearly defined role serving as professional examples and mentors to cohort interns (Myerson, Gallavan, Girogis, Heflich, Putney, Ramirez, & Regin, 1999). Professional development with technology in the PDS is a goal of Project THREAD (Strudler, Heflich, & Anderson, 2000). The professional development is targeted towards grade level interventions and will support the use of technology-infused, field-based instruction of students.

Technology support for PDS teachers will be ongoing, supported by Project THREAD and the PDS coordinating committee. Teachers' use of field-based methodologies will be monitored to evaluate the extent to which it is used in school, and the effect that its use has on students attending the school. These results will be reported as they become available.

Discussion

Field-based methods of teaching science and mathematics with technology have been positively described (Heflich, Dixon, & Davis, 1999). The use of environmental probes connected to laptop computers provides students with tools that will allow them to collect and record data that can easily be transferred to desktop systems for more detailed analysis and presentations. The use of technology in field-based methodologies to teach science and mathematics supports the process of wondering, exploring, and discovering that are significant elements of elementary education (Heflich, Dixon, & Davis, 1999). It further allows students to engage in the scientific method, allowing them to engage in the process of forming hypotheses, searching for data to address the hypotheses, analyzing data to address the hypotheses, and reporting their results. All of these steps are aided and supported with the use of computer-based technologies.

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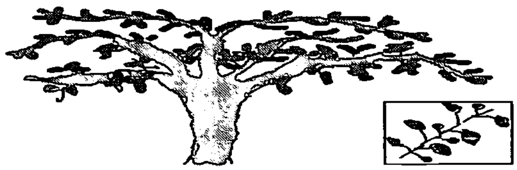
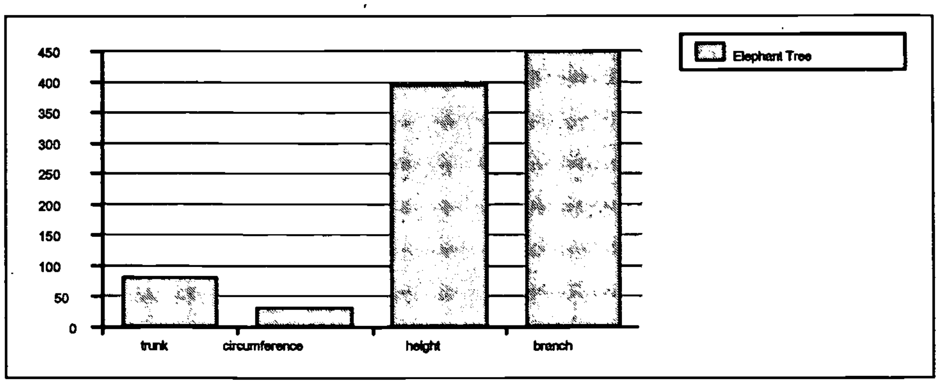
Attatchments

Attachment 1
EMate generated picture and description from PDS field trip.



Elephant Tree...smooth bark, many small leaves, small green berries, thin, long reaching branches, dagger shaped leaves, provides lots of shade, most small branches have 6-8 leaves on a branch, evenly spaced small branches for leaves

Attachment 2
Data collected during PDS field trip regarding the tree, stored in a spreadsheet on an eMate, uploaded and converted to a graph using spreadsheet software.



Site-based Inservice that Works: Using the Internet to Integrate Science and Mathematics Instruction

Keith A. Wetzel, College of Education, Arizona State University West, USA, Keith.Wetzel@asu.edu

JoAnn V. Cleland, College of Education, Arizona State University West, USA, Jo.Cleland@asu.edu

Ray R. Buss, College of Education, Arizona State University West, USA, Ray.Buss@asu.edu

Peter Rillero, College of Education, Arizona State University West, USA, Peter.Rillero@asu.edu

Ron Zambo, College of Education, Arizona State University West, USA, Ron.Zambo@asu.edu

Alice Christie, College of Education, Arizona State University West, USA, Alice.Christie@asu.edu

Abstract: Project SCOUT provided inservice and preservice teachers opportunities to experience inquiry-based learning, which combined hands-on and Internet investigations in science and mathematics. The goals of the project were: (a) to provide staff development in standards-based strategies for teaching science and mathematics for teams of inservice and preservice teachers at a single elementary school that hosts a site-based university teacher preparation program; (b) to enable mentor and student teachers to learn knowledge navigation strategies using the Internet and develop teacher and elementary student web sites to accompany their curricular units; and (c) to conduct a summer camp for local school-age children, which would allow participants opportunities to practice the strategies they learned during the institute. The results suggest that appropriate training, which allows significant time to explore and adapt instruction; immediate practice opportunities with children; and significant follow-up opportunities will engender confidence and foster use of the Internet as a part of K-8 classroom instruction.

Introduction

Rationale/Need

Surveys of K-12 teachers (Sowell, et. al., 1995) revealed that elementary teachers felt unprepared to teach mathematics and science and to use technology effectively in math and science instruction. Needs assessment surveys of the SCOUT project teachers indicated similar needs. With the increased nation-wide emphasis on standards-based education, the need for assisting teachers in developing both the competence and the confidence to teach these three discipline areas has intensified.

Hands-on Learning

Evidence clearly indicates that hands-on activities increase skill proficiency in processes of science (Mattheis & Nakayama, 1988; Tobin, 1990). Inherent in the constructivist approach is its meaningfulness to children. Additionally, although it has long been understood that the power of inquiry learning is its focus on applicability in authentic contexts (Bruner, 1961), teachers face the challenge of keeping current. In a rapidly changing world, on-going staff development is vital if instruction is to remain relevant. Thus, we elected to utilize an inquiry style of delivery for the institute as a model of the kind of teaching we hope participants will employ in their own classrooms.

Self-efficacy

Bandura (1997) cogently argues that teachers are responsible for creating instructional environments that foster effective learning. He asserts that their doing so is dependent upon their confidence that they have sufficient knowledge and an adequate understanding of strategies for effective teaching. It is therefore incumbent upon staff developers and teacher educators to offer current techniques that will engender this competence and confidence.

Simultaneous Inservice-Preservice Staff Development at a Single School Site

Research on implementing innovations shows that successful programs provide training and support for the entire faculty of a given school (Fullan, 1991). Moreover, at a single site where the principal supports the program, colleagues tend to work together knowing that there is an expectation of implementation (Marcinkiewicz & Regstad, 1996). This contrasts with the trainer-of-trainer models where one or two teachers from each of many schools receive the training and take it back to disseminate at their schools. In such a design, there is neither immediate support when teachers experience difficulties, nor a sense of common commitment and vision for implementation. Sadly, these isolated teachers often abandon an innovation before it is fully implemented (Fullan, 1991). Thus, we have chosen to focus on all of the teachers in one elementary school. The impact of the project will not be limited to this local school, however, since the university students, upon leaving this supportive environment, will carry their learning into a variety of school districts where they are employed.

Description of the Project
Two-week Summer Institute

In a summer institute format, 28 participants began these experiences in the role of students, exploring the behaviors of butterflies and weather-related phenomena under the guidance of subject-expert leaders and College of Education mathematics, science, and language arts, and technology faculty. Hands-on experiments led them to seek additional information and real-time connections through the Internet. The intent was to have practicing teachers and future teachers learn in the manner they would later use with their own elementary students. During the second portion of the institute, inservice teachers and the education majors, whom they would be mentoring through internships in the fall, collaborated to develop their own web pages to be used with elementary school children. As a result, technology staff development was designed to have direct applicability as participants learned to search the Internet; bookmark appropriate sites; complete a template with both teacher lesson planning pages and student activity pages; create links; and save their work appropriately for posting on a web site.

Two One-week Summer Camp Sessions

Using the activities and web pages they had developed during the institute, the inservice-preservice teams could field-test their ideas with small classes in an informal climate. One of the institute participants, a teacher from the school site, served as director of two camp sessions attended by 114 children from the community.

Follow-up Sessions

During fall of the school year, the project team conducted monthly follow-up meetings. There were three purposes: (a) to sustain the motivation for implementing and extending the units place on the web pages during the institute; (b) to provide assistance in resolving any technological or curricular problems experienced during implementation; and (c) to maintain the sense of community built during the concentrated summer experiences. Additionally, participants and leaders continued to communicate and shared ideas using e-mail.

Data Sources and Data Analysis

Participants completed several survey instruments at various points including prior to the summer training, after completion of the summer training institute, and during the fall implementation phase. One survey instrument measured participants' confidence in using the Internet to enhance their instruction. This instrument was an adaptation of the Microcomputer Utilization in Teaching Efficacy Beliefs Instrument (Enochs, Riggs, & Ellis, 1993). This valid and reliable instrument was modified to focus on the use of the Internet rather than on microcomputers. The instrument uses a Likert-type, five-point scale from strongly disagree (1) to strongly agree (5). Additionally, two dimensions of efficacy are measured on the instrument—personal efficacy and outcome expectancy. Personal efficacy measured feelings of teacher's confidence for using the Internet including for example, "I know the steps necessary to use the Internet in an instructional setting." Outcome expectancy assessed the teacher's feelings of how it will affect learning, "Students' Internet ability is directly related to their teacher's effectiveness in classroom use of the Internet." At the same three times participants completed the efficacy instrument, they also completed a survey instrument, which assessed their understanding of and their perspectives on the usefulness of Arizona academic standards for mathematics, science, and technology. These measures of understanding and usefulness were measured on a Likert-type, four-point scale from strongly disagree (1) to strongly agree (4). In a third instrument administered at the completion of the summer institute, participants responded to items that assessed their confidence for publishing on the web. Specifically, they responded to items assessing how they felt about publishing on the web prior to and after the summer training. K-8 students and parents completed questionnaires related to evaluation of the summer camps.

The efficacy measures and the understanding and use of Arizona academic standards was analyzed using repeated measures ANOVA. Confidence for publishing on the web was analyzed using a dependent t-test. Student and parent responses are descriptive data.

Results

Results from the repeated measures ANOVA showed a significant effect on personal efficacy for use of the Internet in instruction, $F(2, 42) = 8.82, p < .001$. Means showed a substantial increase from before the summer institute training to after the training, which was maintained during the fall follow-up. Means for the personal efficacy measure were: 3.51, 3.81, and 3.81, respectively for these three time periods. Similarly, results from the repeated measures ANOVA for outcome expectancy were significant, $F(2, 42) = 6.95, p < .002$. These means showed the same substantial increases from pre- to post-training, but the follow-up mean fell back. The means for outcome expectancy were: 3.50, 3.81, and 3.63, respectively for the three time periods.

With respect to the understanding of the academic standards, results showed that participants increased their understanding of the technology standards, $F(2, 42) = 4.22, p < .021$ and of the science standards, $F(2, 40) = 4.60, p < .016$, but not of the mathematics standards. Means for understanding the technology standards were: 2.79, 3.11, and 2.95, respectively for the three time periods. Means for understanding the science standards were: 2.59, 2.97, and 2.84. For the measures of usefulness of the mathematics, technology, and science standards there were no significant differences across the three time periods. Ratings for the usefulness of the standards for instruction were initially quite high, 3.5 on a 4-point scale, and remained stable over time.

The analysis for the measure of confidence for publishing on the web was significant, $t(26) = 3.72, p < .001$. Teachers demonstrated more confidence in web publishing following the summer training institute. Students and parents felt the summer camps were valuable and indicated they were pleased with the camp, happy with what they learned and would participate again if given the opportunity.

Discussion

The hands-on, inquiry-based approach to professional development utilized in the current project was quite successful. Significantly, Internet utilization in classroom teaching easily lends itself to the use of an inquiry-based approach, the kind of instructional approach for classrooms that maximizes understanding and motivation among students. For example, by using the Internet, students quickly can gather information related to their own questions that are based on their needs, interests, and goals. The Internet offers powerful opportunities to teachers and their students to conduct their own research about issues, which concern them.

The success of the project also was reflected when teachers demonstrated greater feelings of efficacy for using the Internet as a result of their participation. With regard to using the Internet for instruction, both personal efficacy and outcome expectancy for use of the Internet increased for the participants. In addition to increasing efficacy for Internet use in instruction, participants also demonstrated increased understanding of the academic standards for technology and science. These outcomes are consistent with Bandura's (1997) work in which he suggests that efficacy, confidence about teaching, is dependent on sufficient knowledge and adequate understanding of strategies for effective teaching. Thus, in the current project, the training engendered feelings of confidence among inservice and preservice teachers about their ability to augment their mathematics and science instruction using the Internet.

For this project, one final issue warrants some consideration. Comprehensive, effective professional development provides sufficient and appropriate opportunities to learn, adapt, and field test newly learned content and pedagogical knowledge. Importantly, in the current project, teachers had sufficient time to carry out these three critical activities. The summer institute provided sufficient depth of material and time for participants to *learn* material appropriate for augmenting their instruction on the Internet, *adapt* the materials and methods to their particular needs, and *field test*, i.e., try out their new understandings during the summer camps. Such opportunities, which provide for depth and time, are critical to the success of any professional development activity.

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A Net-Course for Physics Teachers Supporting Collaborative Learning and Inquiry

Rosa Maria Sperandeo-Mineo
Department of Physical and Astronomical Science
University of Palermo
Italy
sperande@fisica.unipa.it

Abstract: This paper is a report on an experimental model of Net-Seminar tailored to train teachers in transforming their teaching by promoting a constructivistic teaching practice and an instructional approaches computer-enhanced that enables pupils to learn about the process of modeling physical phenomena. A relevant point of the instructional approach is the development of metacognitive knowledge and skills: teachers are engaged in a reflective process in which they evaluate their own and each other's activities and reasoning. The Net-Seminar supports the learning by scaffolding apprenticeship model: teachers experience a first-hand virtual education that includes downloading of electronic documents, participating to group discussions, creating shared knowledge spaces and other activities which they can carry out with assistance and then use by themselves in their own classrooms. Results concerning the characteristics of the network are discussed and conclusions are drawn about the ways of improving the network and the interactivity of the Net-Seminar.

Introduction

The introduction of (IT) Information Technology (Microcomputer Based Laboratory, multimedia, simulation software and hypertext) in teaching/learning environments produces relevant modifications that are the objective of many research studies. A Project is in progress in Italy concerning the physics teaching at high school level: it involves 8 universities and is supported by CNR (the National Council of Research). Its main objective is the implementation of teaching/learning environments using computational tools in order to support student activities concerning exploration and experimentation. Computational tools does not simply offer the same content in new clothing: areas of content have to be recast and new ways of teaching concepts are possible, allowing learners to explore concepts that were previously inaccessible. Moreover, computational tools involve a substantial modification of teacher role and teaching methods.

The research results reported in literature (Riel, 1994, Swan and Miltrani, 1993) as well as some preliminary results of our project show that teachers need an appropriate training in implementing IT innovations: very soon, they act as modifiers since they try to adapt the innovations to their old teaching/learning models. After a training course, the isolation in which teachers work, in most of cases, lead them to limit objectives of their work in corresponding to the met difficulties. Innovative teachers should feel part of a wider community that, while operating locally, helps them to overcome isolation by linking them up in an on-going manner even though they work in separate geographic locations.

The use of Information and Communication Technologies (ICT) in education is currently the focus of much attention: many projects now in progress study the design and the development of telematic learning environments by stimulating learning through communication and peer collaboration (Kaye, 1991, Veen et al., 1998). Some findings concern the new instructional formats that make ICT effective and applicable in different contexts: technology-enhanced distance education environment facilitates collaborative learning, active learning, and independent learning and exceeds the traditional classroom in its ability to connect people and course materials on a round-the clock basis (Selinger, 1998).

This paper reports a currently under-way research in Italy aimed to experiment ICT for teacher training in introducing new physics contents and teaching methods at high school level. Objectives of the project are:

- the understanding of teachers' need in the area of ICT;
- the preparation of new pedagogical environments for teacher education;
- the analysis of new competencies that teachers, using ICT, will need.

A relevant point of the instructional approach is the development of metacognitive knowledge and skills: teachers are engaged in a reflective process in which they evaluate their own and each other's activities and reasoning. The course model is based on the hypothesis that the focusing on the process of metacognition is helpful to teachers to learn how to be engaged in and to reflect on modeling teaching practices. The teachers attending the Net-Seminar are exposed to a broad repertoire of educational strategies, virtual teaching techniques and supporting material for thinking about the discipline.

The paper describes the structure of I.MO.PHY.(Introduction to Modeling in PHYsics education), a Course delivered through digital Network (Net-Course) and some preliminary results of its pilot test involving 50 experienced teachers attending the Net-Course on optional base. They have been engaged by the research groups that supplied their local assistance (hardware, software, etc...).

The Innovations

Our approach to physics teaching is based on the frameworks derived from constructivistic epistemology (Von Glasersfeld, 1993) and focused on the process of constructing predictive conceptual models of the physical world (Hestenes,1987, Gilbert et al., 1998). Model building is considered as a superordinate process skill and the introduction of modeling activities contributes to various content areas, enabling students to see similarities and differences among a wide range of phenomena. Scientific models are usually very different from pupils' personal views of the world, the spontaneous models (Gentner. and Stevens, 1983), and some transformations of scientific models are necessary in order to fill this gap: these will be able to perform the "fitting", that is to gradually adapt pupils' conceptions to scientific models.

This approach involves a construction of the physics content structure that has to be taught not mainly, or even solely, oriented to physics issues but also including educational issues and pupils' conceptions. These two issues, students spontaneous models and statements of the scientific knowledge, are therefore accepted to be of the same relevance and treated as resources for physics education. In this way the physics content to be taught is reconstructed in order to realize the main goal: to allow students to gain a fruitful knowledge of the outer world (in our case physical world). This involves substantial modifications in learning sequences as well as in teacher's role and teaching methods.

The teacher has to transform himself or herself from being a 'dispenser' of knowledge to being a 'coach' managing the evolution of student skills and a 'modeler' shaping and molding learners' knowledge (Watts and Jofili, 1998). Teaching strategies to be implemented have to build new knowledge on pupil spontaneous models and to provide learning environments explicitly promoting an appropriate epistemology of science that has to become the content of instruction and has to be embedded in instructional methods. Consequently, teachers need to have a deep knowledge of the nature of physics models and their functioning in the development of the discipline as well as an awareness of the pupils' spontaneous models in the different content areas.

Usually physics courses, at high school as well as at university level, use a teaching approach based on a lecture format of the classes and few laboratory activities restricted to a mere verification of some physical laws. It has been shown that the direct learning experience as university students functions as the best training in teaching methodology: in fact, very soon they transfer perceived methods and learned contents in their classrooms, simplifying the approaches usually through the teaching models reported in textbooks (Sprinthall, 1995).

Teacher training usually consists in scientific courses and courses about education based on a lecture format of the classes. Moreover, the courses in education are totally separated from the instruction in physics content and teachers have to necessarily synthesize by themselves in order to solve their specific teaching and learning problems.

To modify the high school physics teaching approach by a procedure of transmission of consolidated knowledge to the implementation of teaching/learning environments, where teachers manage and support the pupil processes of knowledge construction, involves a deep modification of the structure of the teacher training courses: substantial modifications of teaching methodology and approaches cannot be transferred to teachers only by using theoretical courses outlining the methodological underpinnings but by making experience to teachers the same teaching/learning environments we think they have to provide to their pupils. In order to communicate new knowledge and new behaviors, we need teachers' training strategies that build the new knowledge on the previous one: there is a close parallelism between how the change occurs in pupils' scientific conceptions and how a change in the conception of teaching can occur (Sprinthall, 1995). A well founded change in teachers' didactic activity involves also a conceptual change (Posner et al., 1982).

As a consequence, the basic principles of the Net-Course are the following:

- teachers themselves have to be learners and to experience the kind of learning they can provide to students;
- they have to be engaged in using the pedagogical tools designed to help learners in conceptualizing physics models and in gaining the abilities connected with modeling procedures;
- they have to be involved in activities aimed at stimulating hands-on learning and metareflection;
- teacher education has to be connected with classroom experimentation of the involved innovations.

For metareflection we intend the activation of those procedures (sometime named metacognitive skills) that direct and steer the information processing-flow of learning, in order to make them explicit, recognizable and reproducible (Simons 1995). In particular, we intend the metalearning development of Shön's (1988) reflective practice that already has been successfully applied in various contexts of science teaching and tutoring (McKinnon and Erikson 1988, Linder et al. 1997). Shön argues that all aspects of teaching-practice supervision should be characterized by fundamentals of "coaching" where:

> through advice, criticism, description, demonstration, and questioning, one person helps another to learn practice reflective teaching in the context of doing. And one does so through a Hall-of-Mirrors: demonstrating reflective teaching in the very process of trying to help the other learn to do it.

Shön (1988) defines the learning activity as the process of "making sense of complexity" and introduces a second reflective domain relevant for the objective of learning to teach: the 'reflection-on-action', i. e. the thought used to review sense-making of complexity. We have applied Shön's hall-of mirror approach in the context of the Net-Course. Electronic conversations, facilitated by moderators, are aimed to perform this kind of reflective coaching.

The IMOPHY-Net-Course

A telematic learning environment, used for teacher training, demands a thorough rethinking of the content and the teaching/learning activities of the involved learners (in our case the Teachers (Ts)) and trainers (in our case the Researchers (Rs) of the projects). Interactions and teaching learning activities are delivered in a setting that it is very different from a classroom and/or a laboratory. Our Net-Course takes into account the results and the experiences rising from previous Projects evidencing that three main categories of functionality seem to be critical for the design and the development of telematic learning environments. These are related to: - information such as documents and other material including images and sound; -interactivity defined as human-machine interaction; and communication taking place among learners and teachers, peers and others.

These functions have been supplied, in an integrated way, in the three phases of our Net-Course:

1. Face-to face Workshops where Ts were trained by the Rs of their local university group to get acquainted with Internet, e-mail facilities and software involved in the project (Excel and Interactive Physics).
2. Net-Seminars where Ts were supposed to analyze the educational materials supplied by Internet, discuss them using e-mail and/or forum facilities and, at the end, to program a classroom experimentation of one Learning Unit (one activity concerning the modeling of a choice category of phenomena).
3. Experimentation in classroom of the chosen Learning Unit and collection of evaluation elements (Ts' logbooks and students' reports).

The physics content of IMOPHY involves modeling activities in different fields of mechanics and thermodynamics. The materials and the pedagogical tools used in the Net-Course had been experimented in real high school classrooms by the researchers and/or experienced teachers. The learning material is structured in modules aimed to support (through Teacher Guides(TGs) and Student Sheets (SSs)) teachers in implementing the modeling activities in their classrooms. The organization of each Teacher Guide intends to engage teachers in their own investigations in order to gain the prerequisite skills and knowledge, concerning the physics content as well as the pedagogical tools. For each module a Net-Seminar has been organized: its term was from 10 to 15 days depending on the materials to be analyzed and/or on the software and experiments to be performed.

The Net-Seminar Structure

The relevant points of our teacher preparation process are the following:

- deep analysis of the physics content structure;
- evaluation of the pupil involved spontaneous models;

- construction of pilot classroom instructional sequences through metareflection on the involved learning requirements.

The starting point of each modeling procedure is the analysis of some easily observable phenomena and the TGs conduct from observations to models through 4 different sections:

- in the first section some examples of questionnaires, used by researchers in order to investigate pupils' common conceptions (the spontaneous models), are supplied and the research results analyzed;
- in the second section , observations about common phenomena that can constitute the ground of pupils' spontaneous models are pointed out;
- in the third section, some experiments, that can be easily performed, are described;
- in the fourth section, different aspects of the modeling procedure and the gradual enlargement of the experimental field, for the further presentation of more powerful conceptual models, are analyzed.

All sections include suggestions about the ways in which to perform the different activities in the classrooms. Moreover, the TGs supply examples aimed to stimulate teachers and students in reflecting on the relationships between real-world observations and results of experiments with modeling activities, in order to foster a common interpretation.

The Net-Seminar audience was constituted by 12 project researchers (6 were the local coordinators supporting locally the teachers) and the involved teachers. Two or three moderators (the project coordinator and the authors of the educational materials) stimulated discussion and reflection concerning the materials as well as their transfer in a classroom setting. They tried to stimulate a reflective domain, relevant for the object of learning to teach. Fundamentals of coaching for reflective teaching were questions and statements stimulating opinion on a question of action, criticism, descriptions of learning situations, demonstrations of cause/effect relationships, etc...This activity was aimed to help Ts to become aware of learning strategies and self-regulation skills applied in the various phases of their work and how these strategies and skills were related to learning goals.

As a starting point, Ts were requested to prepare a report describing a possible implementation of the educational materials in their classrooms. The requirements were to prepare a conceptual map connecting the involved concepts, detailed questions for pupils, activities to be performed and evaluation materials. The need to evidence their role as teachers, in each moment of the programmed classrooms activities, was outlined. Following Schön's hall-of-mirror approach (1988), Ts and moderators continually interchanged prospective: moderators never had to figure out how to solve a peculiar problem, instead they introduced new problematic elements in order to put into evidence the real complexity of situations. The moderator main role was, in simulating pupils meeting learning difficulties and in analyzing these to stimulate Ts in surfacing their own difficulties and in reflecting on their own learning, putting in action some possible ways of searching for appropriate solutions. In few words, the hall-of mirror experience gave Ts the opportunity to share with each other how they dealt with difficulties, questions and problematic situations of their future teaching/learning environments. The researcher experience, during the experimentation of the pedagogical tools in real high school classrooms, has been the main point for the implementation of this phase: to observe the knotty problems of the physical content and the crux of the used pedagogical tools have given useful indications in outlining possible teaching/learning settings for the analyzed context.

Research Design and Preliminary Outcomes

The scope of the pilot test was limited: a case study approach has been employed using a qualitative method of data gathering and analysis. This method involves constant reflection through the observation and data in order to identify key analytical themes grounded in the data (Strauss, 1987). Various data collection sets have been used:

- the analysis of the communication, including frequencies and structure of messages, their peculiarities and so on;
- the analysis of the forum' discussion;
- a questionnaire concerning individual timings;
- a anonymous structured questionnaire;
- the Ts' logbooks and the students' reports of the classroom work.

The analysis is in progress, yet some preliminary results can be drawn:

- Teachers of our sample ranged 35 - 55 years old; their experience with IT had been on optional individual basis and their classroom use of IT had been short and fragmentary. The majority was not accustomed to work with the physics colleagues in studying teaching approaches and classworks.

- Only 70% of teachers who had signed up to the Net-Course completed the work. Those who have given up met two kinds of problems: technical problems and lack of time. The second problem is a consequence of the first since they declared to have under-estimated the required technical competencies. Two kinds of technical problems have been met: access to web and problems in managing software and hardware. Teachers actively attending to all the Net-Seminars had home access to web; access from schools usually was not easy for time problems as well as for computer availability. Many teachers revealed that the face-to-face meetings have been not enough to gain the necessary familiarity with software and hardware in order to actively use them and, then, to actively participate to discussion.
- 153 e-mail messages have been exchanged using the listserver, during all the phase of the Net-Seminars, but 30% of people sent no more than one message. More structured and complete messages were sent to the forum; it registered 35 messages. It is interesting to note that the project coordinator received to its private e-mail address 48 messages: some from teachers that usually did not participated to the group discussion and others from teachers asking a private evaluation of the results of their modeling activities and/or experimental data. Most of the teachers who have been absent from the on-line discussion were graduated in mathematics: they declared to their local coordinator to be not enough competent in the physics content to participate to discussions. This involves the need to reflect about the composition of the groups of discussion: homogeneous or heterogeneous groups? Both the choices present advantages and disadvantages.
- The analysis of e-mails shows that the computer mediated communication, that is communication in writing and in deferred time, presents many advantages in-service teacher training. It involves a much greater degree of synthesis and clarification than in face-to-face oral communication. Moreover, on-line education benefits professional teacher preparation: the possibility of sharing personal experience related to the subjects and to the class management plays a key role in the collective growth of the group.

Some basic principles of metacognitive instruction have shown their validity for teacher education, and among these:

- to emphasize learning activities and processes, rather than learning outcomes;
- to spend sufficient time in reflecting on learning strategies and self-regulation skills.

The application of some aspect of Schön's reflective practitioner in teacher's education helped Ts to think about teaching, planning and classroom management in ways that they had not before. They, through reflection, gained a framework in order to build metalearning awareness in terms of both the content and process of learning. In our opinion, this framework helped them to generate significant changes in their teaching/learning approach.

A preliminary analysis of the anonymous questionnaire shows that the most of teachers judge the experience very positive and give many suggestions for improvement. However, it must be taken into account that for a more effective using of ICT for teacher training a deep teacher knowledge of the involved technology is a prerequisite.

By a large majority, teachers asked to repeat the Net-Course (also amplifying the physics content). In our opinion, the fruitful sense of belonging to a community has been the main factor to stimulate the active participation of teachers.

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The Web in High School Science Teaching: What Does a Teacher Need to Know

Raven McCrory Wallace
The University of Michigan
School of Education
United States
ravenmw@umich.edu

Abstract: The Internet is becoming omnipresent as a resource for K-12 education. Teachers are a diverse set of users who must incorporate this resource into ongoing practice. Research on using the Internet in classrooms is lagging far behind deployment, and teachers are left to their own devices to figure out what works. Using case studies of three teachers, this study considers the work of teaching with the Internet as a site for understanding what teachers need to know to incorporate the Internet into high school science teaching. Results point to knowledge in three areas - technology, pedagogy, and content. Technological knowledge need not be extensive, but technological support is necessary. Pedagogical knowledge is more problematic, as teachers work out how to fit the Internet into their own practice. An important aspect of content knowledge emerged, knowing the boundaries of one's knowledge.

Introduction

Connecting to Internet is a widespread educational innovation in K-12 schools, and some argue, a resource for major reform. But what teachers and students do with this new resource has been little studied. Work from major research and development projects indicate that, with adequate support, the World Wide Web can be used in productive and exciting projects in high school classrooms, projects which engage students in scientific inquiry in line with recent calls for reform (Edelson, Pea, and Gomez, 1996, Songer, 1996, National Research Council, 1996). But few studies have been conducted of teachers as users of the Internet in "ordinary" situations, i.e., when they do not have the extensive help of researchers and developers. We know little about what teachers need to know to make effective use of the Internet in part because we know little about what effective uses look like in practice. Yet it is commonplace to read that the Internet could be an agent of reform in schools if only teachers were "trained" to use it. While survey research indicates that the Web is being used extensively, it provides little insight into how users – both teachers and students – are making sense of the technology in classrooms (Becker and Anderson, 1999). It is this process of sensemaking, of teachers and students constructing a reasonable use of the technology in practice, that provides a window into issues of teacher preparation for the future.

The major question of this study is: What do high school science teachers need to know to construct and manage the work of teaching with the Internet as an on-line resource? Thinking of technologies as resources for the work of teaching changes the point of view significantly, from considering how students might best learn from features of the technology to studying affordances for interactions between the teacher and students in their use of technologies, and how teachers can help students learn with and from technology. The mediating space between students and technologies becomes the site of opportunities for teaching and learning, as well as becoming a site for understanding the possibilities for future technologies, and for designing learning opportunities for professional development. The larger study, of which this work is a part, explores uses of the Web in practice from the point of view of the teacher, identifying challenges and dilemmas high school science teachers face as they use the Web in their teaching and considering how they resolve or manage those problems. It draws on two major research programs for its rationale and methods: research on teaching as problem solving and dilemma management (Ball, 1993, Ball and Lampert, 1999, Lampert, 1985, Lampert, 1995) and research on social construction of technologies (Nardi & O'Day, 1999, Suchman, 1995).

Methods

Ethnographic methods are the basis for the work of this study. Data includes structured interviews with seven high school science teachers and subsequent case studies of two of the interviewed teachers. Teachers were selected for interviews based on solicitation at a statewide conference for computer-using teachers, and by word of mouth. Since the purpose is to explore, gain understanding, and generate theory about use of the Internet in the practice of teaching, cases were selected as probable sites for "telling tales" (Mitchell, 1983, Rex, 1997) not as either typical or exemplary teachers. These cases are telling because they are likely sites for making the work of teaching with the Internet visible, likely because of the teachers' levels of experience (not novice teachers, but not entirely settled in their uses of the Internet), their attitudes toward and knowledge of the technology (eager and willing to use the Internet, but not overly technical), and their willingness to share their ideas and experiences. The case studies include classroom observations during units in which the Internet was in use by students, and interviews before and after classroom observations. Each teacher was observed during one class period for approximately a week, depending on the design of activities using the Internet. For two of the teachers, data collected during the observation period included video recordings of the teachers along with video captured from computer monitors of students with audio of the students' conversations as they worked on the Internet. The third teacher declined to be recorded, so records of her classes consist of observation notes. Data were analyzed by coding transcripts and video using qualitative analysis software, (Quality Solutions and Research, 1997). Coding schemes have been developed iteratively in multiple passes through the data, with constructs and categories emerging from repeated analysis. Nardi's description of information ecologies (Nardi & O'Day, 1999), Lampert's work on domains of teaching (Lampert, in preparation), and Cohen's categorization of teaching terrains (D. K. Cohen, personal communication) provided starting points for initial coding.

The Cases

The three teachers included in this study – Daniel Owens, Lucy Varner, and Mary Robbins – worked in three very different schools with distinct populations of students.[1] The teachers had different reasons for using the Internet, different expectations for their students, and different approaches to the work of teaching with Internet resources. The teachers needed, and used, knowledge in three areas: technology, science, and pedagogy. One intriguing view of teacher knowledge in these classrooms comes from considering teachers' awareness of their own knowledge. What do they report that they know and do not know, and how does this contrast with observations in the classrooms?

Daniel Owens

Owens is a young teacher, in his third year of teaching science in an urban school district. He comes to teaching from a major in biology. Owens' school was wired for the Internet just before he started teaching there, and the science classrooms were each provided with 17 Internet-connected computers. Owens expresses a desire to make use of the Internet in his teaching, but he has not quite figured out how to use it effectively. He struggles with reconciling what he learned about science teaching – that he should let students explore and discover science for themselves – with the reality of the expectations for his teaching – that he will cover a specified curriculum during the year. He expresses a desire to do less talking, to get students more involved and motivated to learn science, and he thinks that doing projects on the Internet can be helpful in reaching this goal. He wants all of his students to get to use the Internet because, for some of them, school is the only place they will get that opportunity. Most of Owens' students do not go on to college, so he feels acute responsibility for helping them learn as much science as possible in what may be their last science class.

During the two-week observation period for this study, the students in Owens's chemistry class (mostly eleventh graders) worked on a project using the Internet to find information about radiation. Owens decided to assign the textbook chapter on nuclear chemistry because he thought it was important

[1] Pseudonyms are used throughout.

and interesting, even though the other chemistry teacher at the school "would never teach that chapter." After they read the chapter, students spent three class periods browsing the Web to find evidence supporting or opposing some use of nuclear energy in preparation for a debate they would have at the end of the unit. This was new content for Owens as well as for his students, so they were, in a sense, learning together. Owens purpose was to motivate the students to want to know more about radiation so they would more enthusiastically learn nuclear chemistry. Owens reported that he felt he did not know enough about using the Web. He wanted to know more about searching, about constructing queries that got better results. He felt certain there were some tricks of the trade that would make his searching more effective. He also reported that he was dependent on the technology support person, located in the building, but shared by several schools, to straighten out technological problems. Although he said he rarely had problems, during the two weeks of observation, many computers were out of use, and printing was not possible except from the computer on his desk.

In Owens' class, students were ranging free on the Internet, looking for information that interested them about radiation. This led to Web sites with little science and lots of opinions, interesting but controversial and not well substantiated claims about scientific phenomenon. Students offered Web sites as evidence that cellular phones cause brain cancer, that radiation therapy should be banned because it is more dangerous than the cancer it is used to kill, that nuclear power plants routinely emit huge quantities of dangerous radiation, and more. Owens worried that the students "were not learning the science" by using the Web, even though he seemed to be accomplishing his primary goal of getting them interested in "the science." Nevertheless, the strengthening of scientific misconceptions via the Web was troubling: Owens knew he was not familiar with much of this content, but was less aware that he too was vulnerable to accepting non-scientific arguments from the Web. In this case, the issue seemed to be Owens' need for a better awareness of *what he did not know*. He ventured into territory where his scientific knowledge was not strong enough to make judgements about validity. Because of his goals for the activity, rather than taking students into the science they would need to make sense of what they found, he participated with the students in using information from the Web rather than scientific evidence or arguments as support for their beliefs.

Owens used the Web for motivation and worked from the assumption that he did not need to know the content to use the Web this way. This is a familiar argument from reform literature: the teacher should become a guide or facilitator and does not need to know about everything students encounter. However, it was worrisome to see students buying into possibly illegitimate or prejudicial content without intervention by the teacher. Owens was experimenting with pedagogy, figuring out what would work to get the students interested in the topic and still get to the substance of the scientific knowledge he hoped they would learn. On the one hand, his strategy worked: students got quite interested in issues related to radiation. On the other hand, he worried that they had not connected that interest to the science of nuclear chemistry, and he was not sure how to go about making a stronger connection. Owens felt he knew the science well and knew enough technology to get by. He was less certain about the pedagogy of teaching with the Web, and knew he was learning as he taught.

Lucy Varner

Varner has nine years teaching experience. She, too, was a science major in college, and she is teaching in her area of expertise, physical science. Varner's school is a large suburban high school with a very successful Advanced Placement science program. Varner teaches the first class in the AP sequence, Advanced Physical Science. Her students, who are mostly tenth graders, are expected to go on to AP Chemistry in the eleventh grade. She takes her mission to get them prepared for chemistry quite seriously. She uses the Internet to get access to content not available in the books she uses, to keep the students motivated, and to work with up-to-date information. She also thinks that these students should learn to use the Internet as part of their education, and that science class is one place where that should happen. Varner sometimes goes to one of the school's connected computer labs to use the Internet, but once a year, she has a set of laptop computers on-line in her classroom. During the observations for this study, the laptops were in her classroom for a week during which the students worked on weather, on and off line, to learn to interpret weather maps and forecast weather.

In contrast to Owens, Varner became an expert on the Web sites she asked her students to use. She took an extensive course from the American Meteorological Society (AMS) about weather and using their Web site in teaching, then she modified their curriculum to fit her class. Each day they were online, Varner went to the site before her classes started (she taught five sections of the course) and prepared questions specifically dealing with the day's weather. During class, she was able to answer questions from across the room about what students saw on the AMS Web site, so familiar was she with what was on the site. The assignments she gave her students were quite constrained – they used only a couple of pages within the AMS site; but they took advantage of the up-to-date weather data available on the Web in ways that would have been nearly impossible without Internet access. Varner also depended heavily on the technology person in her building. The complex set-up of 15 laptop computers in her classroom would not have been possible without his assistance. Varner had used the laptops many times and she was able to handle the few technological problems that came up during class. The technology person came by her class a couple of times each day to make sure things were working smoothly. He helped her put the computers away at the end of the day (they had to be stored in a locked cabinet) and set them back up in the morning. Printing was not available in her classroom, and it was not part of the activities she planned for her students.

Varner taught with the Web as she taught with other resources: she acted as an expert and planned activities to help students gain the knowledge she thought they needed. Her class was carefully planned, and its execution depended on her expertise. She engaged with students on the scientific substance of their work. Varner became an expert in the content her students used on the Web, and had them use it as the basis of their learning. The focus was on science content and Varner's expertise was an important feature of the students' opportunities to learn. Varner's teaching and her content knowledge were seamless across Web and non-Web activities: she directed student activities with a firm hand, gave them demanding and fast-paced assignments, and expected them to learn the required content. In the context of her class – highly motivated, college-bound students – her strategies worked well and her level of expertise was necessary to make the strategies effective. She knew the science she wanted to teach, she knew how she wanted to go about teaching it, and she knew enough about the technology to make it work. In this case, the teacher created an application that took advantage of an important offering of the Web – the up-to-date data – and fit it into her curriculum and pedagogy.

Mary Robbins

Robbins is a veteran teacher with 16 years experience. She teaches in a suburban district, in a school for students who have had trouble in the district's other high schools. Classes are small – no more than 15 students – and the school itself has only 150 students. Her classroom has 12 on-line computers that are used extensively by students for a variety of purposes, including word processing, running applications programs, and using the Internet. The computers are totally integrated into classroom life, with students going on and off computers just as they use reading materials. Robbins teaches science as a means for teaching students to take responsibility for their lives and education. Her priority is on getting students to complete their work, behave well in school, and be able to work independently, with the goal of getting them back into a regular high school before graduation. If they learn science too, so much the better. In the year of this study, Robbins was teaching biology. The class worked on a set of independent assignments – their first of the year – with a short research paper due each week on a specified contagious disease along with a set of questions about the week's biology topics. They were free to use any resources they chose to do the work – textbooks, CD-ROMs, the Internet, and the library were all available to them. Robbins kept a tight rein on the students' work, with many checkpoints and lots of feedback about their progress. She gave them quite explicit suggestions for using the Web, telling them keywords to use in specific search engines to get results she knew would be there. Students moved on and off the Web quickly, mostly using it to find specific bits of information that Robbins knew would be there. The assignments were carried out almost as they would be done using a textbook, looking for specific answers by matching keywords. For these students, doing this work in a relatively independent way, was an accomplishment.

Robbins knew the science content she was teaching well, and yet that knowledge did not seem to be an important factor in these activities because the focus was so much on responsibility and behavior.

Her pedagogical knowledge was also extensive – she had taught this unit before and knew how to manage the class and what to expect students to do. Robbins was something of a "techie," an expert in using and maintaining computers, but she called on the local technical support person when computers went down in lieu of fixing them herself, reporting that her time was better spent working with students. At the end of the unit, Robbins reported that things had not gone quite as she expected and hoped. Many of the students had not been able to work well in this independent mode, and Robbins felt she had not provided enough structure for the activities.

Discussion

Some clear patterns are apparent in these cases, illustrated in Table 1. First, although their expertise varied, all three of these teachers felt comfortable using the Web themselves. They were confident that help was nearby if something went wrong, and they each went into these activities with contingency plans for what they would do if the on-line activity proved to be impossible. It is important to note, however, that two of the three teachers were not technology experts in any sense. They had not received special training in technology, nor did they surf the Web or use technology for their own pleasure. The third, Mary, was much more of a computer expert, mostly self-trained as a programmer and hardware tinkerer. Those skills did not come into play in the teaching observed here. All three teachers were well aware of the boundaries of their knowledge of technology, but they each had adequate support to make effective use of the Internet in their classrooms. Without this support – in all three cases, on-site and readily available – these teachers probably could not have taught as they did. They all had a strong belief that using the Web was valuable for their students, agreeing that one of the values is that students "need to

Area of knowledge	Challenge
Knowledge of technology	Knowing enough to be able to plan effective lessons and units. Knowing enough to get help when it is needed (and having help available).
Knowledge of science	Knowing the boundaries of one's knowledge. Having a grasp of the discipline itself.
Knowledge of pedagogy	Understanding the fit between technological contexts and activities. Predicting how students will engage in activities – knowing what to expect.

Table 1: Teacher knowledge for Web teaching

Second, while extensive content knowledge is almost inarguably a necessity for science teaching, teaching with the Web brings out another important dimension of content knowledge: knowing the boundaries of one's knowledge. The problem may not be that a teacher does not know something, but rather that he is not aware of his own misconceptions or misunderstandings. The idea of teacher as facilitator or guide for students as they engage in inquiry must presume a level of *disciplinary* knowledge which enables the teacher to navigate content he does not know, using disciplinary structures to model a sense-making process. Two of the three teachers studied here dealt with this problem by constraining what students did on the Web to limit them to content with which the teacher was familiar. The third let students explore the Web more openly and unknowingly found himself in new territory. Without a better understanding of the limits of his knowledge, and perhaps without specifically adopting a goal of modeling inquiry for students, he stumbled into student misconceptions that were never rectified.

Third, knowledge of the pedagogical possibilities for teaching with the Web include knowing the kinds of activities that are fruitful and those that, although they sound good, lead to frustration; knowing how to bound student work on the Web so that their actions and products are manageable; knowing what kinds of technological contexts can work for particular activities (e.g., the number of students per computer, number of days on-line needed to accomplish the work, locations of computers, etc.). These teachers varied in their approaches to using their pedagogical knowledge and to learning new things: Owens experimented with pedagogy, Varner designed the work to fit with known ways of teaching, and Robbins built on prior experience.

As predicted by previous studies of technological innovations in schools, these teachers took two approaches: they adapted the technology to their teaching, working to make it fit into established routines and expectations; or they used it for reasons somewhat peripheral to content knowledge – in these cases, for motivation and for learning the technology *per se*. The simple technology of the Web makes this adaptation possible, but also means that the Internet-in-use can have many faces, and that "training" teachers to integrate the Internet into their teaching is likely to be a complex and challenging undertaking.

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A Science Equipment Clearinghouse: Linking Industry to Science Education Reform Efforts

Adele Kupfer
Graduate Center of the City University of New York,
Center for Advanced Study in Education
United States
Adelek@worldnet.att.net

Abstract

The purpose of this paper is to demonstrate how a science equipment clearinghouse may play an important role in science education reform efforts at the 8-12 grade level. Project-STIR's unique program begins with an equipment transfer process which serves many schools in a wide geographical location, bringing them into increasing contact with industry leaders and scientists who view science education reform as a major goal. Begun in 1992 by arranging donations of science equipment from Industry into high schools, the project, now in its seventh year, has led to professional development activities for approximately 800 teachers through year round workshops and intensive summer training institutes.

Introduction

Our mission is to promote reform and creativity in classroom science teaching that results in a better education for all students. Specifically, the Project seeks to intensify student involvement in science by increasing the ability of teachers to employ "hands-on" experimentation and inquiry learning in the classroom. Teachers will become familiar with the ever changing laboratory environment and will be instructed in educational technologies that lead to increasing student skills and understanding of scientific methodology. Improving teacher background and skills in this regard, is vital to stimulating student interest in science, and improving overall student performance. (slide 2)

Although reform in science education receives encouragement from both the public and private sector, urban and inner city schools have become more crowded, poorer, and unable to afford even fundamental laboratory supplies for their science courses. Boards of education and school administrators may recognize the need for such equipment, but budget constraints increasingly prevent their purchase as high-tech apparatus becomes more expensive. As hands-on inquiry-based laboratory science experiences become an increasing part of the standard curriculum, the need for equipment becomes ever more urgent.

Why a Science Equipment Clearinghouse?

Perhaps more than in any other discipline, adequate, up-to-date, well functioning equipment is essential to teach science in today's technological society. As noted, school budgetary constraints can barely outfit their science laboratories with basic equipment, let alone fill the demand for more highly technical instruments and computers.

In many locales, at least a partial solution rests nearby. Chemical, pharmaceutical and even university research labs often update their older equipment, condense lab space or move to new locations, thus freeing up equipment no longer used.

While those organizations may willingly donate unused items to schools, the time and work needed to arrange the donations become obstacles to its happening. The result: older equipment that would be welcomed and used in many school science labs remains on storage shelves for years, eventually becoming no longer useful or functional.

A science equipment clearinghouse can provide the link that brings together potential donors and schools that need their unused items. In addition, the transfer of equipment from the "science rich" community of industry and research institutions to "science poor" schools is a unique way of improving school science programs and bringing about reforms in the training of teachers that result in a better education for students. Stimulated by the transfer process, this linkage of schools and teachers with industry leaders of vision is seen as a major goal of the project. The train of events and activities resulting from the initial transfer of equipment is an integral part of the project design. (Slide 3)

The advantages to donors include finding recipients, supplying documentation, possibility of a tax credit and opportunity for improving public image. Advantages for schools are the procurement of equipment and facilitation of its transfer from the donor to the school site. (Slides 4,5,6).

Who Should Start a Science Equipment Clearinghouse?

To insure that the science equipment clearinghouse be regarded as a public service, it is important that there be an affiliation with a publicly supported group such as a school district, a university or chamber of commerce.

Project-STIR's experience supports the belief that a university is an ideal choice to start a science equipment clearinghouse, particularly a university that possesses a strong education or science education department. Being non-profit and educationally motivated, the university can lend a public service note to the project while also serving as a disinterested liaison between nearby industry and schools.

Consortia of teachers and educators, collaborating with nearby industries, would also be a highly desirable alternative to a university. Such a group was started recently as a spin off of Project-STIR, and is known as WISTA, Westchester Industry and Science Teacher Alliance.

Where Should a Science Equipment Clearinghouse Be Located?

Ideally, a clearinghouse will be located near both donors and schools. Central to its success is its accessibility to a large number of public and private science, industry and research institutions. Although it is important that it be within reach of many schools and colleges, it should not be in the vicinity of another clearinghouse.

Rather than being limited to a single district, a science equipment clearinghouse should cover a wide geographic radius, service several districts at once, and collaborate with university and other K-12 outreach programs in the vicinity.

How Many Participants Should be Involved?

Project-STIR currently has 450 schools on its recipient and mailing lists, compared to about 250 potential donors. (The actual number of donors to date is 56 and the number of school recipients is 165.)

More important than having a large number of potential donors, therefore, is to have a large number of potential recipients that are available and willing not only to accept appropriate donated equipment, but also to pick up the items quickly and efficiently.

How Do We Identify Potential Donors?

Companies that have been increasingly solicited for equipment are in the chemical, pharmaceutical, and bio-technology industries. Others, such as food and cosmetics, public utilities, environmental protection agencies, universities and medical schools are also a very important source of equipment, laboratory supplies and computers. (slide 7)

About the Project-STIR Science Equipment Clearinghouse

Our equipment clearinghouse has led to increasing relationships with industry, schools, teachers and district administrators. Since its establishment in 1992, 165 schools have been provided with approximately 100,000 items of laboratory supplies, technical apparatus, and computers from 56 companies and private organizations. More than 70% of this equipment has found its way to the students in New York City's inner city schools. (Slide 8)

Transfer of Equipment (Slide 9)

Summary of Equipment Transfers : 1992 - 1999

Type of Equipment	Market Value*	Number of Items
1. Research	>$1,000	615
2. Basic Laboratory	$500-$1,000	1,365
3. Laboratory Supplies	<$500	100, 883
		102, 863 Total Items

Total Number of School Recipients	165
Total Number of Donors	56

Table 1. Summary of Equipment Transfers, 1992-1999

Explanation:

* Market values are based on present market value as determined by manufacturer or donor

1. Examples of research equipment: spectrophotometers, ultra-centrifuges, chromatography systems, HPLC, microscopes
2. Examples of Basic Laboratory equipment: small centrifuges, analytical balances, small ovens, incubators, student microscopes, pH meters
3. Laboratory Supplies: glassware, small scales, filter paper , laboratory hardware, Bunsen burners, burettes

Items of transferred equipment range from basic laboratory glassware to hi-tech analytical instruments, from capital equipment such as ovens and centrifuges to computers and computer components. A computerized database system has enabled the Project-STIR director to match the science program and needs of the school with appropriate available items. The amount of equipment donated, the number of recipient schools and the availability of potential donors have increased significantly since 1992.

To provide a measure of the equipment market value or money saved to the schools, we have chosen to divide the equipment into three categories.

Category One, represents research grade equipment and would be any item whose market value would be over $1000.
Category Two , includes basic Lab Equipment : any item whose market value would be from $500-1000.
Category Three, consists of consumable laboratory supplies such as glassware, burettes, plastic ware, hardware

Functional Condition and Educational Value of Donated Equipment

In 1997 a survey of the condition, use, and educational value of the equipment that was donated to a sample of recipients was undertaken. We surveyed schools that had received equipment over a prior two year period. Sixty- two out of 117 schools responded to the survey (52% response rate). The number of items in the survey was about 1,816, with cartons of glassware counted as one item.

Results:

1 82% of the equipment transferred was in excellent or good condition
2. 7% was in poor condition but may have been used
3. 11% was not used, probably because of poor condition. However, some excellent hi-tech equipment may not have been used at the time we did the survey. (Slide 10)

The effect of equipment on student attitude toward science is summarized on slides 11- 13. On a scale of 1-5, over 85% of the teachers rated the equipment as being important in enhancing student technical skills, in understanding current technology, and in using quantitative techniques. In determining its effect on changes in teacher attitudes, the degree of importance of the donated equipment was rated very high with respect to increasing hands-on activities, encouraging student projects, and increasing the numbers of students participating in laboratory experiences.

Need for Teacher Professional Development

Although efforts are made at both the local and national levels to upgrade science education, many classroom teachers, especially those in disadvantaged, minority school districts lack the equipment and the training necessary to implement recent proposed reforms that mandate a hands-on and inquiry-based science curriculum. In New York City there is an urgent need to train not only the large numbers of new teachers coming into the system, but also to acquaint and re-educate older and experienced teachers with modern science technology and its application and use in science teaching.

The need becomes especially pressing as teacher retirement incentives diminish the number of adequately prepared teachers. For this reason, a significant portion of Project-STIR's activities is devoted today to the training of in-service high school science teachers. (Slide 14)

STIR sponsors three professional enhancement programs. A summer technology institute, year-round academic workshops, and summer internships in industry. The last is a training program in which teachers spend seven to eight weeks in nearby chemical and pharmaceutical industrial laboratories. Teachers are paid a stipend which is contributed by the company, and the Project handles all the paper work, documentation and follow-up activities. Companies who have hosted interns for Project-STIR are: Infineum (formerly Exxon Chemical Corporation), Bell Laboratories and Akzo Nobel.

Academic Year Workshops

Project-STIR arranges numerous workshops for teachers given by highly experienced colleagues, industry representatives and members of university faculties. In these workshops and demonstrations, teachers become acquainted with current, hi-tech laboratory instrumentation, chemical analysis, DNA technology, environmental science and integration of computer techniques into all aspects of experiential science inquiry. Since 1993 almost one thousand teachers from districts across the city have attended our year round workshops. Project-STIR, for example, arranges numerous workshops for teachers given by highly experienced colleagues, industry representatives and members of university faculties. In these workshops and demonstrations, teachers become acquainted with current, hi-tech laboratory instrumentation, chemical analysis, DNA technology, environmental science and computer techniques. They learn of new scientific developments and teaching techniques applicable to the classroom. (slide 15)

In meeting with industry representatives and members of university faculties, teachers learn how scientific principles are applied in the world beyond the classroom.

The Laboratory Technology and Classroom Activities Institute

The LTCA is an intensive professional development program that helps to infuse new technology, understanding of scientific methodology, and inquiry-based learning into the classroom. This unique program draws upon, to a large extent, the efforts and expertise of industry, and industry leaders who are very responsive to the need for better science education in our high schools. The Institute trained 103 teachers recruited from 60 high schools in New York City during the 1997-1999 programs.

The Institute begins in early July where the teachers attend one (or two) weeks of workshops and hands-on instruction at the Chemistry Department at Lehman College in the Bronx. It is followed by additional fall workshops at various sites throughout the city, and continues into the spring semester. The teachers, selected by application and principal and supervisor recommendation, receive a stipend, or graduate credit upon completion of the course. (Slide 16)

Workshops Design

The goal of the Institute emphasizes preparing teachers in new instructional techniques, and helping them to follow a model focusing on student inquiry and teaching within a standards- based curriculum. A great deal of emphasis is placed on using computer based science laboratory experiments that require a hands-on application. Other techniques include the use of computerized hand-held graphing calculators, such as the Texas Instruments TI-83, which facilitate the recording and analysis of data obtained during laboratory experimentation. More recently we are devoting considerable time to fostering student research using interactive web sites, with particular interest in Environmental Science, and finally we shall study the use of distance learning to facilitate teacher participation in all workshops and conferences. (slide 17)

Industry Collaboration

A key component of the Institute is the collaboration with Industry in terms of expertise and workshops. Scientists at Wyeth-Ayerst Laboratories, Bell Laboratories, and Infineum (formerly Exxon) are strongly supportive of the project. Companies, including Brinkmann Instruments, Mobil Chemical Company, the Merck Institute, Novartis and Hewlett Packard, provide equipment that helps teachers carry on more highly sophisticated hands-on activities in the classroom. Many other companies provide workshops for the Institute, and still others have hosted site-visits by Institute teachers. During these visits, teachers spend one day at a local industrial or research facility, where they observe the laboratories and become acquainted with science and industrial personnel. Teachers report this as being one of the high points of the entire training program. Thus, Industry collaboration brings the real world of science and its practical applications to the teachers and leads to more interesting and dynamic science instruction in the classroom. (Slides18-20)

Assessment of the Laboratory Technology and Classroom Activities Institute: 1997-1999

Teachers provided responses to pre and post questionnaires containing three main sections: motivation to acquire training in technology and hands-on science; experience or skill levels of the participants, and perceived ability to apply new techniques and laboratory processes into the classroom. Results of the responses of 90 teachers (87% response rate) to the 1997-1999 surveys agree markedly and are summarized below and in Figure 1 on page 6.

1.Motivation: Teacher attitudes towards hands-on science and its correlated objectives were very positive upon entering the Institute as reflected in an overall mean of 4.4 on a 5.0 point scale.[1] These ratings became slightly lower (4.2) on the post-questionnaire at the end of the Institute. All participants who entered the program were highly motivated to acquire more technical skill and to help their students understand and appreciate science as a current and relevant topic.

2. Experience: A dramatic increase in skill level and experience was reflected in the overall initial mean rating of 2.2, which then jumped dramatically to a mean of 4.3 on the post-questionnaire. Thus, by the end of the Institute, skill levels of teachers were aligned with their levels of aspiration with regard to conducting the hands-on science activities that were a focus of the Institute.

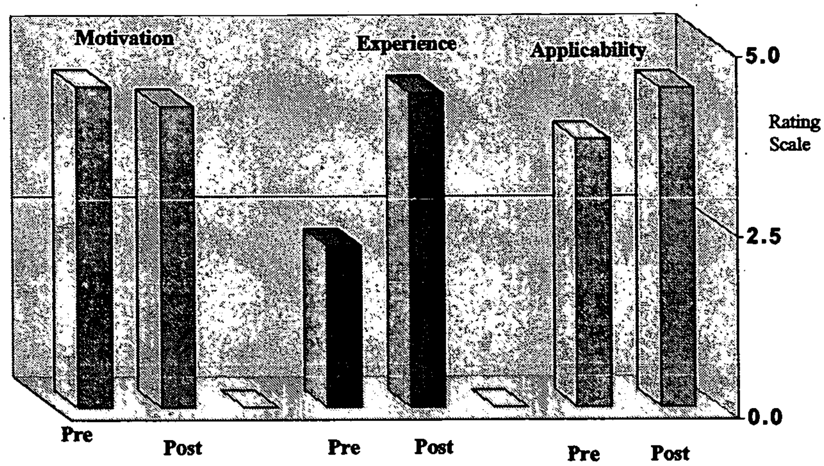
3. Applicability: Positive attitudes were also reflected in teachers' assessments of the applicability of various laboratory processes to classroom activities, as indicated by an initial overall mean rating of 3.7 These ratings became more positive at the end of the Institute as indicated by an overall mean rating of 4.4. Despite positive attitudes and guarded optimism in terms of applicability, teachers recognized that a lack of equipment and limited experience with instruments and systems might prevent their ability to translate aspirations into actions.

This lack of equipment is the most important reason for lack of integration of new activities into the classroom. For this reason, Project-STIR now directs many appropriate donated items to Institute teachers.

The results of the surveys to date demonstrate the success of the Institute in helping teachers to promote hands-on science education and to up-date their use of technology in classroom teaching (Slide 21)

[1] Five point rating scale: 1: lowest ranked response, equivalent to no importance, experience, or applicability; 3: moderate rank for these attributes; 5: highest ranked response

Technology Institute Survey: 1997-99



Average of Teacher Paired Responses to Pre and Post Questionnaires.(n = 66-90 paired responses)

Figure 1. Survey of the Laboratory Technology and Classroom Activities Institute: 1997-1999

Summary

A Science Equipment Clearinghouse is viewed as a design for achieving reform in the teaching of science and technology in high schools. Linking industry and the scientific community with local schools and school districts for the enhancement of science education is seen as a model for this approach. A collaborative effort between science related industry, university leaders and school administrators can help bring about needed change in science education for both teachers and students. (Slide 22)

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The GLOBE Program

Dave Williams
Fresno Regional GLOBE Training Center
Fresno, California
dlw16@csufresno.edu

Abstract: K-12 students, teachers, and scientists are meeting on the Internet to collaborate in a worldwide project designed to expand our understanding on the Earth's environment. Having received strong endorsements from educators worldwide, the international Global Learning and Observation to Benefit the Environment (GLOBE) Program is now being implemented in over 7,000 schools in over 80 countries, on all seven continents. Unlike traditional school science programs, in which students perform isolated experiments with no consequences for increasing scientific knowledge of the world, GLOBE students participate in actual science investigations led by scientists. The GLOBE Program is sponsored by NASA, NOAA, and the EPA, and administered through National Science Foundation. The Program was announced on Earth Day 1994, and implemented the following year

Overview

GLOBE students take environmental measurements in the areas of Atmosphere/Climate, Hydrology/Water Chemistry, Soils and Land Cover/Biology at or near their campus. These measurements are then reported via the Internet to the GLOBE Web site (http://www.globe.gov) for use by students and scientists around the world in research projects.

Though GLOBE is not a free standing curriculum it strongly reflects the National Science Education Standards. It is a framework for use by teachers to enhance and enrich their curriculum. Other than requiring careful adherence to the data collection protocols, GLOBE gives schools complete latitude in determining the grade levels and classes in which to implement the program, the educational activities to provide and the way in which the program will fit into the local curriculum. For example, many schools are using GLOBE activities in math, geography, and foreign language classes, in addition to science classes.

GLOBE is an ambitious attempt to put the concepts of authentic learning, student – scientist partnerships, and inquiry-based education into practice on an unprecedented scale. The results are already being seen in an enhanced environmental awareness of individuals around the world through an increased understanding of Earth as a system.

GLOBE students work under the guidance of GLOBE teachers who are certified after participating in teacher enhancement workshops. These professional development workshops enable teachers to guide students in taking measurements according to scientific protocols; in using the Internet to report and analyze scientific data; and in creating partnerships among students at GLOBE schools around the world. In addition to using the Internet for communication and research, GLOBE students use computers to create graphs, charts, maps, 2-D and 3-D visualizations of their data for analysis.

GLOBE students use hand-held Geographic Positioning System (GPS) units to establish the coordinates for their study sites and to lay out a 30 meter square for biometric studies. This 30 meter square corresponds to the size of one pixel (picture element) that is imaged by NASA's Landsat Thematic Mapper (TM) earth observing satellite. NASA provides each school with a Landsat TM image centered on their campus. GLOBE students use the MultiSpec image processing software, developed at Purdue University, to manipulate the image, conduct unsupervised classification of the features, and analyze the land use and land cover (LULC). In some areas GLOBE training partners are providing schools with historical sequences of satellite images of their school sites for the study of LULC changes over time.

GLOBE students are also being introduced to GIS technology through partnerships with the ESRI and Intergraph Corporations. ESRI (http://www.esri.com), based in Redlands, California, has provided every GLOBE teacher in the United States with a copy of the GIS for Schools and Library CD-ROM. The CD-ROM contains the ArcVoyager software, a four tiered GIS tutorial, and an enormous amount of data to incorporate into learning strategies. Intergraph, of Huntsville, Alabama, (http://www.intergraph.com) has made its GeoMedia software and a CD-ROM called The Power to Learn: GeoData for Schools available to every GLOBE site.

The GLOBE Program is very attractive to educators interested in introducing the technology of Geographic Information Systems (GIS) into the classroom. Through GIS, with its new advances in software technology, geographers, scientists and students are able to import satellite imagery, aerial photography, digital images, topographical maps, vector data, relational databases, and other information to create detailed data maps and models that extract new data more easily than ever before. GIS models and maps can include a wide variety of information, such as GLOBE student data, and be tailored for use in an almost infinite number of scenarios, such as land use planning, transportation, health services, emergency response scenarios, wildlife and resource management, environmental modeling and business development.

High-Performance Computing Technologies, and Pre-Service Teacher Preparation: Is There an Overlap? (Post-Evaluation Thoughts)

Kris Stewart, Ilya Zaslavsky
Education Center on Computational Science and Engineering
San Diego State University
United States
stewart@sdsu.edu, zaslavsk@edcenter.sdsu.edu

Abstract: In this paper, we share our experience in the development of successful programs focused on promoting high performance computational tools in undergraduate science education, and among high school teachers. The two NSF-supported projects we will describe, are the Education Center on Computational Science and Engineering, established on the campus of SDSU two years ago, and STEP, the Supercomputer Teacher Enhancement Program. Both projects have been evaluated, using a variety of questionnaire surveys and interviews. This gave us the material to assess what worked and what didn't, and share the lessons we learned. Pre-service teachers fall in the gap between the target audiences of these two projects. We believe that some of the tried and proven techniques used in our two projects are applicable to pre-service teacher education, and argue for the need of a project focused on integrating high-performance computing technologies in teacher preparation. A replicable project of this nature would address the widening gap between the rapidly changing computing environment and needs of the marketplace, on the one hand, and the awareness of teachers and their students of such changes, on the other hand.

Background: High Performance Computing Technology in the Curriculum

Developing replicable and scalable examples of successful incorporation of advanced computing technologies in the curricula at various levels has always been one of the main priorities within the national effort of making high performance computing more accessible and more useful to as many people as possible. Since October 1997, NSF has channeled its support of high-performance computing in education through two National Supercomputing Partnerships, led by the San Diego Supercomputer Center (SDSC), University of California, San Diego, and the National Center for Supercomputing Applications (NCSA), University of Illinois at Urbana-Champaign. The two partnerships, namely the National Partnership for Advanced Computational Infrastructure, NPACI (NPACI 1999), and the National Computational Science Alliance (NCSA 1999), unite over a hundred leading research universities and national labs over shared use of high-performance computing resources, advanced compute-intensive research, and a variety of education and outreach efforts. These efforts focus, broadly speaking, on promoting computational science curriculum in K-12, undergraduate and graduate schools, and informal learning communities, on shortening the distance between research labs and classrooms, and developing learning tools that utilize the best modern scientific accomplishments (EOT-PACI 1999). As part of this effort, the NPACI Education Center on Computational Science and Engineering (Ed Center) (EC/CSE 1999) was created on the campus of San Diego State University, with the mission to promote the incorporation of NPACI-developed tools within the California State University system, and design relevant exemplar projects which could be replicated and scaled to the national level. The focused education and outreach efforts in the present NSF program are based, in part, on the experiences and successes of several previous programs, including STEP (Supercomputer Teacher Enhancement Program) (STEP 1997) originated from SDSC and UCSD with direct participation of one of the authors of this paper. Both STEP and Ed Center programs are described in details in subsequent sections. During the 1998/99 academic year the NPACI Ed Center program has been formally evaluated by an external group of experts (Foertsch & Alexander 1999). The STEP program was also evaluated (Stewart & Bowers 1997), its materials are now a part of Smithsonian permanent collection (Smithsonian 1996). While pre-service teachers are only a fraction of the clientele of the Ed Center program, and the STEP program is focused on in-service teachers, the evaluation results and

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literature review suggest that the challenges we faced are similar to those experienced in pre-service teacher education. Indeed, finding a meaningful integration of computer technologies in various curricula, convincing faculty that such innovations are effective from the standpoint of student learning, and establishing an environment conducive of change -- remain the central challenges, despite the visible progress in technological infrastructure (Campus Computing 1998). At the same time, access to the Internet which quickly becomes ubiquitous, makes many resources of high-performance computing available to both undergraduate and K-12 faculty.

We believe that the strategies we have developed in the STEP and Ed Center programs, may prove useful for the pre-service teacher preparation in high-performance tools, such as advanced simulation, 3D visualization, web-based collaboration, access to large on-line data sources, etc. In the next two sections, we will briefly describe the two programs, and complete the paper by outlining the strategies appropriate in introducing high performance computing technologies to pre-service teachers, and ultimately - to broad populations of students.

The STEP Project, and its Evaluation

The goal of the NSF STEP program was to introduce in-service science teachers from San Diego area to computational science, connecting the high school classroom with the computational world outside, and enhancing the teaching of high school science. In the course of the program, which was funded between 1993 and 1997 (and still continues, through regular meetings), STEP teachers explored various computing platforms, from Macintosh and PC to UNIX mainframes, wrote their first Web pages, engaged in electronic communication, discussions and collaborations. For the advanced computing technologies to work well in the classroom, teachers had to be convinced that their use *significantly* aids students' learning, supporting conceptual understanding of the material and effective engagement. As Noblitt (1997) stressed, and as the STEP program experiences demonstrate, new classroom technologies, to be accepted, must work substantially better than, or provide a different kind of understanding than the traditional form of instruction. This is an additional justification for focusing the curriculum changes on high-performance computing techniques.

As the teachers were getting interested and involved in the advanced computing world, it was clear that this program would need institutional support to be sustainable. Thus, we emphasized the participation of local school administration in the program. Similar approaches proved viable in our subsequent Ed Center project described below. STEP teachers' experience showed that using advanced computing in the secondary classroom requires additional resources, sometimes not readily available at the individual school level. It is important that pre-service teachers willing to present state-of-the-art research tools to their students, are aware of the available support and computational resources. In the survey at the conclusion of the program (Stewart & Bowers 1997), the teachers indicated that involvement in STEP supported their professional and personal growth, and curriculum development, and was a valuable contribution to their schools. STEP teachers presented a series of workshops at their schools and districts. Turning project participants into enthusiastic "ambassadors" of curriculum change with advanced computing tools was perhaps the main accomplishment of the project, and a lesson for projects to come.

The Ed Center Project, and its Evaluation

With over 31,000 student body, SDSU is the largest university within the California State University (CSU) system, which in turn, is the largest and most diverse undergraduate system in the nation. This reflects the diversity of Southern Californian population - the likely future audience for students in SDSU teacher preparation program. In collaboration with the LEAD Center (Foertsch & Alexander 1999), we examined SDSU faculty expectations and practices in teaching with computers, based on a series of questionnaire surveys and interviews. Analysis of faculty use of the Web, use of computers in the classroom by students and instructors, and the use of high performance computing applications in the curricula, helped us develop Ed Center strategies of curriculum change. In (Stewart & Zaslavsky 1998), we described at least ten obstacles to a wider acceptance of computational science in undergraduate education, and came to the conclusion that a comprehensive educational infrastructure - human, technological and administrative - is needed for successful curriculum change. Thus, from Ed Center's inception its focus has been on building a comprehensive infrastructure to support the incorporation of high-performance computational science tools into undergraduate education. Addressing this problem, we have established an environment encouraging the curriculum enhancement in sciences and engineering with modern simulation and visualization technologies, through the campus-wide Faculty Fellows program, collaboration with NPACI and NCSA researchers, in-house project development, and various outreach efforts.

The rationale for the Faculty Fellows program initiated by the Ed Center is the fact observed by many researchers of educational change: curriculum innovations spread successfully through personal contacts with a respected colleague who has tried the innovation, and hands-on demonstrations (Foertsch et al 1997, Rogers 1995, Noblitt 1997). Therefore, the goal of our Faculty Fellows program is building a synergetic environment supporting such interaction between faculty members from various departments, sharing of ideas and hands-on experimentation. Each semester, the program has provided release time to two-three faculty members who worked on changing their regular undergraduate courses to include computational approaches. This support allowed them to use various compute-intensive approaches ranging from interpretation of satellite imagery and web-based collaborative visualization of large geological datasets, to the exploration of the Network of Workstations (NOW) distributed architecture implemented on a cluster of SUN workstations, to investigating new Web-based 3D visualization strategies for geographic data in an experimental class composed of geographers and computer scientists. Note that these technologies and functionality are almost entirely available on-line, i.e. can be accessed by K-12 teachers and students.

Creating on-line repositories of high performance computational tools, and introducing these tools to CSU faculty through focused presentations and workshops is another Ed Center "mission-critical" activity. However, early in the process we recognized that just presenting the tools is not sufficient. It is important to convincingly demonstrate how these tools can be used, and, possibly, have been used, in the curriculum. Thus, we have been experimenting with various computational techniques in our own teaching. Examples include group-based problem solving environments in our supercomputer classes, real-time distance teaching with Web-based collaborative software (featured as a Microsoft Case Study in Higher Education (Microsoft 1998)), etc. Yet another project, which has significant infrastructure impact, is the development of the Sociology Workbench (SWB 1999), a collection of on-line survey data analysis tools that can be used in various evaluation settings, as well as a teaching tool in classes that deal with sociological analysis. The Ed Center's external evaluation showed that the most successful, though time-consuming channels were through individual collaboration with faculty, and our own in-house curriculum experiments.

An important lesson we learned is that the target audience of curriculum change efforts should be carefully selected. Over ¾ of surveyed faculty have used WWW *often* or *sometimes* in 1997[1], however there is still a big step to being able to effectively use advanced computing techniques in instruction, or even being receptive to technology-induced curricular changes. Many obstacles – including lack of time, tenure and review considerations, lack of awareness about existing tools, etc. may prevent faculty from curriculum innovations even if they believe in their usefulness. A telling graph (Fig. 1) demonstrates how the faculty use of computers in the classroom depended on his/her number of years as a faculty: the difference between those who *never* use computers in the classroom, and those who do this *often*, is the largest for untenured faculty, with the largest gap towards the time of tenure review.

Though advanced computing applications can make a difference in student learning in "any discipline which uses mathematical formulas to examine and understand relationships in complex systems" (Foertsch & Alexander 1999, p.12), only 12% of SDSU faculty respondents[2] saw themselves as having a use for high-performance computing applications in their courses (this number is higher for the colleges of Science: 17.1%, and Engineering: 20.0%). At the same time, 11% of the responding faculty indicated that their students *often* worked with computer models in SDSU courses (16% in the College of Sciences and 22% in the College of Engineering), 23% had students *often* use computers "hands-on" in the classroom (33% and 17% by the two Colleges, respectively), and 18% had students *often* use the Internet in courses (15% and 9% by the two Colleges). As experts in pedagogical reform noted (Hutchinson & Huberman 1993), and our experience confirmed, the best strategy is to focus on most enthusiastic and technically advanced instructors who are

[1] This telephone survey of SDSU faculty was conducted by the Social Science Research Lab at SDSU in the Fall of 1997. The number of faculty who responded to the survey was 402.

[2] The cited survey of SDSU faculty was conducted by the LEAD Center in the course of its evaluation of EC/CSE in the Fall of 1998. Of the 461 faculty surveyed, 175 responded (38% response rate). The sample was representative of the total faculty population in colleges of Arts & Letters, Engineering, and Sciences, in terms of gender, years teaching, and tenure status (Foertsch & Alexander 1999)

already using computing and modeling in their classes, since they are most capable of producing a lasting curricular change (Foertsch & Alexander 1999).

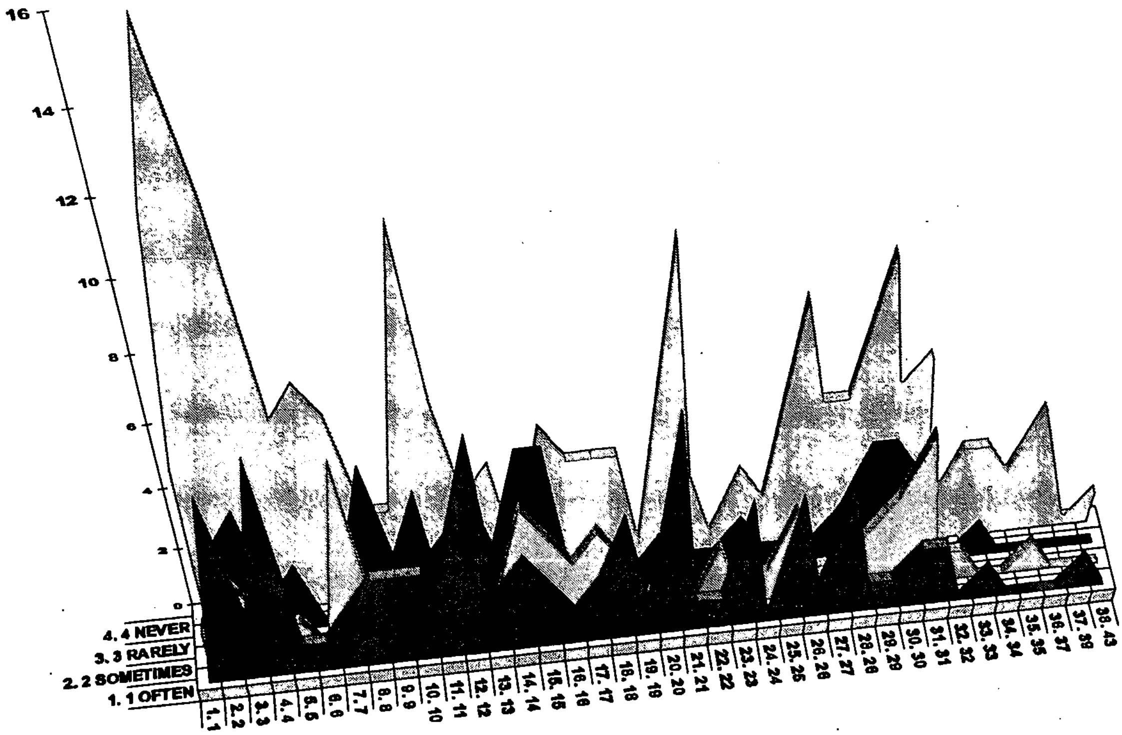

Figure 1. Using computers in the classroom versus number of years as a faculty member. Source: SDSU Faculty Survey, Fall'97.

Channels for influencing pre-service teacher preparation

The pool of undergraduate students at CSU, which is the target audience of the Ed Center, includes large number of future teachers, at various stages of getting their teaching credentials. The following are the major channels for influencing these groups of students, making high performance computing tools accessible and attractive to them:

- The use of advanced computing modules in general education courses. For example, Geol 303 "Natural Hazards" traditionally attracts a number of future teachers. Targeting this student group, the Ed Center sponsored an instructor for this course through the Faculty Fellows program. We hope that this will lead to a wider exposure of future teachers to novel simulation and visualization techniques, specifically new ways of modeling El Nino effects, earthquakes, and pollution.

- Cooperation with College of Education faculty and students, especially those specializing in Education Technology, on various projects which involve experimentation with new technologies and exploration of their use in the curriculum. To promote and support this effort, we organize SDSU Computational Science Olympics (CSO 1999), a competition of student projects focused on various aspects of computational science. Successful student projects are likely to be used again by instructors, eventually becoming a part of curriculum. This "bottom-up" development of computational science modules complements the traditional trajectory of curriculum change.

- Establishing regular meetings with in-service teachers who have been exposed to advanced computing techniques and used them in teaching. STEP teachers are an invaluable source of experiences, willing to share them with future colleagues.

- Providing on-line assessment technologies. Without accessible and relatively simple technologies for classroom assessments and evaluations, it is difficult to demonstrate positive impacts of curriculum changes. *Sociology Workbench* (SWB), a collection of on-line computational tools and resources for social scientists, is one of such technologies developed at the Ed Center. The SWB allows faculty and students to share and analyze social science data (questionnaire surveys, public opinion polls, and similar data) on the Web. In essence, it is a free on-line statistical package implementing a unique data analysis methodology. It emphasizes exploratory social data analysis, integration with other resources available on the Web, convenience of the user interface, and transparency of the analytical approaches. In teacher training, SWB can be used as a convenient instrument for sharing and analyzing student surveys, developing evaluation metrics, comparing results from various surveys, etc. At SDSU, the software has already been used for analysis of faculty surveys and student surveys in several classes. You are welcome to analyze your surveys with SWB, it is accessible from http://edcenter.sdsu.edu.

Conclusion

Within the two programs we described, several successful strategies for the incorporation of advanced computing in classroom teaching have been developed and evaluated. We believe that the tried and proven technologies can be extrapolated to the needs of pre-service teacher education, and outline the steps we are already taking to influence this group of students. As with any curriculum change, a successful integration of advanced computing in the standard curriculum is likely to take years (Green & Gilbert 1995), and result from a focus on most enthusiastic and technically-advanced instructors. We believe that our two programs created the necessary prerequisites for a successful undertaking focused directly on pre-service teacher education.

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Malini Ranganath

Visual Imagery for chemical conceptualization: Picturing knowledge with multimedia

"A soul never thinks without a mental picture." --Aristotle.

1.0. Introduction

A significant aim of education is to enable students to understand and learn in a meaningfully way. Educators around the globe strive to create an environment in the classroom conducive to effective learning. In today's society, greater demands are being placed on education systems at all levels, to produce citizens who can use knowledge in new domains and different situations. Learning to think critically, to analyze and synthesis information, to solve problems in a variety of contexts is important for betterment of life. Studies show that there is little evidence that our educational systems are developing these skills in our children (Bransford, Goldman and Vye, 1991).
Effective learning and teaching science has been the topic of discussion among educators for the last few decades.Learning is the building of new knowledge, skill, or and attitudes. A learner interacts with information and the environment (Jonassen, 1996). Studies have shown that students are unable to understand the basic science concepts. Studies and reports constantly show the difficulties students face in grasping the knowledge imparted in the classroom (Gabel and Samuel, 1987; Gardner, 1991). Learning, in our educational institutions generally emphasizes the output of knowledge.The general tendency among students is to memorise the information and repeat the information transmitted from the teachers to students. In schools all over the globe, certain performances predict the signs of knowledge or understanding. Outcome is stressed more than the understanding of knowledge. The aim of educators is to emphasize an effective and meaningful learning, for a bright future for students. The learning process is often overlooked. The students' cognitive processes remain in the background.This passive cognitive environment is unhealthy for any educational institution. Many theories have evolved, such as the generative theory of learning, and the metacognitive theory of learning, to encourage the active thought processes of the learners (Forrest-Pressley, 1985).

To create such an active cognitive environment in the classroom, we as educators have to incorporate various strategies to create a true learning environment. Piaget (1920) believes that it is not the accuracy of the child's response that is important, but rather the lines of reasoning the child invokesSome studies have shown, that the development of visual imagery can enhance learning in general (Paivio, 1971; Shorr, 1980; Pylyshyn, 1973). However, fewer studies have been conducted to show the importance of visual imagery in chemistry learning. Here the focus is on using visual imagery to enhance chemistry learning. The unit in review is electrochemistry. This paper is divided into four sections: (a) conceptual difficulties in chemistry learning; (b) visual imagery for chemical conceptualisation; (c) theoretical and practical implications of visual imagery and (d) multimedia for visualising chemical knowledge.

2.1 Conceptual Difficulties in Chemistry Learning

Chemistry has been the primary source of description and depiction of chemical changes. Volumes of articles and notes on chemistry depict chemical reactions and equations with little emphasis on the meaning of chemical equations. Students' conception area of research point out the difficulties students have in learning chemistry . Driscoll (1960) was one of the first people to conduct a study on students' "misconceptions" and the difficulties involved in understanding chemistry. Gordon McCalla (1989) points out, "a student's knowledge is more complex than an expert's knowledge because it may be imprecise, contradictory and full of misconceptions". For example, Ben-Zvi, Eylon, and Silberstein (1982, 1987) discovered that students found it difficult to relate the macroscopic phenomena to microscopic level spontaneously and simultaneously. The foregoing studies reveal that students have difficulty in understanding the microscopic nature of a chemical change and perceiving the abstract or invisible agents involved in the total chemical transformation (Hesse and Anderson, 1992).
More specifically in the domain of electrochemistry, Australian researchers Butts and Smith (1987) through surveys examined the difficulty level of students' conception of electrochemistry.Garnett and Treagust (1992) found that students had difficulty understanding electric current, differences in potentials, the charge law, electromotive force, designating

oxidation numbers, utilising oxidation numbers to distinguish redox equations, utilising methods apart from oxidation numbers to specify redox equations, and the dependence of redox reactions with each other. Garnett and Treagust (1992) also found that students overgeneralised the utilisation of the charge law to improper situations:

.......In a cell the anions and cations attract each other and this affects the movement of ions to the electrodes.

Ogude and Bradley (1994) found most students capable of solving electrochemical problems in chemistry tests, but only few students could answer qualitative questionnaire which required a sound conceptual knowledge of electrochemistry. Sanger & Greenbowe (1997) believe that some misconceptions of the student have a strong influence in describing the experiential and observational experiences, relating to the logic of the student, and consistent with his /her understanding of the universe. (Herron, 1990 as cited in Sanger & Greenbowe, 1997). This explains the reason behind the usage of simulation softwares to explain the microscopic nature of electrochemistry concepts and as depicted later the usage of visual imagery in reviving the abstract thinking process and thereby making the learning of electrochemistry concepts meaningful.

2.3 Visual Imagery for Chemical Conceptualisation

Some students are able to grasp conceptual knowledge while others find it more difficult. This is where imagery might be useful. Since the focus of my study is on using images to enhance chemistry learning, I would like to explore the construct of imagery in detail. Alan Richardson (1969), defines mental imagery as "(1) all those quasi-sensory or quasi-perceptual experiences of which (2) we are self-consciously aware, and which (3) exist for us in the absence of those stimulus conditions that are known to produce their genuine sensory or perceptual counterparts, and which (4) may be expected to have different consequences from their sensory or perceptual counterparts" (p.). "Quasi-sensory or quasi-perceptual experiences" refer(s) to the sensory, perceptual ,and experiential states represented in a concrete manner. Paivio (1971) one of the pioneers of conducting studies regarding visual imagery, examined how imagery affected the acquisition, transformation, and retrieval of various types of information. According to Paivio, the theoretical assumptions of learning is that it is linked with two specific coding systems, namely, the use of verbal processes to acquire information; and the use of nonverbal processes (visual imagery) to assimilate knowledge, the cognitive mode. Moreover, both the codes are interconnected to each other, and it is possible to create a bridge between the two for better understanding of the concept. A verbaliser might require to understand better, the meaning of the information by using its visual counterpart and vice versa.

Paivio argued that images need not be specific in their representation but rather it can be schematic, and consciously functional. Paivio also pointed out that "meaning" from a psychological point of view might not be rigid or fixed, but might vary depending on the prior incidents and the present situational contexts. Furthermore, Piovio stated that stimuli accelerates the formation of images. An extension of these ideas to my future study is that imagery is connected to words and that it is an important component to comprehend chemical language. Pylyshyn (1973, 1979) believed that knowledge was represented by a single abstract or propositional code. Piaget incorporated both the representational and operational planes of thought within his theoretical framework.

Paivio (1971) believed that verbal coding is attributed to using "abstract stimulus information"; While imagery is the iconic representation of the concrete situations. Richardson (1969) stated that imagery by its figurative nature, could bridge the communicative gap between the abstract information and its meaning. The difference between visual imagery and verbal representation is that, visual imagery is stored in the brain as iconic units and the excess of information is stored spatially; while verbal or abstract information synthesises knowledge sequentially.

Psychologists describe "meaning" to be an output of direct and indirect reactions derived from iconic objects, words, and various other symbols. Roger Brown (1958) considered "meaning" to be the end product of "response disposition". Paivio (1971) explains that meaningful reactions are kindled, inferred or are direct expressions of the human arrangement. Titchner and Paivio stressed that regardless of visual or verbal method of thinking, individuals' meaningful reactions are aroused involuntarily in contextual settings. For example, outside a chemistry classroom, a chemistry teacher might refer forest fire as "burning of trees"; while in her chemistry classroom, her chemical jargon will be "oxidation of carbon to carbon dioxide". Thus response variation depends on that particular environment. These responses are due to reflective thinking which might either be a verbal or visual process of thinking. Reflective thinking is accomplished by taking time to think. This is the main difference between an impulsive reaction and meaningful reaction. In a chemistry class, reflective thinking needs to be encouraged to arouse meaning in and outside the scientific environment. How do we encourage such thinking processes? Using the "coding processes" described by Paivio (1971), we can try to understand the various kinds of information coding techniques may be to synthesis an impetus. This will give science educators an insight to help their students to think reflectively and make science classroom an active learning sanctuary. Some of the different levels of encoding the various stimuli can be divided into four distinct categories (Paivio, 1971). The first level of information encoding process, comes into the fleeting category. The information vanishes within seconds and does not leave a lasting impression (Sperling, 1960; Crowder and Morton, 1969 as cited in Piovio, 1971). The next three levels of informational processes facilitate meaningful learning. Piovio classified them as "representational, referential, and associative levels of meaning":

2.4. Multiple intelligence theory:

Howard Gardner (1983) deduced a theory after researching the cognitive abilities of various individuals. He named this theory as the multiple intelligence theory. The theory indicates that there are seven kinds of thinking and each has a specific use:

- <u>Logical-mathematical</u> The thinking skill which involves the use of logic, pattern of numbers, and use reasoning deductively. For example, the thinking skill used by individuals in the field of science, mathematics, and others.
- <u>Linguistic</u> The thinking skill which is sensitive to sounds and understanding of words and linguistic abilities. For example, literary experts, poets, journalist, novelists, and others.
- <u>Musical</u> The thinking skill that is sensitive to melodious tunes, rhythm, pitch, and taste for musical jargon.
- <u>Spatial</u> The thinking ability to perceive spatially, use visual imagery, and manipulate and transform spatial objects. For example, spatial manipulation used by architects, artists and some scientists.
- <u>Kinesthetic</u> The thinking skill to control and articulate body movements. For example, ballerina, athletes, sportsmen and others.

- Interpersonal The thinking skill used to perceive the personalities, behaviors, temperaments, and deal with other people. For example, the skill used by solicitor, counselors, lawyers, priests and others.
- Intrapersonal The thinking ability to understand oneself, strengths and weakness, control, direct one's behavior and feelings.

Driver and Erickson (1983) and Posner (1982) explained the integration of cognitive psychology into the activities of students while learning science. They point out that, "We ought to engage in research endeavors which will uncover student frameworks, investigate the ways they interact with instructional experiences and utilize this knowledge in the development of teaching programs (pp. 39-40).

2.5. Imagery and hemispheric function of the brain

Forisha (1988) defines mental imagery as "the act of schematically representing things internally or the process of transforming these schematic representations" (p. 311). Visual imagery is the visual representation of these processes. As seen earlier, creative thinking skill is associated with imagination or spatial form of intelligence. Creativity is the process of innovating new ideas, events, concepts etc. Efforts have been devoted towards the measurement creative potential (e.g. Guilford, 1989; Torrance, 1979). Attempts have been made to increase creative behaviors (e.g., Osborn, 1953; Parnes, 1967). Taylor & Williams (1966) report a survey of the relationship between creativity and instruction. Let us understand the underlying relation of creativity and cognition with hemispheric functions of the brain. Often visual imagery, creativity and cognition are related to neurobiological processes of the brain.

Studies reveal the difference in the operation of the two cerebral hemispheres of the brain (Bogen, 1969; Nebes, 1971). Research show that the left hemisphere is considered "analytical" while the right hemisphere is "global" (see Levy et al., 1972). The left hemisphere analyses verbal mode while the right hemisphere is assigned for visuals, images and others. Frued (1949) described the function of both the hemispheres as follows: The left hemispheres coordinates the verbal interactions with our fellow humans everyday. The right is considered to regulate the emotions, metaphorical, fantasies, dreams, impulsive processes. Some researchers believe that, those people who are analytical and use verbal descriptions, use their left hemisphere frequently; while people who use "holistic approaches" operate their right hemisphere often (Mintzberg, 1976; Restak, 1976; Bakan, 1971). In simple terms, the left hemisphere is used for logical, analytical thinking, supposed to be used by mathematicians, scientists and others; the right hemisphere is used by people with artistic, aesthetic, spatial abilities, generally used by artists, poets, architects and others (Gardner, 1983; 1991).

Creativity is considered to use both the hemispheres, although the general tendency is to lean on the right hemisphere (Sperry, 1974; Galin & Ornstein, 1974). Utilizing logical thinking and using the imagery aspect of right hemisphere, creative innovation is attained. Schachtel (1959) argues that, creative individuals transcend from one hemisphere to another, rather than restricting themselves by either/or perspective of the world. Thus using a multimedia software creatively and efficiently involves the collaboration of both halves of the brain: with a balance of holistic (right hemisphere, imagery), analytical (left hemisphere) and cognitive processes of thinking. Teachers must be aware of the potential of visualization, and its affects on the learning process. Visual literacy though dormant for quite some time, needs to be a prominent curriculum agenda. The sensitivity to using multimedia effectively is increased with a classroom of visual literate individuals. It is seen that from the time of birth, an infant accumulates representation of his idea of the environment around him through perceiving the concrete objects and occurrences around him. Before learning to formulate words or to speak, a child conceptualises his/her framework through imagery. Recognition power increases when his perceptual information matches with the concrete objects seen by the child. This further reinforces the connection and thus the child reinstates the information in his brain. Multimedia can invigorate the conceptual knowledge of a student and can direct a path towards better understanding of the abstract concepts.

Similar to the associative type of learning which the child undergoes when he/she relates to a static object like photos or slides and the individuals moving around; this pattern continues and is reinforced in a different surrounding too. This further concretizes the information stored in his/her brain cells. Similarly, complementary to multimedia stimulation with verbal information, laboratory experiments further reinforces the meaning of the chemical concepts.

3.0. Conclusion

In this paper, we have seen some of the major misconceptions students have in science and in particular electrochemistry. Students do not have a clear idea of the concepts and the microscopic level of electrochemical processes. Students cannot comprehend some of the principle concepts of electrochemistry. Educators have strived to make science learning meaningful. Difficulties arise during transfer of the science concepts in the real world settings. This proves that an indepth understanding of science concepts is required.

The objective for science education as specified in the science literacy section of the curriculum guide zeros in on the strong foundation of learning science concepts. In other words, the goal is to enable students understand the science concepts meaningfully and thoroughly so that they can use them in: their personal lives whenever required, use it in strange, unfamiliar situations in their environment, help them in using their basic concepts in future academic endeavors. Moreover, the guide specifies that students need to be aware of various career options to choose according to their capabilities. All of these require sound content foundation for appropriate application whenever required. As stated by Paivio (1986), the dual coding theory, pictures and words activate both visual and verbal codes. Visualization techniques can be revived by using multimedia software.

Williamson and Abraham (1995) suggest that using the technique of providing animations increases the understanding of concepts. This triggers the formation of mental models of the "phenomena." They believe that the "dynamic" feature of animation might increase deeper encoding of information compared to the static pictures. This further states that there will be an increase in reviving the visual imagination of students, thereby leading to better understanding of abstract conceptual models. Multimedia provides an innovative organizational structure for science learners, to represent their understanding and evaluate their knowledge structure through simulations and node-link structure. With the advent of multimedia, and its appropriate usage in the teaching and learning process, the experience of meaningful learning can be achieved. Constructing multimedia software with a specific science concept helps to represent the abstract concepts visually.

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