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ABSTRACT

This document contains the following papers on science from the SITE (Society for Information Technology & Teacher Education) 2001 conference: (1) "Using a Computer Simulation before Dissection To Help Students Learn Anatomy" (Joseph Paul Akpan and Thomas Andre); (2) "EARTH2CLASS: A Unique Workshop/On-Line/Distance-Learning Teacher Training Project" (Cristiana Assumpcao and others); (3) "Using Technology To Help Strike a Blow for Education and the Environment--A Case Study in 'Real World' Preservice Teacher Education" (Candy Beal); (4) "Teacher's Stages of Development in Using Visualization Tools for Inquiry-Based Science: The Case of Project VISM" (Michael T. Charles and Robert A. Kolvoord); (5) "Teacher Created Virtual Field Trips" (Kenneth F. Clark and others); (6) "The Quest for Scientific Inquiry: A Document Analysis of Quest Projects" (Gregory A. Coverdale); (7) "Science Investigations: Onsite--Online--On the Mark!" (Marianne K. Dove and Joyce A. Zikovich); (8) "Problem-Solving-Based Model of WBI" (Tianguang Gao); (9) "Sustainable Environmental Education for Brasilian Teachers" (Lenise Aparecida Martins Garcia and Doris Santos de Faria); (10) "Helping Teachers and Students Use Advanced Technology in Teaching High School Science: A Preliminary Feasibility Study of the Use of a WWW-Controlled Atomic Force Microscope in High School Science" (Thomas Andre and others); (11) "The Internet Science Education Environment (ROL)" (Zdena Lustigova and Stanislav Zelenda); (12) "Meeting the Need for Technology Integration: Math, Science and Technology Integration for Pre-Service Teachers" (Skip Marshall and others); (13) "Aiming a Better Understanding in Science Courses through Mathematical Reasoning" (Simon Mochon); (14) "Revolution in Hand: Handheld Computers in the Science Classroom" (Beverly Ray and others); (15) "Mining for Problem-Solving Styles in a Virtual World" (Brian M. Slator and others); (16) "Integrating Mathematics, Science, and Technology Goals: An Interdisciplinary Approach" (Scott W. Slough and others); (17) "The Design of Instructional Technology To Help Students Connect Phenomena to Scientific Principles" (Jerry P. Suits); and (18) "Life and Death of the Lymphocytes: A Didactic-Pedagogic Game for Teaching Immunogenetics" (Gerlinde Agate Platais Brasil Teixeira). Most papers contain references. (MES)

SCIENCE

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The 2001 SITE Annual Meeting Science section offers 21 presentations that encompass a wide range of topics related to use of instructional technology in a variety of classroom settings, from the elementary school classroom through the university setting. Authors provide information about both preservice and professional development projects, specific project and program reviews, and research about how students and teachers learn. Inquiry in teaching, integrating the science disciplines, is a common theme across the articles. Roach has a Ph.D. in science education. She teaches science methods courses and curriculum courses at Northwestern State University of Louisiana. Her e-mail address is roachl@alpha.nsula.edu.

Project and Program Reviews

Assumpcao, Passow, Corder, Baggio, and *Ortiz* describe a unique, on-line, distance learning teacher training project called Earth2Class. This series of workshops focuses on integrating technology into an Earth Science curriculum. Presented by scientists, teacher-participants gain content background about earth science concepts through videoconferences and work through classroom-ready instructional materials at a supporting website. Other resources on the Earth2Class web pages provide links to scientific, education, and government sites.

Beal explains an innovative project in which preservice teachers work with middle school students to preserve a North Carolina inner city wetlands area. After completing real-world, action research the participants compiled data and presented their research to the North Carolina State University Spell of the Land Symposium. Beal describes the process of building a meaningful service learning program.

Coverdale presents results of research on the value of a technology-rich interdisciplinary curriculum, *Quests* (i.e. *AfricaQuest, AsiaQuest, AmericaQuest*). It analyzes the projects with respect to students' abilities to conduct investigations, and understand both science concepts and the nature of science, after completing the curricular units. Preservice teachers' reflections on their own participation in *Quests* are also reported.

Dove and *Zitkovich* report on a collaborative project, *Boardman Local Schools Our Lake Online*, in which elementary students take a digital expedition to the Lake Erie shoreline. Results of one set of 33 students' onsite observations and experiments were digitally transmitted to over 450 students who participated remotely through asynchronous inquiry-based science. High school students provided technology training and assistance for the elementary teachers and students. Information about student learning about science and technology are presented as well as "lessons learned" by the researchers in undertaking this innovative learning experience.

Gao reviews a technique for embedding problem-based-models into a class web site as a supplement to traditional instruction. The model includes problems to be solved, review, tutoring, hints, self-tests, and solutions.

Hochman, Marshall, and *Oyenarte* demonstrate how technology can make outdoor education more authentic. At *Camp Crystal Lake*, 2nd grade and 5th grade students collect data in each of three ecosystem environments. Prior to their field experiences, students participate in on-line activities which coincide with the types of activities they will be doing in the field. This presentation provides an overview of the camp experiences, including data collection techniques and the connectedness of the on-line and field experiences.

Lustigova and *Zdena* review an Internet-based package called Remote and Open Laboratory based at Charles University in Prague, Czech Republic. Geared toward both initial teacher training and inservice professional development, participants use modern tools and techniques for data acquisition and processing. Large databases of experiments and computer models provide teachers with a wealth of information and allow them to compare the results of their own experiments to those of others. Users can download experiments and models and adapt them to their own classroom conditions and needs.

Technological Field Trips

Clark, Hosticka, Schriver, and *Bedell* report on use of technology to create virtual field trips. They provide advantages and limitations of such and undertaking and review types of technology commonly found in public schools which can be utilized in such efforts.

Slator, Saini-Eidukat, and *Schwert* take us into a virtual world where learners become geologists, planning an expedition, and dealing with the virtual environment to report their findings. As goals are satisfied, learners move to progressively higher levels of expertise as they learn to think and act like real geologists. In addition to a description of the field trips, a report of research into student learning and accomplishments is presented.

Technology in the Classroom

Akpan outlines the use of computer simulations to prepare students for dissection activities.

Jones, Superfine, Taylor, and *Andre* use advanced technology in high school classrooms. They provide detailed information about the use of the Atomic Force Microscope, controlled by scientists, via the World Wide Web, in biology classrooms. Research conducted by this team with regard to gender differences, students' understandings of the nature of science, scientists, and scientific careers is also reported.

Mochon offers a description of a program in New Mexico that utilizes mathematical based explanations to support science teaching at the high school level. Students use spreadsheet technology to enhance science learning.

Molenaar presents multimedia techniques used in a high school physics classroom and preliminary research results.

OToole and *Doe* provide strategies for integrating diversity issues into the science classroom through the use of the Internet. A review of the web-site is presented as well as suggestions for use at all grade levels.

Ray, Patterson, Jenks, and *Hocutt* show how to use Palm Pilots, hand held computers to grade student laboratory activities in real time.

Slough, Chamblee, and *Aull* describe an integrated middle school weather unit. Local weather measurements, taken by students, are supplemented with TV weather reports. With Internet enhancement, climatological data, not previously available can be included in classroom experiences. A fully developed unit will be shared.

Suits shares results of three types of instructional technology are used to help students make meaningful connections between phenomena and scientific principles. Microcomputer-based laboratory experiences, computer-simulated experiments, and multimedia learning modules are discussed.

At The University

Garcia and *Faria* present an integrated, Environmental Science based inservice studies via an online course. Teachers develop integrated learning activities for use in their own classrooms.

Kiser, Bell, Flory, Miller, and *Pushnik* work to enhance the basic core university science curriculum with an integrated course based on the topic of Global Warming. Using computer modeling, traditional laboratory experimentation, web-based research, and problem-based learning in an integrated format, the emphasis is on the processes of doing science.

Marshall, Pringle, Dawson, and *Hochman,* at the University of Florida offer an integrated math, science, and technology block to undergraduate education majors. They offer information about the course, program planning, and preliminary research results.

Teixeira describes a game developed to teach students the intricacies of lymphocytic immunogenetics. It consists of steps which simulate the developmental stages of lymphocytes.

Using a Computer Simulation Before Dissection to Help Students' Learn Anatomy

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Abstract: The scientific community and the nation's schools have been experiencing a self-proclaimed ethical crisis over animal dissection in classrooms. While this issue involves intractable ethical and philosophical positions, one ethical implication of the debate is that if dissection is used in schools, it should be used for maximum educational benefit. One intriguing previous finding was that use of an interactive videodisc dissection learning from subsequent actual dissection. This study examined the prior use of simulation of frog dissection in improving students' learning of frog anatomy and morphology. There were four experimental conditions: simulation before dissection (SBD), dissection before simulation (DBS), simulation-only (SO), or dissection-only (DO). Results of the study indicated that students receiving SBD and SO learned significantly more anatomy than students receiving DBS, DO. The genders did not differ in achievement.

Introduction

Use of computer simulations for dissection in the classroom has gained popularity. The idea that experiences are most essential to conceptual development is central to several theoretical perspectives. Piaget's (1954) theory argues that knowledge is constructed through action. Bruner (1966) adapted Piagetian theory into the idea that learning requires experiences at an enactive level before iconic and symbol experiences can become meaningful. Andre (1986) argued that developing effective problem-solving schemata required appropriate experiences to promote the development of the pattern recognition component of a schemata. Simulations provide a potential means of providing learners with experiences that facilitate conceptual development. As Thomas and Hooper (1991) put it, when a simulation precedes didactic instruction, the simulation experience may provide motivation, improve performance, provide an organizing structure and may reveal misconceptions. Thus, a simulation of frog dissection provided before actual dissection may function as a conceptual model that allows students to better understand and encode the dissection presented information. Students who experience simulation after dissection may not have a meaningful model with which to assimilate the dissection information. The effects of engaging students in simulation tasks either before or after completion of actual dissection have been the focus of a number of research studies for example Kinzie, Strauss, & Foss (1993) compared the achievement and attitudes of students who conducted a frog dissection either with or without the use of interactive video (IVD) simulation as a preparatory tool before actual dissection. In these studies, students who received simulation as preparatory tool before actual dissection learned more effectively than those students who received no preparation and more effectively than students whose preparation consisted of viewing the linear videotape. We further explore the use of simulation before or after dissection in the present study.

The Study

The participants were approximately 127 students (59 males, 68 females) ranging in age from 13-15, enrolled in a seventh grade life science course in a mid-size mid-western middle school of 800 students. These students had some experience in animal dissection, but had no experience in the use of a simulated dissection. These students participated in the study as part of a normally scheduled laboratory involving frog dissection. Because it was a regularly scheduled class activity, all students in the classes participated in the activity. Data, however, were used only for those students for whom signed permission was obtained from both the student and a parent. Of the 127 eligible students in the participating teacher's sections, 44 were absent during at least one of the experimental sessions due to illness or inclement weather. Two students whose identifiers could not be matched with their ITBS scores were also excluded from the study. These factors reduced the total number from 127 participants to 81 (34 males, 47 females). To maintain student confidentiality, all data were coded with assigned identification numbers rather than names.

Design

Participants were unsystematically assigned to the periods at the beginning of an academic school year based on teacher recommendation and final grade in sixth grade science in a manner so as to roughly equalize ability across sections. In this study, class periods were randomly assigned to four experimental conditions: In the simulation before dissection (SBD) condition, students completed a simulated dissection before completing an actual frog dissection. In the dissection before simulation (DBS) condition, students performed an actual frog dissection before the simulated dissection model. In the dissection only (DO) condition, students completed an actual frog dissection only. In the simulation only (SO) condition, students completed only the simulated dissection.

Simulation sessions

The simulation sessions for the SO, SBD and DBS conditions were conducted as follows. Students met during class times in the regular computer lab. The participants were seated individually at computer stations. The participants were introduced to the computer simulation and given an instructional guide, which included pictures of dissected frog parts and a description of their functions. The students were shown six systems of the frog dissection that they could navigate on their own in any sequence they chose. They were also shown four interactive minilabs, in which they could investigate the frog's respiration, digestion, circulation and muscular capacity.

Dissection sessions

In the dissection laboratory, student worked at one lab table side by side in the room. Two researchers were present during dissection sessions. When a student was not able to perform an assigned step or could not remove an organ, the researcher assisted the student after the finished dissection products had been evaluated. The achievement posttest was administered three days after the dissection was completed.

Findings

The anatomy and morphology achievement test. Preliminary internal consistency analysis using Cronbach's alpha indicated that five items had negative or zero item total correlations. These items were eliminated from the achievement pretest for that reason. The internal consistency estimate (using Cronbach's alpha) of the remaining 20-item scale was 0.55. The alpha for the posttest was 0.60. While low, these reliabilities were judged acceptable for this research. Lower internal consistency should increase error variance and reduce the likelihood of finding a significant effect. Thus relatively low internal consistency should increase condifidence in any significant effects found.

Pretest Data

In the analyses of differences between conditions, an alpha level of .05 was assumed unless otherwise specified. F-values are reported for significant effects only.

Achievement pretest. Differences between the four conditions on the pretest were assessed by Gender (male versus female) X Treatment (SBD, DBS, SO, DO) ANCOVA with ITBS Science score as the covariate. There were no significant main effects or interactions found indicating pre-experimental equivalence of the four conditions and the two genders. The treatment means are reported in Table 1.

Table 1. Cell means, F-ratios, p-values, and standard deviations for each of the variables for each of the conditions.

Factor		Treatments						
		DBS[a] (n=28)	SBD[b] (n=21)	SO[c] (n=17)	DO[d] (n=16)	Total (n=81)	F- ratio	p-value
Pretest Achievement score (25-items)								
	M[e]	8.1	8.5	8.5	8.9	8.7	1.17	.326
	SD[f]	3.2	2.8	2.0	3.1	2.7		
Posttest Achievement score (43)								
		15.6	20.0	18.5	14.9	17.2	12.64	.000
		3.4	3.0	2.2	3.2	3.6		

[a]DBS = Dissection before simulation
[b]SBD = Simulation before dissection
[c]SO = Simulation only
[d]DO = Dissection only
[e]Mean
[f]Standard deviation

Posttest Data

The anatomy and morphology achievement posttest. The posttest achievement data were analyzed using a 2 (Gender) X 4 (Condition) X Test Time (Pretest vs. Posttest) between/within ANCOVA with ITBS science score used as a covariate. Test time was the within subject variable. The ANCOVA revealed a significant main effect of Condition, $F(1, 72) = 53.135$, $p = .0001$, and of Test Time, $F(1, 72) = 18.746$, $p = .0001$, but these main effects were modified by a significant Test Time by Condition interaction, $F(1, 72) = 13.080$, $p = .0001$. As shown in Table 1, students in all conditions seemed to improve in anatomical knowledge from pretest to posttest. However, students in the SO and SBD conditions appeared to improve more than did students in the DBS and DO conditions. This apparent difference was assessed by conducting follow-up gender by time between/within ANCOVAs for each condition. These tests indicated a significant improvement from pretest to posttest the SBD and SO conditions, but not for DBS and DO condition. It had been expected that males would do better than females. This prediction was not confirmed. No main effect or interaction involving gender were significant. The ITBS covariate was significant, $F(1, 25) = 19.609$, $p < .0001$.

Discussion

The results of this study supported the theory that prior use of a simulation before dissection can improve learning. The treatment group that completed the simulation activities before the actual hands-on dissection performed significantly better on the achievement posttest and dissection performance test than the other three groups. These results are consistent with those of Kinzie, Strauss, and Foss (1993) who compared the achievement and attitudes of students who conducted a frog dissection with and without the use of an interactive video-based simulation used as a preparatory experience for the actual frog dissection. As in the present study, their results indicated that students in the interactive video simulation preparation group scored significantly higher on the posttest achievement measures than did other three conditions.

The results obtained in the current study offered little support for the hypothesis that there would be a significant difference in the learning patterns of male and female on the posttest achievement means and the dissection performance test. No differences in posttest achievement or dissection performance were found between male and female participants in any condition. This failure to find a gender difference in the present study run counter to the results of Andre and Haselhuhun (1995). Andre and Haselhuhun found that males who completed a simulation activity before reading a text on principles of motion learned more from the text than males who did not use the simulation before reading. For females, no significant differences were found. In a followup study, Andre et al. (in preparation) found positive effects of a prior simulation on learning the principles of motion for both males and females, but overall males did better than females. The differences between the Andre and Haselhuhn and the present study may be due to gender differences in interest and experience with the content. The present study focused on biological content whereas the Andre and Haselhuhn study focused on physics. Differences between females and males in interest in the biological sciences are substantially smaller than differences in interest in physical science and in physical science course taking (Kahle & Meece, 1994; Andre, Whigham, Hendrikson & Chambers 1997).

A second possibility is that the nature of the simulations used related to the gender differences. The simulation used in the Andre and Haselhuhn (1995) study was more exploratory and less directive than the simulation used in the present study. In the present study, the simulation directed students to remove particular organs.

It may be that directiveness and prior knowledge, experience, or interest interact. When interest, experience or knowledge are low, as is typically the case with women and physical science, students may have difficulty connecting experience in an open-ended exploratory simulation to later didactic instruction. With higher knowledge levels, or greater directiveness in the simulation activity, connections between a simulation experience and a later experience may be easier for students to perceive. However, these interpretations are speculative; the large number of differences between Andre and Haselhuhn (1995) and the present study preclude firm conclusions. But the differences in the studies raise fruitful lines of inquiry for subsequent research.

In the current study, the lack of gender differences support the results of Tylinski (1994) who found no significant difference in the learning patterns by gender when using either a computer simulation or traditional hands-on method of dissection. The present results also are consistent with Choi and Gennaro (1987) who found no gender differences in their study of the use of simulations to teach volume displacement to eighth grade students.

The most intriguing result of the present study was that a simulation used before dissection led to better achievement performance than a simulation used after dissection. This difference cannot be attributed to a difference in the amount of instruction received as the students in the simulation before dissection and dissection before simulation conditions had equivalent amounts of instruction. Nor can the difference be attributed to a Hawthorn effect of using a new instructional tool or to a motivational effect of the computer based simulation. Both the simulation before dissection and dissection before simulation conditions received the same computer experience. The difference has to be due to the sequence of presenting the simulation before the dissection.

The study also looked at the students' attitudes toward dissection. The dissection-only condition was more accepting of dissection than the other two conditions; dissection before simulation and simulation before dissection. However, attitude toward dissection did not change differentially as a function of experimental condition over the study. Similarly, the students' attitude toward computers and attitude toward school and science scale remained consistent from the pretest to posttest. These results supported Kinzie, et al. (1993) who found that the attitudes toward dissection remained relatively stable from pretest to posttest. McCollum (1988) also compared lecture versus dissection in a high school biology and found no significant differences in group attitudes toward frog dissection before and after the end of the experiment. One reason why the student attitudes did not change may be that their opinions were formed across experiences in six school grades. A single experience is unlikely to change such long-term attitudes.

The results obtained in the current study offered little support for the hypothesis that there would be a significant difference in the learning patterns of male and female on the posttest achievement means and the dissection performance test. No differences in posttest achievement or dissection performance were found between male and female participants in any condition.

There are a number of limitations in the present study. The participants were mostly white, middle class, seventh grade middle school students in a single, midwestern, homogeneous school district. The limited diversity in students obviously limits generalization to students in other environments and grades or from different cultural and socioeconomic backgrounds. Nevertheless, it is assumed that students in the present study were reasonably typical of the population of white, middle-class, midwestern middle school students. In addition, we excluded data from all identified special education students from the study; generalizations to special needs students should not be made. It is possible that taking the pretest influenced posttest scores. This potential influence may mean that data obtained from the study could not be generalized to situations in which pretests are not used. Because the pretest was administered three weeks prior to the time of the actual dissection, it is possible that learning occurred between the pretest and the beginning of the study. However, as this difference occurred for each of the groups, it is unlikely that it influenced the different results found between the conditions. Finally, because the standard error of the statistic is decreased with an increased in sample size, the smaller sample size of this study may limit its generalizability.

Conclusion.

The results of the present study suggest that presentation of a computer simulation before the actual dissection may provide an experiential base that enhances learning. This finding suggests that computer-based simulations can offer a suitable cognitive environment in which students search for meaning, appreciate uncertainty, and acquire responsibility for their own learning. These results are in agreement with previous results that the use of computer simulation before actual dissection or alone can provide a better experiential base for students to master the anatomy and morphology of frogs than can the use of simulation after dissection or dissection-only.

Although the use of simulation before actual dissection may provide an experiential base that enhances learning of new information, simulation may not be equally effective for all students. The degree to which students benefit from simulation before actual dissection may depend on the prior interest, knowledge, and experience that the student brings to the instructional situation.

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EARTH2CLASS: A UNIQUE WORKSHOP/ON-LINE/DISTANCE-LEARNING TEACHER TRAINING PROJECT

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Abstract: "Earth2Class" (E2C) is a unique science, math, and technology learning resource for K-12 students, teachers, and administrators created through the collaboration of researchers at the Lamont-Doherty Earth Observatory, curriculum and technology integration specialists at the Institute for Learning Technologies, a Maury Project Peer Trainer, and teachers from the New York City metropolitan area and rural upstate New York. During the winter and spring of 2000, E2C presented workshops for teachers at the Lamont-Doherty campus in Palisades NY that were transmitted live to others in Glens Falls. Before, during, and after each workshop, participants and others were able to utilize the resources available on the E2C Internet site, www.earth2class.org. E2C relies on a unique synergy of specialists in curriculum, educational technology, and scientific research, but the key feature is involvement of the Lamont scientists. Their availability through workshops, web site postings, and e-mail expose teachers to stimulating cutting-edge research that help the teachers develop K-12 curriculum activities linked directly to "real world questions." Drawing on the scientists' expertise, teachers can show students how the science they are learning applies outside the classroom, as well as to other aspects of their studies.

Introduction

While expectations for student achievement are increasing, many teachers do not have adequate content knowledge to effectively teach science or math; nor do most undergraduate-level science and math courses model the pedagogical approaches prospective teachers will need in the K-12 classroom. Once in the classroom, beginning teachers are usually expected to be fully qualified, and often do not receive the support needed to improve and refine their content knowledge or pedagogical skills (CEO Forum on Education and Technology, 1999).

Teacher education should be viewed as a career-long process that allows teachers of science, mathematics and technology to acquire and regularly update the content knowledge and pedagogical tools needed to teach in ways that enhance student learning and achievement in these subjects (CEO Forum on Education and Technology, 1999; Getting America's Students ready for the 21st Century: Meeting the Technology Literacy Challenge, 1996).

"Earth2Class" (E2C) is a unique science/ math/technology learning project that combines workshops by research scientists with on-line resources available at www.earth2class.org and distance-learning staff development programs. E2C has the potential to become a major resource for educators in the atmospheric and related sciences. This paper provides a general description of the "Earth2Class" project.

Project Background

"Earth2Class" developed out of a series of workshops organized by AMS Maury Project Peer Trainer Michael J. Passow and held at Columbia University's Lamont-Doherty Earth Observatory in Palisades NY. In each session, participants gained background information concerning atmospheric, oceanographic, climatic, and other concepts related to the theme, then interacted with the featured scientist describing his/her cutting-edge research. In addition, teachers worked through teacher-training and classroom-ready instructional materials developed by the Maury Project, Project Atmosphere, and other AMS Education Program efforts, among others. Kelly Corder proposed a collaboration that could make the benefits of the scientists' presentations available to more teachers, using as a pilot program those associated with the North Hudson Electronic Education Empowerment Project. Cristiana M. Assumpcao and Frederico Dalmas Baggio from the Institute for Learning Technologies, Teachers College, Columbia University, provided the hardware and expertise to develop the supporting web site (www.earth2class.org) and handle the videoconferences, as well as bring in the technology integration components to the curriculum. Through teleconferencing links with the North Hudson Electronic Educational Empowerment Project (NHEEEP), based at Adirondack Community College, Glens Falls NY, they were able to present the "live" presentations at LDEO to teachers more than 320 km away. Using a supporting web site, www.earth2class.org, participants were able to access and work through some of the workshop activities as they were being presented. These were later edited and made available to anyone interested in the PowerPoint, activities, and other components of the workshop. In addition, other resources on the www.earth2class.org web pages provide educators and their students with links to many useful government, science and science education, and other Internet sites; web-based classroom activities; and examples of appropriate curriculum and assessments.

Workshop Themes

Briefly, the themes for this year's Spring series and guest scientists included:

"Predicting Natural Disasters" with Arthur Lerner-Lam

"Nothing can beat the excitement of collecting a singular piece of data, of measuring it delicately, of pronouncing it fit, and extracting its story. One thing an academic program in science must do is communicate science by current example and past history. Columbia's Department of Earth and Environmental Sciences and Lamont-Doherty Earth Observatory combine to do this very well. Whether we're in the field, at the bench, or in front of a computer, we all seem to feel and draw on the institutional memory here. You have to keep poking at the earth to learn its secrets. As a seismologist, I do a lot of field work collecting data from earthquakes and explosions. I use these data to model the structure of the upper mantle and crust."

But just how predictable are natural disasters? How can appropriate information and warning reach the general public? What about other kinds of natural hazards--hurricanes, tornadoes, winter storms, heat waves, etc? This workshop will provide the chance to find out more about such problems, and develop some ideas about how to present these topics to your students.

"El Nino, La Nina, and the North Atlantic Oscillation" with Martin Visbeck

My main research interest is to understand the ocean's role in the climate system and its consequences for society. How is decadal climate variability orchestrated? Does the ocean influence atmospheric variability in mid-latitudes? What is the North Atlantic Oscillation? Does primary productivity depend on decadal variability? Can we forecast deep convection in the Labrador Sea? And what role do the polar oceans have in the climate system? I have worked on a number of problems using ocean models and data from sea-going expeditions and enjoy thinking about the nuts and bolts of the daily science as much as developing new multidisciplinary research programs for the years to come.

"Winds, Currents, and Cores" with Donna Witter and Rusty Lotti Bond

The recently launched QuikSCAT satellite scatterometer (NASA) is returning high-quality data that will be used by oceanographers and atmospheric scientists to study winds over the ocean on a wide variety of time scales. From a climate perspective, one of the most exciting applications of this technology is that statistical analysis of short records of satellite data can be used to improve estimates of wind variability on long time scales (e.g., decades to a century). On these longer time scales, the wind record from ships at sea is spatially and temporally filled with gaps and subject to larger errors. Several of us at LDEO are using satellite wind observations to better understand deficiencies in the historical data sets and to develop new wind climatologies for the historical period. My presentation will describe this work, and discuss its use for assessing climate change during the past century. The specific topics which will be covered in the presentation include: 1) the technological aspects of measuring winds from space; 2) using these measurements to understand recent wind variations, and 3) using these measurements to understand wind variations on climatologically significant time scales and for times prior to the launch of wind-observing satellites.
Rusty Lotti Bond, Curator of the Lamont-Doherty Deep-Sea Sample Repository, oversees the collection, processing, archiving and physical properties analyses of the largest collection of material from the below the ocean floor. The Lamont-Doherty Deep-Sea Sample Repository collection of sediment samples provides material for scientists worldwide to research many facets of our earth's systems. Deep-sea cores contain microfossils and minerals that can be used as environmental indicators, or reveal climate change. The cores hold a permanent record of geological events such as earthquakes, changing sea levels and shorelines, and the earth's magnetic history. Variations of color and texture resulting from changes over time in the sediment are clearly visible in the cores. Samples from the different intervals can be easily processed for observation of the variations in number or kinds of microfossils or minerals. The dynamics and significance of these changes will be explored in the workshop.

"Climate Changes over Various Time Scales" with Joseph D. Ortiz

The objective of this workshop was to provide teachers with an introduction to the factors that drive climate change on a variety of time scales. Dr. Ortiz will discuss processes that drive climate on a variety of timescales from the seasonal to 10's of thousands of years. Study of the Monsoon system serves as an example of how some of these climatic forcing functions interact. On seasonal timescales, Monsoon circulation systems in African, India and Asia are driven by the thermal contrast between land and sea. Likewise, during times in the geologic past when orbital parameters maximized seasonal contrast, enhanced Monsoon systems existed. This effect has been successfully simulated with global climate models (GCMs) and observed using geologic data such as lake level records. Material presented in the workshop, including a presentation of educational software on the Monsoon, and lists of internet-based educational material provides a rich context for teacher to explore the natural phenomenon of climate with their students on a variety of levels.

"Studying the Sea Floors and Sea Surface from Space" with Christopher Small

Studying the sea surface and deep ocean floors has come a long way from the lead weights on piano wire lowered over the side of the "HMS Challenger," and even from sonar so widely used since the 1940s. Today, satellites flying high above the surface can send radar and other beams that reflect off the sea surface and bottom, and can be translated into detail images. Such satellite data has made possible new understanding of how changes in sea surface temperatures can affect global climates. They can measure variations in sea surface heights, revealing that the "sea level" is actually far from "level." They can discover previously-unknown volcanoes and other features lying in the ocean depths.

Dr. Christopher Small shared his expertise in Geophysics and Remote Sensing. His current research involves analyzing seamount volcanism in the southern Indian Ocean using multibeam sonar data and image processing software.

"EarthView Explorer (part 1 and 2)" with O. Roger Anderson, Raymond Sambrotto, John Armbruster and Kevin Griffin.

Earth View Explorer (EV) is a novel, computer-based learning application based on constructivist principles that encourages students to explore data, invent hypotheses and test them, and in many respects inquire about their environments as do scientists. The EV application contains four units: 1. Geosphere, 2. Hydrosphere, 3. Atmosphere and 4. Biosphere. In the first session, we will introduce the basic rationale for this curriculum innovation and its use, and through group, hands-on, experience develop with the workshop participants how to use the first two modules in teaching. All participants received a free copy of the CD-ROM disk.

In the second session, we explored the use of the modules on Atmosphere and Biosphere though presentations by Columbia University scientists and science educators and explore, through hands-on use of the modules, how these can be applied to teaching earth and environmental sciences in pre college education.

General Workshop Setup

Briefly, for each session, video cameras and two-way audio connections enabled participants at each location to view what was happening on large-screen projections, so interactions were easily made. Computer connections allowed participants to work through activities as the presentations were in progress. By using Netmeeting, one computer was connected just to share the desktop of the scientist's computer in order for the distance teachers to be able to follow more easily what was being demonstrated, while a second computer was connected with video and audio, so that the distance teachers could see the presentation and ask questions. Teachers could also explore other aspects of the CDs and web-based activities during the sessions. In this way, the workshops moved far beyond the "talking heads" often involved in distance-learning formats.

Teacher Enhancement

Announcements about these workshops were distributed through List-Servers, regional teacher centers, conference fliers, and other formats. Teachers involved in the workshops at the LDEO campus came from a variety of public and parochial schools in the New York/New Jersey area. They paid a nominal fee of $10 per session toward costs. Credit for attendance was possible, but no graduate course credit arrangements were available. Teachers at Adirondack Community College were participants in the North Hudson Electronic Educational Empowerment Project, a three-county consortium serving many districts in the region. Assessment of E2C workshops was obtained from the teachers through an on-line section of the web site. Information from the responses is being used to shape future offerings to enhance technological skills and subject area knowledge of participants.

Future Plans for Earth2Class

Based on the experiences obtained in this series, the "Earth2Class" team is engaged in efforts to expand the scope of the program considerably in the 2000 – 2001 academic year. Nine workshops are planned for the current year. These include updated presentations by most of the past presenters, stand-alone online asynchronous modules using the scientists as instructors in association with Earthscape, Columbia University Press, as well as new themes dealing with applications of educational technology, rocks and minerals, core/mantle studies, and hydrology. Partnerships with established Columbia University electronic education programs are underway that will significantly improve the technological basis of E2C offerings, as well as expand the potential participatory base.

Conclusions

"Earth2Class" provides an excellent example of how research institutions schools of education can work with classroom educators to enhance science achievement. Despite occasional glitches from pushing the limits of bandwidth and other aspects of currently available technology, this approach received excellent responses from participants. E2C will expand to include additional scientific areas, for-credit training in both science content and educational technology, and more effective use of Internet-based resources.

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Using Technology to Help Strike a Blow for Education and the Environment -- A Case Study in *Real World* Preservice Teacher Education

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Abstract: This research paper follows a process used to build a meaningful service learning project that integrated all core subjects and the arts and enabled preservice teachers to aid classroom teachers in teaching and learning about issue driven curricula whose study is enhanced by technology. The project was built around an effort to study and save an inner city wetland. The team of teachers, preservice teachers and students used computer technology to research the issue and build a case for preservation which they presented at a university-wide symposium. This project clearly demonstrates that technology integration is most powerful when used as a tool for real learning, especially about real world issues.

WANTED: Early adolescents and their teachers in need of a reality based/service learning project to serve as a capstone for their eighth grade year, preservice teachers eager to put middle school teaching and learning theory into practice and university professors seeking meaningful ways to teach the importance of sense of place, interdisciplinary curriculum development and technology integration. JOB DESCRIPTION: Work with a coalition of church groups, Partners for Environmental Justice, to learn about and champion a woefully neglected wetland area in the capital city that is home to plants, animals and educationally and economically deprived minority citizens who have been under served by their city government representatives.

One hundred eighth graders and their four teachers teamed up with North Carolina State University professors and their students and representatives from the State Department of Public Instruction to become part of a reality based integrative service learning project. It was a match that enabled the middle school students to see that what they learned in school could be applied to solve real world problems. College students found the same. Theories of adolescent development and approaches to teaching and learning using technology could be observed and practiced in a middle school setting rather than just read about in college textbooks. University teacher educators were able to demonstrate theory to practice by developing a service learning project that partnered schools and community in an issue driven curriculum (Beane, 97).

Schools are struggling today to balance the teaching of discrete facts and skills demanded by the testing craze with the importance of students understanding how to apply what they have learned in a thoughtful and reflective manner. Increasingly, it has also become more difficult for teachers to compete with the high tech toys that promise flash and dash and give immediate feedback and gratification. Helping students focus on their studies, set goals for their own achievement and see themselves as successful learners demands meaningful, worthwhile lessons. The added pressure of having all students ready for tests and jobs that require technology competence leaves teachers wondering how to get it all done.

Selecting a high interest service learning project is the answer to many of the challenges that face teachers today (Arnold & Beal). Students achieve focus in their study of a meaningful project and see the application of what they have learned in school to a real world situation. They are able to apply technology skills to the study of that problem and understand the importance of developing and using technology to get facts and information that was previously unavailable through conventional means. They are empowered and feel valued by the contributions they make to their community.

Teachers at the Centennial Campus Middle School and at North Carolina State University in Raleigh, North Carolina , joined forces to engage the middle school students in an environmental service project of a neglected capital city wetland that bordered an impoverished housing area. The middle school teachers taught a theme based, multidisciplinary, integrative unit that addressed all facets of wetlands research from the study of science -- living systems and habitats, flowcharts of problem cycles, topography mapping, social studies -- GIS mapping of demographics, disenfranchised groups and social change throughout history, community activism, city government and history (Beal, 92), environmental justice, laws and the decision making process, understanding diversity and respect for differences, math -- study of proportions/ratio, cost calculation, preparation of a spreadsheet to show the types and amount of garbage found at the site, language arts -- reflective and creative writing, preparing effective letters to city officials. Case studies of the Centennial Campus development and Neuse River water quality, as well as labs that dealt with erosion, river systems, and area profiling were augmented by exploratory classes in the use of Excel to graph data findings, word processing and PowerPoint to prepare presentations, use of the arts to express appreciation or concern through photojournalism, song writing and sketching.

Preservice teachers were part of the process from the beginning. One student teacher with expertise in environmental education planned and presented a workshop about the plants and animals that students would see in wetland areas. She and a botanist brought in tubs of wetland plants for the students to touch and feel. They discussed environmentally sensitive ways to conduct a field trip to a wetlands. Students brainstormed what was needed to live, how much of our own bodies were water and the importance of water to everyday life. They discussed the purpose of the wetlands and shared the information that they had gleaned from their weeks of research on the web. College students from a middle school foundations class attended the workshop and had the opportunity to interact with the students. Following the hands-on workshop at the school, 100 students did field research in the wetland area.

The field trip involved an entire day. Fifty students conducted action research in the morning and fifty did the same in the afternoon. Each time the fifty were divided into three groups. One group sketched and observed the area, another heard from community leaders about the history, scope and timeline of the project and a third walked the area and took digital pictures of interesting flora and fauna, planted trees and shrubs and kept a tally of the trash as well as identified types and sizes of trees. Middle school teachers, parents, university faculty and student teachers were involved in the planning and execution of the trip.

Teams of preservice teachers spent several days with the students at the end of the unit to help them prepare for a university-wide presentation of their findings. The middle school students and their research project were featured at the Tenth Annual Spell of the Land Symposium. The title of the symposium was *Sense of Place, Use of Space*. The students reflected on how their own sense of place changed as they became proactive for a better use of space for the wetlands area and the neighborhood. They developed their own 30 minute program to share their research findings and help the audience understand the importance of stewardship of the land. They determined that the questions they had investigated would guide their presentation. Questions: 1. Where does your water come from and is it safe? 2. How does a massive, new interstate highway built next to the wetland area impact the nearby creeks and the neighborhoods? 3. Why should we save a wetland? 4. Does development always equal progress? 5. How do you break a cycle of environmental injustice?

Preservice teachers helped the groups prepare a mock newscast that described this wetland, discussed its purpose and importance, issues and conditions that influenced how this particular wetlands was being addressed by city government, the importance of an open space bond issue that the voters would vote on and what would happen if the wetland was so destroyed that it would not be able to serve its purpose. Students also prepared dances and poems to be recited. The presentation culminated with a digital picture stream that showcased their field research. Many students took part in the digital presentation as they rose and spoke from the audience about their feeling and hopes and dreams for the wetland area.

This technology enhanced community service learning project was a success for all of its participants. Teachers successfully taught an integrated unit that captured the interest of their students, students developed a strong sense of place for their community and felt empowered through the recognition of their accomplishments to involve themselves in more community projects, university faculty were able to demonstrate to preservice teachers how theory informs practice and visa versa and preservice teachers got valuable observation and practice with early adolescents. Finally, everyone saw that technology is most powerful when used in the context of a real world problem. It captures the interest of the students, enables timely action research and is seen as a tool to help everyone achieve success.

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Teacher's Stages of Development in Using Visualization Tools for Inquiry-Based Science: The Case of Project VISM

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Abstract: Scientific visualization tools have shown tremendous promise in drawing today's increasingly visual learners into in-depth inquiries in mathematics and science. One of the critical questions surrounding the use of these relatively advanced tools is the stages which teachers go through in moving these tools into their own practice. In this paper we examine existing schemas for these stages of development. Then we relate one of those schemas to Project VISM, an ongoing NSF-funded project intended to help middle school and high school math and science teachers learn the techniques and application of data visualization for their own classroom. We describe these stages of development for each of four different scientific visualization tools. Then we conclude the paper by proposing some further development of the models based on our experience followed by a brief discussion of related issues.

Scientific visualization tools offer a rich use of the more powerful computers that are becoming more and more plentiful in school districts today. These are a set of inquiry-based tools, many of which were originally designed to help scientists understand and explore different datasets or physical phenomenon. Visualization tools have shown great promise in drawing today's increasingly visual learners into in-depth study of scientific and mathematical topics (Baker and Case, 2000; Greenberg et. al, 1993; Gordin and Pea, 1995; Jonassen, 2000; Thomas, 1996;).

Both the promise and the relatively advanced nature of this software leads to the question of how to get more teachers involved in using visualization tools in their classrooms. Many projects offer extended training for teachers in one tool, but extended training is often too much, too soon. Project VISM is an NSF-funded project intended to focus more broadly on the techniques of visualization and not so much on particular tools. In addition, the project intends to build a cadre of trainers able to introduce teachers to techniques in short, focused sessions and then enable them to go back to their classroom and try an initial lesson or two.

One of the critical questions surrounding the work of this project is the stages which teachers go through in adopting these new and relatively advanced technological tools (such as scientific visualization) into their own practice. In this paper we first examine two existing descriptions of these stages of development: The CERA conceptual framework and the ACOT model. Then we describe Project VISM in greater detail, relating the ongoing work of the participating teachers in the project to the ACOT model. We propose some refinements to the ACOT model in conjunction with our work in Project VISM and conclude with a brief discussion of some of the larger questions related to how teachers bring these tools into their teaching practice.

Stages of development in using technological tools

Discussions of using inquiry-based technological tools to promote better learning in science and mathematics often begin with concerns about the preparedness of teachers to use these tools in the chronically undersupported technological infrastructures of K-12 education. In the midst of these concerns, it is often recognized that teachers progress through identifiable stages of development in using these tools in their classroom. There are two outlines of these stages of development that are particularly noteworthy for consideration: the CERA framework and the ACOT model. Both of these have been articulated in the context of long-term professional development efforts carried out in the field with practicing educators.

Researchers at the Center for Highly Interactive Computing in Education (hi-ce) proposed a conceptual framework called CERA. CERA stands for Collaborative construction of understanding; Enactment of new practices in classrooms; Reflection on practice, and Adaptation of materials and practices (Krajcik et. al, 2000). This framework provides the background for a number of collaborative professional development efforts carried out with a particular urban school district. Thus far their work suggests that it takes teachers about three years to become proficient in doing inquiry-based science supported by technological tools (Blumenfeld et. al, 1994). These researchers have used this framework to enact five middle school curriculum projects that address particular topics using an inquiry-based science approach that utilizes scientific visualization tools.

A second and more general model of the stages of development teachers progress through in adopting technological tools into their teaching practice was first articulated as part of the Apple Classroom of Tomorrow (ACOT) project. The ACOT model suggests that teachers may progress through as many as four stages of development in using technological tools in their teaching practice (Sandholtz, et. al, 1997). Those stages are:

- *Entry* level-competent using the tool
- *Adopt* the tool into their teaching practice
- *Adapt* the tool into their teaching practice
- *Innovate* with the tool in their teaching practice

The ACOT model suggests that it often takes about three years to progress through these various stages, and that in fact adopting the tool often corresponds to the first year's use, adapting the tool corresponds to the second year's use, and innovating with the tool corresponds to the third year's use. It is important to note that this is not a causal model. It is not suggested that all teachers inexorably progress through these stages. Many remain at one or another stage of development. In fact, with the proliferation of different software tools of increasing sophistication, it may not be possible (or even desirable) for many teachers to reach the innovation level with all the tools they use in their teaching practice.

Project VISM

The Integrated Science and Technology program at James Madison University (with the sponsorship of the National Science Foundation) is holding summer workshops in the techniques and application of data visualization for math and science teachers. These three-week long workshops are intended to help teachers see the forest (data visualization possibilities in the classroom) as well as the trees (software and curricula). Teachers will learn four specific data visualization tools:

- Image processing with NIH Image or Scion Image software
- Geographic Information Systems (GIS) with ArcView GIS software
- Molecular visualization with RASMOL and Chemscape Chime software
- Systems modeling simulations with STELLA software

The overall intent of the project is to help more teachers and students involved in using data visualization to learn more about science and mathematics. Below is a brief description of each of these four tools.

Image processing involves the manipulation and analysis of digital images. It has a significant heritage in biomedicine and planetary science research, and images can come from spacecraft in the far reaches of the solar system or from a digital camera in a student's hand. Geographic Information Systems (GIS) have been described in a recent popular journal as "mapping applications that take spatial data for a variety of topics and layer them one on top of the other in order to see a correlation that is otherwise difficult to notice" (Geographic Informations Systems in the Classroom, 2000). GIS systems are currently being used in everything from environmental research to urban planning to marketing and law enforcement. Molecular visualization is a technique that has long been in use by research scientists on high performance computers. But recently the tools have become available for students and teacher to be able to create sophisticated molecular models that play in readily available web browsers with the use of a simple plug-in. Systems modeling tools such as STELLA allow students to create a linked set of processes in a given situation without first getting bogged down in the mathematics. Teachers and students can create models of the spread of infectious diseases, or the trajectory of a water balloon, or the stresses in the life of a high school senior.

Instructors who have used these tools in their own classrooms, both high school and university faculty teach these sessions. This ongoing project has already worked with its first cadre of teachers in the summer of 2000. Online and limited in-person follow-up in the classrooms of these teachers will permit us to follow the stages of development that they follow in moving these tools into their own teaching practice. In addition, the project is recruiting participants for the next two summers. Middle school and high school teachers who have experience in using technology and want to learn to use these new visualization tools in their classes and share their skills with other teachers are encouraged to apply at the Project VISM (2000) webpage listed in the references section: http://www.isat.jmu.edu/common/projects/vism/summer.htm

Deliberate discussions of the ACOT model were held with the instructors during this past summer's workshop. Initially they were presented with a summary of the model and then asked to specify what the use of each of their respective tools would look like at the entry, adopt, adapt, and innovate level in the classrooms of the teachers in the project. In this way they were asked to make explicit their expectations for the participant's use of each tool.

Table 1 lists the a summary of those conversations. This matrix was initially developed to assist in identifying each participant's stage of development for each tool at the end of the first year of the project. Thus some of the descriptors may be a bit cryptic for readers not involved in the project, and further explanation is in order. The first column of the figure lists the four different tools. Then the at the top of the next four columns there is a list of the four stages of tool development: entry, adopt, adapt, and innovate.

For this project we defined the *entry* category as being competent to use the listed tool after the workshop was completed (see Table 1). Under each tool we listed what the instructors described as the competencies that each participant accomplished through the course of the workshop. For example, the instructor for the image processing portion of the project listed the specific image processing skills that were taught. The instructor for the molecular visualization tool listed the particular software-related skills, and then described the tutorial that each participant created that applied those skills to telling a molecular story. The instructor for the geospatial analysis tool listed the three main activities that all participants completed in the course of the workshop. The instructors for the systems modeling software took a somewhat different approach. They listed in order of increasing difficulty the things they hoped the participants would be able to accomplish using STELLA software. Thus at the entry level they state that the participants will be able to add an interactive "shell" or front end to an existing simulation and use it with their students. That is precisely what the participants did during the workshop with the instructors, but the next step for the participants to take is to create such a front end for a model that relates to their own curriculum.

The *adopt* category in Table 1 is defined as having the participants use the tool with their students in the context of their own teaching. Typically it is associated with the first year of use of a new tool. For the image processing and geospatial analysis tool, this stage is characterized by the participants taking one of the activities from the workshop and trying them out with their students. This process of adoption was facilitated by the instructor of the molecular visualization tool by an activity she had the participants carry out at the end of the workshop. The participants compiled a list of RasMol files of other molecules to use with their own students. These files, also called .pdb or Protein Data Bank files, are 3-D macromolecular structure data files. One of the ways in which the participants might adopt this tool into their teaching practice is to use this list to build molecules related to topics that they are studying in the classroom. Two other ways in which participants might use RasMol are listed in the adopt category: 1) participants might use RasMol files to create molecules for presentations to their students and 2) participants might use the interactive webpage they created in the workshop with their students. The instructors of the systems modeling portion of the workshop described the adoption phase in two different ways as well. First, participants in this stage will operate a STELLA simulation with their students, perhaps in a teacher-directed activity to simulate something related to a topic in their curriculum. This might be a part of a lecture or demonstration in the class. Second, participants in this stage will

Tools	**Entry**-competent in using *the tool* at the workshop	**Adopt** *the tool* into their teaching practice (Year 1)	**Adapt** *the tool* into their teaching practice (Year 2)	**Innovate** with *the tool* in their teaching practice (Year 3)
Image processing: *NIH Image* or *Scion Image*	Skill set taught to participants: • Open an image • Manipulate LUTables • Measure/set scale • Profile plot/surface plot • Stacks and animations • Capture their own JPEG images • Average images • Copy/Paste images	Participants select one of the workshop activities and successfully use it with students (preferably on a regular or recurring basis).	Participants significantly modify one or more of the workshop activities into their own teaching practice.	Participants bring in their own images and apply a variety of image processing skills as part of a student-initiated inquiry.
Geospatial Analysis: *ArcView GIS*	Participants successfully completed the identified activities in the workshop • ArcView project intro • Exploring Projections • GeoProcessing Wizard	Participants successfully do one or more activities from the workshop with their students	Participants significantly modify an activity from the workshop to fit the needs of their curriculum/students/ technical constraints and incorporate found data.	Participants can create their own GIS activity using an original data set/source
Molecular Visualization: *RasMol* and *Chemscape Chime*	All participants were successfully able to: • embed Chemscape Chime structures within a web page • write scripts to interact with and animate the Chime structures. They used these skills to create tutorial websites on molecules that they selected as part of the "mineral web."	• Participants use existing .pdb file collections to manipulate molecules to create graphics, make measurements, and show molecular properties. • Participants use the web page they created in the workshop to teach a concept in their curriculum. • Participants use the list of .pdb resources (for their content area) with students.	• Participants are able to find and download .pdb files from Internet sources and use those to write scripts in RasMol. • Participants are able to write animated scripts in RasMol that tell a molecular story related to their teaching.	Participants are able to embed Chemscape Chime structures within a web page and write scripts to interact with and animate those structures to create tutorial websites on molecules they have selected.
Systems modeling: *STELLA*	Participants put an interactive front end on an existing STELLA model and adapt it for their own use in their teaching.	Participants operate a STELLA simulation with their students. Participants read & interpret STELLA system diagrams with their students.	Students can name and document an existing STELLA model , e.g.: • Given a generic system diagram and a physical description of a system, students can name and document the model and input the equations that run the system	Students can build their own STELLA model from a written description of a system with the assistance of the participants.

Table 1. A matrix of the stages of tool use by the participants in the VISM project

read and interpret STELLA system diagrams with their students as part of efforts to better understand a particular topic that is being studied.

The *adapt* stage in this model is the step when the participants begin significantly changing the activities that they have already adopted into their teaching practice. Judi Harris describes this process in another context as "tweaking" an activity (Harris, 1998), pointing out that good teachers modify activities to make them their own. In fact she points out that this reinvention process is a critical part of effectively using any new learning. This stage is generally not reached until the second year of use of a new tool, though it is not expected that all participants would necessarily reach this stage. For both the image processing and geospatial tools in this workshop, the adapt stage is described in Table 1 as modifying one of the activities that was completed in the workshop in such a way that it better fits the curriculum of the participant's classroom. For the molecular visualization tool, the adapt stage was described in two possible ways. First, that participants would locate new.pdb files from the Internet and use them to write new scripts in RasMol. A second possibility is that participants would write animated scripts in RasMol that tell a molecular story related to a topic in their curriculum. Note that both of the activities could be part of enhancing teacher presentations of material to their students, versus being tools that the students themselves would use for their own projects. For the systems modeling tool, the adopt stage is described as when the participant's students can name and document an existing STELLA model. For example, if the students are given a generic system diagram and a physical description of a system, the students can name and document the various features of the STELLA model and input any necessary equations. Note this is not the same as "authoring" a STELLA model. In a sense it is the ability to "rough out" such a model on paper before working to write such a simulation with STELLA.

The *innovate* stage is the one that almost any workshop leader hopes their participants reach for any given tool. But as was pointed out earlier, it was not an expectation of the leaders of Project VISM (nor is it a realistic expectation for any suite of software tools) that all participants would reach this stage. In the ACOT project it was generally found that it took at least 3 years to get to this level. For all the tools in Projects VISM, the innovate stage can be summed up in one word: authoring. With the image processing tool, the innovation stage means that participants help their students bring in their own images and use their image processing skills to help students carry out (or author) their own scientific inquiries using this tool. In the case of the geospatial analysis tool, the innovate stage means that the participants create (or author) their own GIS activity using original (and, in many cases, local) data. For the molecular visualization tool, the innovation stage means that the participants create (or author) their own webpage that uses Chemscape Chime structures to create a tutorial for their students. For the systems modeling tool, it means that the students can build or author their own STELLA model from a written description of the system with coaching from their teacher.

Refinement of the ACOT model for scientific visualization tools

As part of our work with the instructors and participants Project VISM, we have developed some refinements to the ACOT model that we think are pertinent to the kinds of more advanced tools we are asking teachers to use with their students. The current ACOT model bases each of the stages on a given level of competency with the technological tool, and describes their development in using that tool with their students. But in working with scientific visualization tools with teachers we have noticed that this competency really has three component parts. Those three parts are:

- Competency with the software **tool**
- Competency with the scientific **data** that the tool uses
- Competency with the **pedagogical content knowledge** needed to teach curricular content using the tool

We believe that these three components help determine a teacher's ability to move forward into the next stage of development in using a given tool. For example, imagine a teacher has just attended a workshop and learned how to use NIH Image, an image processing tool, and also has some images and classroom-ready activities prepared for their first efforts at using this tool with their students. What I've just described there is a teacher ready to *adopt* image processing into her classroom because she has the capabilities to use the tool (NIH Image), has the necessary data (the images) and has a first "cut" at knowing how to "chunk" this activity to achieve particular educational objectives that are in her curriculum (classroom-ready activity she received or created at the workshop). These same three components come into play as that teacher moves to the *adapt* level of development. For example, in the second year that same teacher uses the activity, she might significantly "tweak" the materials and/or the approach she uses to teach the same material. One might argue that this "tweaking" is a prerequisite for even first time use of the activity, but the kind of changes we are suggesting here are more substantive and often require teaching the material once to "kick the bugs out" of a given lesson or project. In addition, tweaking the activity might also involve learning some new aspect of the software tool, or refining one's approach to teaching the tool to students. Then in the *innovate* stage many teachers begin to bring in their own (and often locally more meaningful) data with their students. In NIH Image that might mean learning how to bring in a JPEG file from a digital camera at the best level of resolution, or how to find uncompressed TIFF files at a NASA website and download them onto their local computer from the World Wide Web. Moving to the innovate stage is often dependent on learning how to bring in new data sources. Or it might be dependent on certain kinds of new pedagogical content knowledge, such as how to better enable student-initiated projects in the context of increasingly high stakes testing and standards-driven curriculum. Our idea is that significant development in one of these three components is consistently linked with moving forward to the next stage of development for many teachers.

Discussion

At this writing we are still completing our discussions with the first year participants in Project VISM. We have not yet determined what stage they have reached with each of the different tools nor whether our notion of the importance of these other three components will be confirmed in our experience. We do expect that there will be some of the tools that they will have adopted into their practice and some that have not yet been used.

But we do note that in many of our conversations with colleagues about the journey that teachers go through in using new technological tools to enable better learning situations in their classrooms, there is a good deal of discussion of "building capacity" in the system and "ramping up technological change." To our ears these sound like production metaphors. And while they may be helpful in reminding us to strive to create "sustainable" professional development efforts, they may also miss the fundamentally constructivist nature of teacher learning. In following up with our participants in the coming years we look forward as much to the parts of their professional development that do not find a place on matrices such as we have included in Figure 1, but nevertheless have terrific personal significance to the teachers in their day to day work in the classroom.

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Teacher Created Virtual Field Trips

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Abstract: This paper will discuss the use of technologies, commonly found in schools, to develop and create virtual field trips. The discussion will focus on the advantages of both using and creating these field trips for an instructional situation. A virtual field trip to Cumberland Island National Seashore, St. Marys, GA will be used to discuss the technologies involved and the value of their use for instruction in a science classroom. While this field trip is being used as a discussion point, the techniques and advantages identified can be applied over a P-16 grade range in all subject areas. Thus creating a virtual field trip can be as simple as using digital pictures and text in Microsoft Power Point or Hyper Studio or as complex as using digital video and panoramas in Macro Media Director. The level of complexity will depend on the technology available and skills of the developers.

Virtual field trips are a hot buzz word for integrating the Web into the curriculum. If one does a web search using "Virtual Field Trip" as a key phase, hundreds of sites will be identified. These sites overwhelmingly provide an abundance of pictures with limited information about locations that are deemed to have educational value. Krupnick states that, "The Web is now crowded with sites that are considered "Virtual Field Trips" and they vary a great deal in content and usefulness." She further states that, "For teachers who already have a curricular unit assembled and are looking for online enhancements, these are adequate. But for teachers who are looking for a source of new and exiting curriculum such sites are only a starting point. In order to make them useful, an instructor would need to develop curriculum." (1998, p. 43) A virtual field trip should be much more than a web-based presentation of a location. The focus should be to design a field trip, not confined to the WWW, that allows the student to "learn" from the field trip in a way that is similar to actually taking the field trip. Coulter states, "The key is for (instruction) to drive the technology implementation and not vice versa, despite pressures to integrate technology into the classroom....Virtual field trips in the form of Web sites...enable students to refine and extend their growing understanding as they explore other parts of the world" (2000, p. 49). In addition, a virtual field trip coupled with an actual field trip to the site will vastly increase the educational value of the experience. However, this requires teachers to control creation of the trip to meet their curricular needs.

A major concern of using field trips in educational situations is that they are 'just a day away from school', with limited tangential educational purpose. Many teachers state that there is not time to take full advantage of what the site has to offer, so by definition the experience becomes superficial. Bellan and Scheurman (1998) discuss ideas about actual and virtual field trips and list the pitfalls of both. In their article, they outline the teacher involvement necessary to alleviate some of the pitfalls. Among these are; the teacher visiting both the actual and virtual site, the teacher's plan for student use of a virtual site, student use of the virtual site before visiting the actual site, and follow up instruction using both the virtual and actual trip experiences. All the concerns about how field trips are used are not eliminated by taking the field trip on the computer. Two important points are made, first that the virtual field trip is usually not sufficient by itself and second that pre-planning the trip and the follow-up experiences should all be an integral part of the teacher's curriculum.

Definition of a Virtual Field Trip

Stainfield, Fisher, Ford, & Solem (2000) feel that virtual refers to 'digital alternative representations of reality' and that a virtual field trip is not an attempt to create a virtual reality. Virtual field trips are computer based simulations of an actual field trip which allow the user to experience the environment of the intended location. They provide the teacher and learner the opportunity to experience aspects of an actual trip without leaving the classroom. They should include all elements of a well designed field trip and provide the student with experiences that are beyond those that could be obtained from a pamphlet or a photo display of the location.

Advantages of Creating a Virtual Field Trip

The main advantage of a teacher created virtual field trip is that it can be specifically designed to meet the objectives of the curriculum and the needs and ability levels of the students. Other advantages of virtual field trips are that they:

- can be used either as a replacement for or in conjunction with an actual trip to the same location.
- provide opportunities for repeated visitations to the site for further study.
- encourage learners to plan and prepare for activities to be carried out on the trip.
- allow the teacher to focus on one specific aspect of the trip at a time.
- provide for the presentation of a wider variety of experiences than may be possible on one trip.
- can be designed to illustrate time sensitive issues, i.e. seasonal changes, etc. that could not be viewed on a single actual trip.
- provide integration of multiple aspects of the field trip into a number of different curriculum areas.
- allow for commonality of experiences.
- allow students to take a closer look at areas that they could not fully explore during an actual field trip.
- provide a simulation for students who may not have been able to attend an actual field trip.
- can be used for assessment purposes.
- can be shared with colleagues and parents.
- can be used repeatedly by the teacher year after year.

Limitations of Creating a Virtual Field Trip

The main limitation is the time needed to create the experience. However, if the teacher views the design of the field trip as dynamic, construction of both the actual and virtual field trips will grow over time. Also, involving others; colleagues, community members, students and parents can help to reduce the extended amount of time that the teacher spends in creating a virtual field trip.

Because curriculum design requires content expertise, another limitation is the teacher's knowledge of the content area of the field trip and the curricular objectives. As teacher's get involved with the design they often need to extend their knowledge of the content of the field trip thus increasing the time necessary to design the experience.

A third limitation is the availability of the technology. However with the increasing availability of technology in the schools, homes and work places this is becoming less of a barrier. Coupled with the availability of the technology is the teacher's ability to use the technology effectively. Again this can become a learning situation and thus increases the time to create the product. This limitation can also be minimized by the involvement of colleagues, community members, students and parents.

Student Involvement in Creating a Virtual Field Trip

Student involvement in the creation of the virtual field trip can take the form of; collecting information at school, using aspects of the technology in the construction of the product, taking the actual field trip and gathering the images and information to present in the virtual field trip. This involvement focuses student attention and learning on the intricate aspects of the content presented. In addition, it provides ownership by the student of the project. Last, but not least, it provides opportunities for students to use the technology in a real world situation, which addresses the NETS standards by preparing them to function in a technology rich information society.

Creating a Virtual Field Trip

The field trip we chose to illustrate the process of creating a virtual field trip is used within a course for Middle Grades pre-service teachers. This trip is a visit to Cumberland Island National Seashore. The objective is to prepare pre-service teachers to design and use field trips effectively in their classrooms.

The steps for creating a virtual field trip are:

1. Examine the objectives of the course and choose a field trip that includes experiences that fit within the realm of the objectives while enhancing learning.

The purpose of this virtual field trip is two fold, it provides information that will be used on an actual field trip and it provides information about parts of the island that are inaccessible to the students. The objectives of the field trip are: to learn about the ecosystems of a barrier island located off the southeastern coast of the United States; to understand the history of man's inhabitation of the island and his impact on its ecosystem; and to design and carry out experiments that survey the island and its inhabitants.

2. Create a concept map of the experiences to be included in the field trip.

A concept map provides an overview of all the elements to be included in the virtual field trip and acts as an organizing framework to build upon in construction of the final product. The concept map should not be considered the final blueprint for the field trip, rather it should be seen as a dynamic overview and a starting point from which the product evolves. The concept map for the virtual field trip to Cumberland Island can be seen in Figure 1.

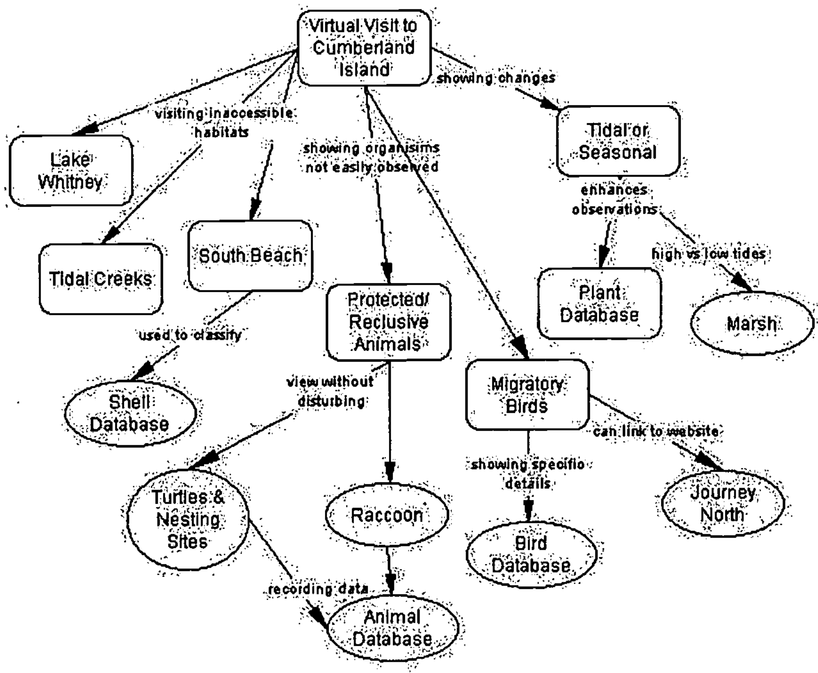

Figure 1: Concept Map – Virtual Field Trip to Cumberland Island National Seashore

3. Select the appropriate technology to be used based on the content and the curricular objectives of the field trip. The technology includes the organizing program and tools for collecting and presenting data.

The equipment and software used will depend on the complexity of the trip and the grade level of the students. Virtual field trips can vary in their complexity based upon the experience of the creator with the technology available.

Based on the concept map, the technology used for the Cumberland Island trip included; digital cameras, computers, scanners, CDR's. In addition, a variety of software was utilized including: word processing, database management, electronic spreadsheet, graphics program, Quicktime VR, and an authoring program.

4. Collect and organize materials to be included based on the curriculum objectives to be accomplished and the concept map. Examples of desired materials might be;

- still pictures, both digital and photographs,
- videos,
- text,
- databases and graphs,
- sound clips.

As materials are collected and organized decisions must be made. For example, panoramic videos can be used to give an overview of the location. If panoramas are to be used, decisions will have to be made before hand as to the location and the concept to be illustrated.

The decisions made for the Cumberland trip were centered around the curricular objectives. Decisions were made concerning:

- whether flora and fauna should be presented as single pictures organized as a field guide or presented in a database which could be continually updated.
- presentation of the history of man's inhabitation of the island.
- presentation of time sensitive aspects of the ecosystems (high/low tides, seasons, effects of long term drought, etc).
- the use of panoramas to give the learner a holistic feel for the elements of each ecosystem and location. Both panoramas and time-lapse videos were used to show the ebb and flow of tides in the marsh areas.

5. Convert all materials to digital format.

When converting materials to digital format the question of designing for dual platforms (Windows and Mac OS) must be considered. While designing for dual platforms is not more difficult or time consuming, the decisions made about the format of the individual parts (pictures and text) must be considered to insure that they are appropriate for the platform(s) chosen.

When converting the materials for the Cumberland Project we converted all images to JPEG format. Both the Windows and Mac platforms have the ability to use the JPEG format and if at some future date the decision is made to make the materials web based this format is standard to the web. Apple Quick Time was chosen for all video production for the same reason and at this time is the only program that allows one to view 360-degree panoramic movies. Since some text came from National Park Service brochures or previously written documents they were converted to digital format with the use of a scanner. The scanner also was used to convert photographs taken with non-digital cameras, such as the historic pictures.

6. Assemble all elements in the organizing program based on the concept map.

Here decisions on the presentation format of the field trip must be made. Will it be one stand-alone program presentation or a series of parts that can be accessed separately? Also, before assembling the materials one must consider the platforms that can present the materials. Will the field trip best meet the needs of the teacher if it is dual platform or is one platform sufficient? These decisions along with the assemblers knowledge of presentation programs will determine if Macro Media Director, Hyper Studio, Power Point or any of the other available authoring program meet the needs of the designed field trip. The choice of the authoring program used is often the assemblers personal choice based on familiarity and skill with the program

For the field trip to Cumberland Island the authoring program Macro Media Director was used to provide access to all the different parts of the field trip. For development of the field guides and databases File Maker Pro was chosen. The main reasons for choosing these two programs were; their power, their dual platform capabilities, and copyright issues. These programs provide run-time viewing programs that can be provided to the user royalty free. (Hyper Studio and Power Point also provide the dual platform and royalty free advantages.)

7. Evaluate the finished product to be sure it meets the objectives.

In a teacher created product, evaluation will be formative in nature, providing a continuously changing and evolving product. There will always be questions of: how could the product be improved, what additions should be made; have the needs of the learners using it changed; and how can new learner groups add to the information presented?

The Cumberland Island field trip has evolved over several years. At first, it was designed as an actual one day field trip. Then the question of how technology could be used on the field trip arose. Teacher use of digital cameras to record student participation in information collection was added. Next, students were provided with digital cameras and recorded information on the ecosystems and other related data. The use of technology to present pre and post field trip information and the teacher's organization of student input was the next challenge. The most recent effort is the result of trying to solve the question of how to present material that was not available to the student on a single trip and how to organize all elements into a product that will be available to the students in an easily accessible manner.

This paper uses the terms teacher created, creator, and assembler in an interchangeable manner. This is due to the principle that while the teacher is the driving force in the design and creation of the virtual field trip, the tasks can be done in conjunction with students, parents, interested community members and colleagues. The technologies used to develop and create Virtual Field Trips are commonly found in public schools today. The Cumberland Island Project used Macro Media Director whose cost at this time may prohibit public school usage, but the project was not dependent on this choice. The process of creating virtual field trips can be as simple as using digital pictures and text in Microsoft Power Point or Hyper Studio or as complex as using digital video and panoramas in Macro Media Director. The technology skills necessary in the creation of the field trip all are within the scope of the National Educational Technology Standards (NETS) for Teachers, and many are within the scope of the NETS for students.

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The Quest for scientific inquiry: A document analysis of Quest projects

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Abstract: The 1996 release of the *National Science Education Standards* (NRC, 1996) energized the national focus on improving U.S. science education in K-12 schools. The standards provide a strong emphasis on inquiry as the primary pedagogical framework in promoting science literacy. Similarly, the recent release of the National Educational Technology Standards (ISTE, 2000) has catalyzed the process of integrating information technology across the curriculum. The ISTE standards provide a curricular framework for technology integration and correlate technology-rich learning activities to standards in several content areas. Thus, these two policy documents provide teachers and students a detailed roadmap for pursuing science and technology literacy; the cornerstone of both literacies being the inquiry process. This paper is a qualitative document analysis of one commercially produced Quest project: AsiaQuest. The paper also examines preservice teachers' reflections on their participation in Quests as part of their professional preparation.

Introduction

In reflecting about the history and philosophy of the natural sciences, Edward O. Wilson (1998) states:

> Today the greatest divide within humanity is not between races or religions, or even as widely believed, between the literate and illiterate. It is the chasm that separates scientific from prescientific cultures. Without the instruments and accumulated knowledge of the natural sciences—physics, chemistry, and biology—humans are trapped in a cognitive prison. They are like intelligent fish born in a deep shadowed pool. Wondering and restless, longing to reach out, they think about the world outside. They invent ingenious speculations and myths about the origin of the confining waters, of the sun and the sky and the stars above, and the meaning of their own existence. But they are wrong, always wrong, because the world is too remote from orderly experience to be merely imagined (p. 45).

While Wilson's view of the natural world seems to ignore the world view of indigenous peoples and non-Western cultures, it does delineate the two periods of human existence: the scientific and the nonscientific. A similar chasm exists in K-12 schools today vis-à-vis the use of information technology as a learning tool. A so-called digital divide (Tapscott 1998) exists in society, in individual school districts, and within individual schools. Even though current technology standards require teachers to be technologically literate, there remains a long continuum from the technophobe to the technophile. Most K-12 teachers whom I have observed or worked with are somewhere in the middle of the continuum.

The purpose of this paper is twofold. First, the paper provides a qualitative document analysis of Classroom Connect's AsiaQuest curriculum guide. Next, the paper examines preservice teachers' reflections on their participation in Quest projects as part of their professional coursework requirements.

Rationale

The National Science Education Standards (NRC 1996) established the direction of science education for the 21st century in K-12 schools. In contrast to traditional science instruction, the standards promote inquiry-based learning situated in constructivist classrooms (NRC 2000). The inquiry standards (NRC 2000) describe the following essential features of classroom inquiry:

- learners are engaged by scientifically oriented questions;
- learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions;
- learners formulate explanations from evidence to address scientifically oriented questions;
- learners evaluate their explanations in light of alternative explorations, particularly those reflecting scientific understanding;
- learners communicate and justify their proposed explanations (p. 25).

The National Educational Technology Standards (ISTE 2000) boldly pronounce "our education system must produce technology-capable kids" (p. 2). The reasons are utilitarian and pragmatic: "Parents want it! Employers want it! Communities want it! The nation wants it!" (ISTE 2000, p. 3). This mandate sets the table for establishing classrooms and learning environments that are technology-rich and produce a technologically literate populace.

The NETS standards are congruent with most content area standards in that they promote inquiry as the key vehicle to teaching and learning. The standards also promote a new paradigm of educational practice that highlights increased emphasis on collaborative work, information exchange, inquiry-based learning and informed decision-making, all situated in a real-world context (ISTE 2000).

Over the past decade, network science projects have extended the curriculum to include the integration of emerging technologies into the extant curriculum. These technologies allow students and teachers to create electronic communities of learners who are focused on common, "real science" problems (Feldman et al. 2000). These projects have evolved from simplistic email exchanges in the late 1980's to sophisticated web-based projects today. How effective is network science as an instructional strategy? What do these projects look like? How much real science is involved? These are all questions posed by classroom teachers and curriculum developers interested in taking the plunge into network science projects.

Study Participants

In teaching elementary science and social studies methods courses, I have integrated several Quest projects into my syllabi as a method of introducing preservice teachers to thematic, interdisciplinary, technology-based projects. While the number of students in these classes is relatively small (n = 150) they encompass a sample from two different universities: a small liberal arts college in the Midwest and a large, research institution in the northeast. My rationale for introducing Quest projects in preservice education classes focuses on two salient points: 1) the need for novice teachers to develop technological literacy and 2) to expose students to a sample of Quest and other network science projects.

AsiaQuest Project Overview

Classroom Connect Quest projects are Internet-based, interdisciplinary, and focus student inquiries on a common issue or question. For example, the inquiry question in the AsiaQuest project is "Did Marco Polo actually go to China?" Anyone can participate in the month-long Quests on the Internet but a subscription is necessary in order to utilize all the Quest features. Subscribers are provided user ids, passwords, and the curriculum guide to help teachers implement the Quest in their classrooms. Below is a description of the AsiaQuest project:

> AsiaQuest is an adventure into a fascinating and complex world. For five weeks, you and your students will travel with our team of explorers on an exciting expedition to China. Together, we'll search for clues regarding the history of Marco Polo's expeditions and we'll investigate the contemporary culture and environment of the areas we visit, attempting to determine the effects of one upon the other. Along the way, we'll mount camels, cross deserts, visit temples, and explore cities of the past and present. AsiaQuest's interactivity makes it possible for students to have an effect on the expedition logistics, latest scientific developments, and ethical debates (Classroom Connect 1999, p. 3).

Thus, unlike many Internet-based activities, teachers and students are active participants in the Quest. This interactivity is further described in the analysis section below.

AsiaQuest Curriculum Guide

The curriculum guide is 142 pages in length and provides a step-by-step set of instructions for K-12 teachers to follow. The guide begins with a 10-page overview that introduces teachers to the project, provides a detailed map of China, and provides a weekly and monthly schedule called the Trek Calendar. The features of the web site are explained and the navigation bar includes areas for research, communication, and accessing online resources (Classroom Connect 1999).

Teaching tips are delineated into different grade levels: K-2, 3-5, 6-8, and 9-12. Thus teachers at any grade level can utilize a specific section of the guide without feeling the need to browse the whole guide. Teaching tips also include a useful section on assessment, a piece that is often missing from network science projects (Feldman et al. 2000). Descriptions of assessment methods include sections on ongoing embedded assessment, self-evaluation, portfolio use, and culminating activities. Sample evaluation rubrics cover the following: cooperative learning project, portfolio, and oral presentations.

The technical tips section provides a step-by-step procedure for setting up the computer, downloading plug-ins, setting the preferred browser, setting preferences, registering and using passwords, and navigating the site. Instructions are also given for the interaction component of AsiaQuest. Students are encouraged to email the AsiaQuest travel team in China to help set travel schedules and explorations strategies. Students can also email content experts, subscribe to the listserv, participate in online discussions, and access an extensive Quest library. Thus, one of the hallmarks of the Classroom Connect approach to designing network science projects is the high degree of embedded interactivity.

The rest of the curriculum guide is devoted to a large Background section for teachers, and specific descriptions of the Quest activities. Each week, activities are focused on specific themes. The tables below illustrate the daily activities and the thematic sequence of the project.

Monday	Tuesday	Wednesday	Thursday	Friday
Team Update	Fox's Files	Team Update	Cool Science	Culture Shock
Christina's Critters	Gross & Disgusting	Myths & Legends	Kid Profile	Week in Review
Set the Course	Get a Clue!	Dan's Dilemma	Science Stumper	History Mystery
Mystery Photo	Mystery Photo	Mystery Photo	Mystery Photo	Mystery Sound

Table 1 – Week At A Glance

Week 1	Unity and Diversity
Week 2	Stability and Change
Week 3	Cooperation and Conflict
Week 4	Conservation and Waste
Week 5	Solutions and Resolutions

Table 2 – Curricular Themes

The activities listed above are designed to allow students to probe the topic from a variety of perspectives. The scope of this paper does not allow detailed descriptions of the activities, but every activity allows students to engage with the inquiry questions embedded in the project and in students' own research.

Preservice Teacher Reflections

Preservice teachers in this sample were asked to reflect on their own participation in the Quest projects. Specifically, they were asked to describe how the Quest promoted scientific literacy and inquiry, and how they might implement a Quest project in their own classroom. Responses include reflections from the AfricaQuest and AsiaQuest projects.

How did the Quest promote inquiry?

Teacher 1: I found that all of the different sections promoted inquiry. This was done through the way the information was presented. For instance, in Dan's Dilemmas, Dan asked questions as if he were having a conversation with a person about the dilemma. The dilemmas make you stop and think. The next thing you know, you're trying to figure out a solution. In all the different sections the material was presented with questions that left you wondering. If I were working with students and AfricaQuest I would encourage the students to act on the questions that the team posed. Although the sections make students wonder, it takes a teacher to move them beyond wondering and toward inquiry.

Teacher 2: This AfricaQuest team offers numerous opportunities for students to go beyond the traditional classroom walls and interact with experts, team members and other students. The interactive features on the Web site pose challenging questions and compelling mysteries for students to solve. Voting and posting in these areas enable students to take an active role as they direct the expedition and help solve the mystery. As the students take part in this interactive adventure, they broaden their research skills, their communication skills, and their skills in accessing online resources.

How did the Quest promote scientific literacy?

Teacher 1: AfricaQuest promotes scientific literacy and technological literacy. This occurs by allowing students to interact with the scientists, asking them questions and helping them find a solution to problems that scientists are investigating. The adventure team poses problems every week to the students and makes them a part of the research. It promotes inquiry with the students as they work to find answers to the problems. It also allows the students to respond, and express their ideas with real scientists.

Teacher 2: While using AfricaQuest, students are also exposed to scientific and technological literacy by following individual interests and sharing their findings with the rest of the class and with people from around the world. In order to get students to explore science in more detail and become scientifically literate, teachers need to allow their students to build on their own ideas. Whether stumbling onto their theories by accident or by intentions, students love the challenge of discovering new ideas or inventions, especially if it comes from them. Thus, by including the Internet in the classroom, teachers can provide the students with an opportunity to navigate, investigate, experiment, and extend their scientific inquiry through active scientific investigations rather than through passive lectures about science facts.

How might you implement a Quest project in your own classroom?

Teacher 1: To incorporate a project like AsiaQuest in the classroom, the teacher needs to be familiar with the background of the program and how to use it. For instance, one evening when I accessed AsiaQuest, I read a comment from a student and wanted to respond. However, I could not figure out how. I then discovered there are directions on how to use their web site. To use AsiaQuest in my classroom, it would be necessary to first understand how to navigate the site. I would also have to be able to connect with other teachers so I could share and get ideas of how others are using the project.

Teacher 2: Since not every person has the same interest I think it is important for each child to find a topic in AsiaQuest that interests them. I have a strong interest in literature and would like to integrate trade books into the AsiaQuest project. For example, I would read a trade book relating to an Asia elephant. The children could then find information about Asian elephants in Christine's Critters. The children could then create a collage based on Asian elephants.

Findings

The activities included in AsiaQuest provide ample opportunity for students to pursue inquiry-based science. The activities and related projects described in the curriculum guide are closely aligned to national standards in several content areas, including science. Information technology is central to the project's design and thus many of the national technology standards are met.

Most participants found Quest projects to be exciting new technology tools although data indicate many students also found some aspects of Quests to be problematic. The table below summarizes some of the implementation issues raised by participants.

Issue	Participant Comment
Time	I was overwhelmed trying to find the time for this…
Access	Several times I could not log on when I wanted to…
Feedback	I did not receive nor view much email feedback that was in-depth…
Communication	When the teacher didn't write back, I totally lost interest…
Content	I often found it superficial…
Availability	Many schools may not be able to afford the Quest…

Table 3 – Problematic Issues of AsiaQuest

Conclusion

Network science projects such as Quests present teachers with a bold vision of learning and technology integration. In their recent findings, Feldman et al. (2000) have found that in many cases, network science projects fail to live up to their stated vision. Areas for further research might include a closer analysis of the vision of Quest projects and how teachers and preservice teachers implement this vision.

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Science Investigations: Onsite – Online – On the Mark!

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Abstract: The evolution of Internet-based communications and capabilities of mobile digital technologies have empowered teachers and students to move beyond "click and learn" science classroom environments to one whereby learners can conduct onsite science expeditions and showcase their investigations online. This paper documents the collaborative efforts of a public school system, a county joint vocational school, a non-profit outdoor learning organization, telecom corporations, a state park system, a state division of wildlife, and universities to launch a digital expedition to study environmental conditions. The paper examines the opportunities related to these emergent technologies and elementary students' abilities to engage in onsite group investigations at the Lake Erie shoreline. The Our Lake Online project involved more than a year of collaborative planning and was funded by a foundation grant, telecom corporate financial support, and non-profit organizational sponsorship. The expedition can be viewed at [http://www.digitalexplorers.tzo.com/erie/default.htm].

Introduction

The use of the Internet as a tool to facilitate collaborative projects for science data-sharing investigations is a fairly recent phenomenon (Berg & Jefson, 1999). However, the evolution of Internet-based communications and capabilities of mobile digital technologies have empowered teachers and students to move beyond "click and learn" science lessons posted on URL sites. Now learners can use mobile digital technologies, laptops, the Web, and environmental analysis tools to launch expeditions at onsite/outdoor locations and conduct their own science investigations. Students that are driven by their own curiosity and natural exploratory instincts can gather scientific data and conduct independent analyses that they can post and share with fellow students and the WWW community.

This paper describes the Boardman Local Schools Our Lake Online project, a first-of-its kind "digital expedition," to the Lake Erie shoreline. The Our Lake Online expedition was conducted by thirty-three elementary students (identified as gifted and talented) from Boardman Local Schools located in Northeastern Ohio. The fourth, fifth, and sixth grade elementary students' Internet-enabled outdoor learning adventure can be viewed at the website [http://www.digitalexplorers.tzo.com/erie/default.htm]. The students' digital pictures capture the day they spent collecting baseline data for an environmental study of the Lake Erie shoreline contiguous to Geneva State Park, Geneva, Ohio. The results of the students' onsite work and experiments were transmitted via digital connections back to students at their respective six home schools, thus also enabling approximately four hundred and fifty students to participate remotely in the online adventure.

Descriptive Narration About the Our Lake Online Website

Digital photographs posted on the website show students, teachers, parents, administrators, and resource experts engaged in collaborative learning as well as individual inquiry-based science investigations. Rotating through five workstations, this community of learners used digital cameras to photograph erosion control practices and wetland plants and creatures, including plankton samples. From a microscope lab housed in a tent near the shore, students magnified images of the microscopic samples and digitized these images for transmission. Sensor-based lab kits by Imagiworks and PASCO Scientific Corporation were used by students to gather data about the water quality of Lake Erie. The students graphed water temperature readings, analyzed oxygen levels, conducted salinity readings, and determined pH levels. The graphs were then downloaded to four of eight laptop computers set up at base stations (two tents and a recreational vehicle). From the four laptops housed in the RV, information was sent via four temporary telephone lines provided by ALLTEL Corporation to students at the six home schools to enable remote participation.

Background Pertinent for the Design and Implementation of the Our Lake Online Project

The expedition, which involved more than a year of planning, was the first-of-its kind to be conducted in Ohio or on one of the Great Lakes. It was primarily organized and headed by expedition leader Joyce Zitkovich, teacher for Boardman's Gifted Services program, Boardman, Ohio. The model for the digital expedition was drawn from the goals and methodologies of the Digital Exploration Society (DEX) [www.digitalexplorers.com]. DEX refers to its excursions as "digital expeditions" or DEXpeditions. Joyce Zitkovich first worked with DEX in 1999 when the non-profit group launched a DEXpedition to Carlsbad Caverns in New Mexico. Based in Los Angeles, California, DEX was founded in 1998 to foster a better in understanding of the interdependence between people, our planet and the technologies we create. The all-volunteer organization supports and launches Internet-enabled learning adventures for students and educators, and was instrumental in providing the guidance and technical support to ensure the success of Our Lake Online Erie project. DEX also hosts the Our Lake Online website. Robert Lindstrom, executive director for The Digital Exploration Society traveled to Ohio to participate in the expedition.

Implementation of the Our Lake Online digital expedition was also made possible by grant monies ($3,984) awarded by the Martha Holden Jennings Foundation, Cleveland, Ohio. ALLTEL Corporation provided telecom services free of charge. PASCO Scientific provided the Science/Workshop Interface 500 Starter Bundle for students to use free of charge, as well. This kit included the Science Workshop and DataStudio Software on CD, an experiment library, teacher's guide, student workbooks, and a set of Starter Sensors that were used to conduct shoreline and water experiments.

Technology assistance and training sessions for Boardman students and teachers were provided by the Mahoning County Joint Vocational School under the direction of Steve Bennett, Susan Dunn and Melissa Thomas- Hackett, vocational education instructors. Eleven MCJVS high school students served as technology assistants and provided the help necessary to support elementary students' technological endeavors at Lake Erie. Four Bloomington, Indiana high school students and two Indiana University college students also provided onsite technical assistance. These students had prior experience with an ongoing environmental study program known as the Wetlands in the Wild Project. Under the guidance of project director, Jo Gilbertson, the Indiana students guided the elementary students in the use of the water quality sensors and palm-held computers.

Few technology projects are successful unless a lot of other people want them to be and are willing to share their expertise. Additional members of the digital expedition included: Carl Myer, ALLTEL Corporation; Neil Cramer, PASCO Scientific; Kevin Kayle, aquatic biology supervisor at the Fairport Fish Station, ODNR Division of Wildlife; and, Jonathan Fuller, Lake Erie Geology Group, ODNR, Division of Geological Survey. Geneva State Park personnel included: Doug Burgett, Park Director; Rick Alderman, Park Ranger; and Dean Heisey, Marina Manager. Support and consultation regarding gifted education teaching models (group investigation and problem based learning), evaluation procedures, and construction of evaluation survey instruments was provided by Marianne Dove, Department of Teacher Education, Youngstown State University.

Boardman Local School District personnel that participated remotely from the six home school sites (Boardman Center Middle School, Glenwood Middle School, Market Street Elementary School, Robinwood Lane Elementary School, Stadium Drive Elementary School, West Boulevard Elementary School) included: Claar Barbour, David Brenner, Eva Convery, Jan Harvey, Mark Haverstock, Debbie Hinkle, Judy Lipkovich, Lee Messerini, Terry O'Halloran, Paula Ritter, Janet Sandy, Marilyn Scheetz, and Pam Tabak. Educators who served as onsite teachers were Bob Campbell, Pam Murray, and Michele Nespeca. Bob Wright, District Technology Coordinator, coordinated technical services at the six home schools and also provided technical assistance at the Lake Erie site. Librarians Cathy Santangelo and Judy Carson catalogued and housed reading materials and resources at the school system's libraries. Elaine Raffety, retired mathematics teacher, graciously permitted the expedition team to use her recreational vehicle as a home base for the expedition. In addition, thirteen Boardman parents served as chaperones for the expedition.

Purpose and Goals for the Our Lake Online Project

The purpose for designing the Lake Erie expedition centered on investigating the ecological vulnerability and sustainability of Lake Erie, the eleventh largest lake in the world. Although Lake Erie is the most biologically productive of the Great Lakes in the United States (e.g., the walleye fishery is considered the best in the world), discharge of municipal and industrial wastes by the early 1970's had severely polluted the water and threatened the ecosystem. Thus, an onsite/outdoor experiential learning opportunity such as Our Lake Online held promise to spark students awareness about their connection to this important natural resource and their understanding about environmental interdependence. The digital adventure to the lakeshore also held promise as the means to enable students to understand the power technology holds to study, analyze, and investigate present day ecological conditions of this vitally important natural resource.

Goals for our Lake Erie digital expedition included the following: (a) to develop learning activities that integrate best practices in gifted education and reflect science learning goals stated in the National Science Education Standards; (b) to integrate emerging technologies in the elementary curriculum to personalize learning; (c) to extend the public school's classroom walls electronically; (d) to design onsite/outdoor learning activities that spark children's intrinsic joy to learn; (e) to work collaboratively to facilitate children's learning opportunities; (f) to understand the power technology holds to study and communicate ecological concerns; (g) to learn and experiment together as a local and co-local community of learners.

Our Lake Online Project Learning Activities

In the initial planning stage, (September 1999), Joyce Zitkovich, expedition leader, contacted several agencies, and requested curricula and resource materials specific to the environmental study about Lake Erie. These materials were used for in-service sessions with teachers and were also used as research resources by the elementary students. Some of these materials were the *Great Lakes Atlas* from the United States Environmental Protection Agency and the Government of Canada, numerous materials compiled by the Ohio Sea Grant Program/Ohio State University, and *The State of Ohio - 1998 State of the Lake Report: Lake Erie Quality Index* prepared by the Ohio Lake Erie Commission. Librarians catalogued and housed these materials in the schools' libraries to ensure easy access for teachers and students.

In January 2000, all fourth, fifth, and sixth grade gifted learners began to read, study, and discuss the ecological state of the Great Lakes and specifically, Lake Erie. Students became aware of the major issues regarding the vulnerability of Lake Erie. Since Lake Erie is the warmest and shallowest of the Great Lakes, it is the most easily affected Great Lake in regards to pollution, endangered aquatic plant and animal life, and invader species. Viewing the film "Great Lakes Ecology: Unwelcome Visitors in America's Great Lakes" produced by Jim Danielson for Ohio Educational Telecommunications also served to establish a motive learning state with the children.

Based on these initial studies, the fifth and sixth grade academically gifted children selected independent study topics to research and develop reports and presentations. The children were given guidelines for these individual research projects that included student reading logs and completing all necessary steps of the research process (e.g., library research, Internet searches, note card compilation, research paper writing according to Modern Language Association [MLA] style, and bibliographic documentation). Regarding class presentations, students were required to deliver oral reports, and develop a visual aid related to their topic. The students were afforded the opportunity to select a visual medium of their choice. Student choices for visual aids included: PowerPoint presentations, art work, puppets, models, mobiles, photographic displays, posters, story boards, flip charts, and brochures.

Boardman Local Schools employs the strategy of curriculum compacting for academically gifted learners, therefore some of the children's instructional time was freed so that they could use the school library and computer labs for their individual investigations. Students also used the public libraries to obtain resources, and conducted Internet searches and visited established science URL sites from both school and home computers. Notably, six students engaged in telementoring experiences with science experts throughout Ohio. Email exchanges between the students and telementors were made on a weekly basis for approximately two months. Professionals who served as telementors were Jonathan Fuller, Lake Erie Geology Group, ODNR, Division of Geological Survey; Nancy Leonard and Geoffrey Steinhart, Aquatic Ecology Laboratory, The Ohio State University, Columbus, Ohio; and, Joseph Koonce, Department of Biology, Case Western Reserve University, Cleveland, Ohio. Some student research projects were entitled: "Round Gobies Invading Lake Erie," "Zebra Mussels," "The Spiny Water Flea," "Erosion Control Practices at Lake Erie," "The Effects of the Eurasian Watermilfoil and Purple Loosestrife Plants on Lake Erie," "Yellow Perch," "Identifying Rocks on the Shore of Lake Erie," "Sea Lamprey: An Invader Species," "Plankton," "Wetland Aquatic Creatures," and "Shoreline Pollution on Lake Erie." The academically gifted students made research presentations to classmates in the regular class rooms two weeks prior (early May 2000) to disembarking on the expedition to Lake Erie. The students also made formal presentations about their Lake Erie adventure to graduate students at Youngstown State University, Youngstown, Ohio in July 2000.

Fourth grade academically gifted students' learning tasks did not involve independent research projects. After assessing learner readiness, educators believed that directed study was most appropriate to engage fourth graders in mini lessons regarding topics such as microorganisms, aquatic life, water quality, shoreline erosion, and wetland plants and creatures. These mini lessons were taught by teachers of gifted educational services, and provided the necessary foundational learning these young children would need to successfully accomplish onsite tasks at Lake Erie. These fourth grade students, however, were required to make oral presentations about these mini lesson topics to classmates in the regular fourth grade classrooms two weeks prior (early May 2000) to the expedition to Lake Erie.

All fourth, fifth, and sixth grade gifted students completed two days of training (March 30th and April 7th, 2000) at the Mahoning County Joint Vocational School (MCJVS) to learn how to use several forms of technology prior to their Our Lake Online expedition (May 18, 2000). On the first workshop day, students learned several basic technology skills in the Visual Arts & Design Lab and Tech-Prep Computer Lab. For example, the elementary students learned about the operation and features of the digital camera and the use of photo editing computer software. To determine if students could apply these newly learned skills, they were asked to venture outdoors and take digital photographs of the natural setting, download these images to laptops, and send them as email attachments to their home schools. Thus, students practiced the procedures they would use the day of the onsite expedition. Vocational education teachers also shared design possibilities for students to use to compose web pages, storyboards and PowerPoint presentations to create dynamic records about their Lake Erie experience. The second workshop afforded students the opportunity to use microscopes, micro projectors, and Elmo visual presenters to magnify and project samples from pond water found at the MCJVS site. Once again, students were directed to apply these skills with the help and guidance of the vocational education teachers and twenty- nine MCJVS student assistants.

The Our Lake Online expedition was conducted on May 18, 2000. Students embarked for the expedition at 6:30 a.m. (1.5-hour bus ride, one way, to lake) and returned to Boardman schools by 5:30 p.m. Five workstations were set up on the Lake Erie shoreline so students could conduct group investigations about the natural environment. These work stations dealt with pollution, geology, wetland plants, microorganisms, and water quality. The educational technologies used to complete assignments were IBM and Mac laptop computers, palm-held computers, water quality sensors, digital cameras, microscopes, and a micro projector. Results of the students' onsite work and experiments were transmitted via digital connections back to classmates at their respective six home schools, thus enabling approximately four hundred and fifty students to participate remotely in the online adventure.

Evaluation

The recent literature on evaluation regarding technology implementation indicates that "effectiveness is not a function of the technology but rather of the learning environment and the capability to do things one could not do otherwise" (Jones, Valdez, Nowakowski, & Rasmussen, 1999). Certainly this onsite digital adventure provided learning opportunities that had previously not been possible for Boardman school children. The Our Lake Online expedition was the first-of-its kind in many respects. It was the first DEXpedition to be conducted on Lake Erie or any one of the Great Lakes in the United States. It was Boardman Local School District's first pioneering effort to discover and understand the potential of digital technology and Internet-based communications for expanding learning beyond the boundaries of the classroom. In addition, it was the first time students had used environmental analysis tools such as water quality sensors and palm-held computers; it was the first time students had used mobile digital technologies; and, it was the first time a collaborative effort of this magnitude had been implemented. According to these "firsts," the Our Lake Online expedition has been considered a highly successful undertaking.

Evidence of effective teaching and learning that occurred during the Our Lake Online project was also compared to criteria specified by Barbara Means of SRI International. This researcher identified variables that, when present, indicate engaged and effective learning. These variables include: (a) children are engaged in authentic and multidisciplinary tasks, (b) assessments are based on student performance of real tasks, (c) students participate in interactive modes of instruction, (d) students work collaboratively, (e) the teacher is a facilitator in learning, and (f) students learn through exploration (Jones, Valdez, Nowakowski, & Rasmussen, 1999). The Our Lake Online project participants were involved with collaborative online learning opportunities that concerned real-life tasks that valued learners' personal interests, and supported multidisciplinary learning. The data students collected serves as an ongoing baseline for study of the lake region by Boardman students as well as the WWW community. The Our Lake Online project is a prototype for other teachers of gifted services to use for onsite/online learning opportunities.

Evaluation data that involved triangulating students, parents, and educators' responses to survey instruments about the expedition also revealed a resounding endorsement for the digital learning adventure. Parent chaperones were delighted to watch the children "actually do science" and see "state-of-the-art technology" in use. Parents also indicated they enjoyed being part of a "leading edge experience" and acknowledged the "tremendous effort" undertaken by the expedition organizers and teachers. Educators were very pleased with the development of students abilities to use advanced technologies; engage in research projects; collaborate with fellow students; and, demonstrate problem solving, communication, and presentation skills. Perhaps most important were the responses from the student surveys that indicated overwhelmingly that they would like to participate on another expedition and that they greatly valued the opportunity to study and learn in an environmental setting.

Conclusions

Designing an Internet-enabled outdoor learning expedition that integrates mobile digital technologies and environmental analysis tools is a multifaceted task. The Our Lake Online project required months of planning and collaboration with countless individuals, corporations, organizations, universities, and state agencies. Our experience with the project has revealed that educators should embark on such a venture with the understanding that this is an emerging process. Therefore, it is realistic to expect that technology glitches and disruptions will occur. Although the Web environment is rapidly moving toward complete interconnectivity, we experienced a number of connectivity challenges. At times, it was impossible for the students to quickly and efficiently log on to the network. We also experienced difficulties due to hardware and software incompatibilities given our attempts to use both Macintosh and IBM platforms with young children. Also, given the budgetary constraints of public school systems, educators often do not own the hardware and software necessary to embark on mobile digital adventures. Simply stated, the Our Lake Online project would have been impossible without the digital equipment, environmental analysis tools, and technical assistance provided by ALLTEL, Pasco Scientific, and the Digital Exploration Society as well as grant monies awarded by the Martha Holden Jennings Foundation.

Indeed, the use of new technologies translates into trouble shooting at a moment's notice, being able to accept product failure, and coping with systems' incompatibility. Traditional teaching practices are also inadequate for such learning expeditions and onsite student learning requires a radical departure from students seated at classroom desks. Onsite learning requires student mobility and invites learners to be actively engaged and independent to investigate their interests at multiple workstations. The Our Lake Online project represents a significant pedagogical shift as compared with traditional science instruction, and definitely a step beyond using the Internet as a static tool. In the traditional classroom, the role of the teacher is one of transmitter of knowledge. The role of the teacher on a science digital expedition is one whereby the teacher is a guide and facilitates the students' ability to use technologies to learn and create their own dynamic learning records. It enables teachers to teach to the moment quite unlike teaching to a specified, sequential lesson plan. Although a digital learning expedition requires formulating a well thought out plan, there simply is no teacher's guide appropriate for such an adventure. In fact, the highly experimental and exploratory nature of the project embodies the learning philosophy on which it is based. Namely, a digital expedition is an attempt to encourage and enhance the natural tendencies in young children to explore, discover and share.

Today, the true power of digital exploration is connectivity. One day, it will be routine for students to explore, discover and share with others all over the planet in real time from anywhere. Although the Our Lake Online project is an account of just a single digital expedition, we hope that this description will encourage others to embark and experience the power and promise of using mobile digital communications for Internet-enabled outdoor learning adventures.

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Problem-solving-based Model of WBI

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Abstract: This paper describes a problem-solving-based model of web-based instruction. The model is based on the idea that the teacher can model a problem-solving process to help students to solve problems as an expert does. It was designed and embedded in a class web site that was designed for Heat and Mass Transfer, a engineering class. There are five parts in this model: answer(s) and relevant reading, your own tutor, hints and solutions, self-test your understanding, and report generation. Informal feedback from students showed positive results from using this model.

There are two broad categories of Web-based instruction. One is using the Web as a supplement to a normal class, while the other is using the Web as the sole instructional resource for the teaching. In the first category, a class web site is created to provide valuable information such as course, syllabus, assignments, grades, projects, and useful links (Rank, 2000). This kind of class web site provides students convenience in getting class information, checking their grades, interacting with the instructor and other students, and finding other information online. However, this approach may not help improve students' problem-solving skills very much. Another format of Web-based instruction focuses on improving students' problem-solving skills by integrating cooperative learning strategies with asynchronous communication technologies like listserv, newsgroup, bulletin board, and discussion groups. Currently, the first category of using the Web as a supplement is the most popular format. We explored how to make use of this supportive format to improve students' problem-solving skills when we implemented a class web site. In addition to maintaining the basic format of a class web site, we explored embedding a problem-based-model into the class web site to foster students' capability to build models and solve problems.

It is believed that modeling plays a very important role in the problem-solving process and is actually an essential part of the problem-solving process not only in science and math education but also in other disciplines (Starfield, Smith, & Bleloch, 1990). One way to solve a problem is to build a model and then refine it. To help students learn skills to build models and solve problems with a class web site, the problem-solving-based model was developed and embedded in the ME315 class web site. The idea is that the site acts as an expert tutor to guide students to build a model based on a specific problem, to get the answer(s), to use existing knowledge, to refine the model and explore further, and to reflect on the problem-solving process.

The model is composed of five components: answer(s) and relevant reading, your own tutor, hints and solutions, self-test your understanding, and report generation.

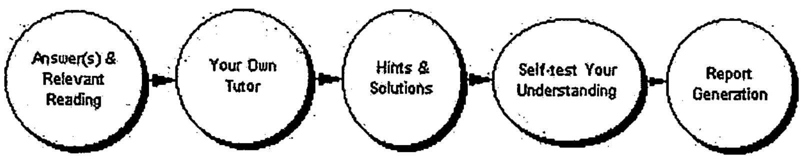

Figure 1. Diagram of problem-solving-based model

Answer(s) and Relevant Reading gives students the answer(s) and the information needed to solve the problem either from the textbook or/and other resources with the intention of helping the students locate and review the needed materials related to the problem. The purpose of providing relevant reading is to lay the foundation for the students to get the needed prior knowledge to solve the problem.

Your Own Tutor asks students questions to help them really understand the problem and acquire the needed information to solve the problem. In this part, very specific questions about equation(s) and variables, and how to interpret the relationship among variables in students' own words, were asked to ensure that students really understand them.

Hints and Solutions provides some clues to students for solving the problem and one or more ways of solving the problem. The first part provides some clues that could lead to a solution by the students themselves. If students still have problem(s), the second part provides a diagram model of the problem and one or two ways to solve the problem.

Self-test Your Understanding asks students about the solution (s), how to interpret the solution (s), what if the conditions change, if the solution is efficient or not, and finding the cause (s) if an error occurs.

Report Generation asks students to write a report for the whole process. This process lets students reflect on what they have learned from their problem-solving process.

This model is a variation of the ideal process of how to teach a novice to solve a problem as an expert does. Research shows that novices have a different problem-solving process from experts due to their different knowledge structure and ways of seeking additional information and better definition of the problem (McCowm, Driscoll, & Roop 1996). However, the teacher can model a general approach with the students, which includes identifying, defining, representing the problem, making assumptions, predicting solution(s), evaluating solutions, and reflecting on the problem-solving process to train them to solve problems as an expert does. That is the theoretical base for using this model.

The model was implemented and embedded in the HEAT AND MASS TRANSFER class web site, which is a class for mechanical engineering students, for a one-semester trial. During the trial, students tried one specially selected representative problem each week and twelve problems for the semester by using the class web site. Due to time limits, no formal evaluation was done to evaluate the impact of this model on students' learning. However, feedback from some of the students showed that this model has positive results. A student was even inspired to go to graduate school because one semester's learning made him feel that doing research was very interesting. More trials and formal evaluations need be conducted in the future.

Although this model was implemented with an engineering class, the author believes that it has very positive implication to Science and Math Education in K-12 and can provide a way to use regular web sites for improving students' problem-solving skills.

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Sustainable Environmental Education for Brasilian Teachers

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Abstract: Environmental Education (EE) is considered, in international declarations and in brasilian laws, as a dimension of the Education itself. One implication of this is that all teachers are involved in it. In Brazil the 9795 law, April 27 1999, determines that all teachers have to study EE, when they are in graduation or by inservice studies. In order to facilitate these studies for teachers from all the country, we began at Brasilia University an online course in EE. The methodology they learn at the course helps them to insert EE in their own school discipline, considering their own surrounding reality. The focus includes sustainability, and we call the methodology "Sustainable Environmental Education".

Introduction

The need for an increasing awareness on environmental problems is being emphasized in several forums and congresses especially since the early seventies. Indeed the decrease of human impacts upon the environment and the sustainability perspective depend, to a large extent, on the education of new generations that will take care of the local and global problems in the future.

At the First World Conference on Environmental Education (Tbilisi, 1977), Environmental Education (EE) was identified as a dimension given to Education contents and practices. This aspect of *dimension* was a new way to see the question. It was not a matter of introducing new isolated contents, such as pollution, contamination, water quality, solid waste disposal, bio-diversity, deforestation and reforestation, nature conservation and management of natural resources. In order to live in harmony with the environment, and to promote sustainable development, it is essential to create methods, techniques and new approaches to EE, as an important part of Education in general.

The solution of environmental problems also needs an interdisciplinar approach. So, EE needs to be inserted at all disciplines and to promote the active and responsible participation of the society. In this perspective, EE represents a way to see things, a new focus on reality.

Environmental Education in Brazil

One implication of this way of thinking EE is that all teachers must be involved in it. But in Brazil, only recently EE is reaching the schools. It is more given as isolated initiatives, by associations for nature protection or even public initiatives, in extra-curricular activities.

Statistics of 1999 (MEC/INEP/SEEC, 1999) show that Brazil has 36 million students at the first 8 years of school and 7 million from the 9th to the 11th series. It's a large population to receive EE.

Recently, Environmental Education National Policy was regulated by 9795 Brazilian law, April 27 1999. This law determines that:

- EE is an essential and permanent component of national education, and needs to be present, in articulated manner, in all levels and modalities of the educative process, in formal and informal types.
- The environmental dimension must be present in the curricula of teachers' formation, in all

levels and in all disciplines.

- Teachers in activity must receive complementary studies in their actuation areas, in order to adequately approach the principles and goals of the Environmental Education National Policy.

We have, in order to reach these goals, to offer inservice studies to a great deal of schoolteachers. Statistics from 1999 (MEC/INEP/SEEC, 1999) show that Brazil has over 2 million teachers in activity at Basic Education.

Inservice studies for teachers

How can teachers from all the country, however, take inservice studies? Thinking about that, we began at Brasilia University an online course in EE for teachers. The objective of this course is to enable teachers at any place in Brazil for the insertion of EE in his own school discipline (Faria 1997). Along the course teachers learn fundaments in EE and in pedagogic methodology, doing also practical exercises (Faria & Garcia 1997). At the end of the course, they have a study program (made by themselves) to apply with their students (Garcia 1997).

The focus of the EE given by us includes sustainability and sustainable development. The methodology is itself sustainable, because it is adaptable to all circumstances of the students and teachers. So, we call it *"Sustainable Environmental Education (SustEE)"*.

SustEE is a methodology, a way to give EE at school Education. It goes through the curriculum and does not suppose the study of any specific environmental question. On the other hand, it allows the treatment of any environmental problem or goal that is important to that community at that moment.

All teachers do their work in the course considering their own reality. So, they work with their students in context situations.

The online course involves a group of tutors, so every teacher that is our student can have a personal guide. He can make questions by e-mail and he sends, also by e-mail, all the personalized activities he has to do for his personal learning and evaluation. We have also a discussion list and some chats.

Our students can be from any part of the country. We have the opportunity, so, to change ideas with fellows that live in very different circumstances, and have to cope with many different environmental problems: from those characteristic to big cities as São Paulo to those existing in areas of recent (or maybe present) deforestation. In a new course version, we are introducing mechanisms of cooperative learning, with activities in which the students work together on a teaching program proposal. Afterwards, each of them works on his own proposal, considering his own circumstances.

SustEE methodology

An important aspect of SustEE methodology is the link that is made between EE and all contents of the official curricula. We will describe here the basic steps teachers do to apply it in school, after learning the SustEE in the course. Really, most of them do both things together and bring to discussion the results and the problems they have.

Step 1: Survey of the *necessities, interests and problems* (NIPs) of the community, particularly the students. This is done by the application of questionnaires to the students and their parents, interviews with school and /or local authorities, observation of the surrounding environment. At this moment we are interested in all NIPs they have, independently of an involvement of environmental questions.

Step 2: Determination of the region and the community profiles. To do that they consult region statistics and other data, verify local documents and so on. Here we are interested in social, economical, technological educational profiles. They see also the environmental policies for the region and the community initiatives and habits referring to the environment.

Step 3: Analysis of the official or school curriculum. At this point they study some principles of pedagogical sciences and apply them on the analysis of the school programs and of their own practices.

Step 4: General elaboration of *Integrated Learning Unities* (ILUs). To do that, they consider together what they have after the first 3 steps. ILUs congregate some of the disciplines – or preferably all them – over a same goal, which is related with a NIP, frequently a local environmental question. At this point we try to encourage the teacher to be creative, looking for themes that could be attractive for the students.

Step 5: Proposition of some interdisciplinar activities, to be made by the students, that could "nucleate" the ILUs. Those activities could be: a visit to some place, a search in Internet (if they have access to it), a laboratory experiment, a bibliographic investigation, prepare a theater presentation and so on. They can think about some independent activities or also plan a school project.

Step 6: Determination of specific links that can be made between the contents of the curriculum and the ILUs, on each one of the activities; selection of disciplinary contents, ethical and behavioral aspects that will be developed on each activity.

Step 7: Elaboration of a teaching program, in the discipline of the teacher that is having the course, covering all the contents he selected to that ILU. It is the moment to specify *Learning Generating Nucleus* (LGNs). A LGN is a nucleus that congregates contents of his own discipline and the collective goals of the interdisciplinar activities. Each LGN is expressed in a creative manner, trying to attract student's attention and interests.

EE at hotspots and other significant regions

Although everybody needs EE, some need it urgently. Brazil is a country of continental dimensions, and is widely recognized as the world's leader in terrestrial biological diversity, a significant portion of which is threatened today. (Mittermeier et al. 1999). We can focus on 5 very different biomas that deserves a citation here:

Atlantic forest is considered one of the most threatened ecosystems on World. It has been reduced to less than 8% of its original area. Even the name of the country, Brazil, is derived from "pau-brasil", a tree from this forest that began to be devastated in the early 1500, by the first portugueses that arrived at the country. 70% of Brazil's population resides in this region. In spite of it, this bioma still contains an extraordinary amount of biological diversity and levels of endemism. For example, it is estimated that 54% of the region's trees and 80% of its primates are not present at any other place on Earth.

Amazon is the largest remaining tropical rain forest, with 4,2 million square kilometer. It expands into 9 South American countries, but 62% of it are in Brazil. It has from 5 to 30 million living wild species, only 1,4 million already identified. Today it is the target of rapid economic development, with 16 million habitants already living in the region. Projects to improve conservation and sustainable development are very important to Amazon.

Caatinga is the prevalent ecosystem on the least populated and poorest region of the country. The long cycles of severe droughts periodically force local populations to either migrate to urban zones or temporarily exhaust the region natural resources. Understand their ecosystem characteristics and identify possible alternatives of economic development is very important for the communities there and EE has a central role on it.

Pantanal covers 140,000 square kilometers and are home to the largest concentration of wildlife in South America. Its wetlands are vital to the survival of countless migratory birds. There are very beautiful places there and tourism is increasing rapidly. It could be an excellent alternative for improving sustainable development of the region, if adequately accomplished. Otherwise, it can be very dangerous to the ecosystem if not controlled.

Cerrado is the ecosystem at the central region of the country. Agriculture, cutting for crops and cattle has destroyed much of the forest. Heavy pollution from nearby cities and from pesticides used in agriculture contributes to the degradation of forest ecosystems. It was recently included among the hotspots. One reason for that is its diversity of plants. Of the 10,000 species of plants, 44% are endemic, being not found anywhere else on Earth.

Except the Atlantic forest, most of these regions are distant to big cities and the more developed centers. In many cases the teachers working there haven't even the necessary formation in the discipline they inservice studies. Communication technologies, however, are reaching rapidly these places, by government and private initiatives.

So, online studies appear as an excellent alternative to these teachers. In fact, we have already in our course students that live in all of the mentioned ecosystems. Some of them acquired a computer and a phone line in order to do the course. They bring very interesting experiences to change with their colleagues and are already applying SustEE at the schools they work.

We know that capacitating teachers, we can multiply our effort to preserve our environment and to have a real sustainable development.

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Helping teachers and students use advanced technology in teaching high school science: A preliminary feasibility study of the use of a WWW-controlled atomic force microscope in high school science

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Abstract: This exploratory study investigated the use of an Internet controlled nanoManipulator and atomic force microscope to allow students to explore properties of viruses. The activity was embedded in a week long learning experience in which students interacted with scientists. The study demonstrated the technical feasibility of using such advanced equipment in classrooms. It also demonstrated that students gained in the understanding of the structure and functioning of viruses and changed their conception of scientists as people and science as an activity. A majority of the students were excited about the activity.

Science classes around the world have become involved in Internet-based investigations such as the JASON Project and Journey North (e.g. see http://njnie.dl.stevens-tech.edu/cyberteacher/realtimeprojects.html). These internet-based science programs engage students in using the technology for conducting and sharing science. The American Institute of Physics (1997), and Linn, Shear, Bell, and Slotta (1999) argue educational technology should: a.) focus on learning with technology; not about technology, b.) emphasize content and pedagogy, not just hardware, c.) provide accessible goals so students can connect new ideas with those they already have, d.) ensure the social context of learning supports the process of building on ideas of others, and e.) promote autonomy by creating learners who can move on into life with new skills and knowledge. In the present study, we investigated a new technological innovation called the nanoManipulator (nM) connected to an Atomic Force Microscope (AFM) . The nM allows students to investigate nanometer-sized materials through an Internet connection to an AFM located at a university. An unusual aspect of this technological tool is that students get tactile feedback about the nanometer-sized object they are studying.

When using the nM, students move a pen-like joystick that sends signals to the AFM. The AFM probe moves across a sample (such as a virus) and the deflection of the probe is used to provide tactile feedback through the nM. The feedback includes sensations of hardness, elasticity, friction, shape, and stickiness. The combination of physical manipulations and tactile feedback is known as haptic perception (involving kinesthetics and touch). The nM also uses 3D graphic technology to provide a visual 3D image of the sample. Haptic perception potentially provides the learner with information about viscosity, softness, texture, elasticity, graininess, pressure, temperature, and involves kinesthetics (muscle, tendon, joint). Klatzky, Lederman, and Reed (1987) noted that haptics is oriented towards the encoding of substance (microstructure). By providing haptic as well as visual feedback, the nM technology provides students with the opportunity to combine visual and verbal representations with haptic. In this exploratory study we sought to understand how students' use of the nM and AFM in collaboration with scientists influenced their knowledge of viruses, microscopy, nanometer scale, the processes and nature of science, science as a career, and perceptions of scientists.

Method

Participants

24 male and 26 female students in two introductory biology classes (n=22, n=28) in a rural-suburban high school in North Carolina participated. The school included 72% Euro-American, 24% African-American, 3% Hispanic students, and 1% other. In each class 6 males and 6 females were followed for qualitative research.

Instruments

Pre-Knowledge Test (PKT). The researcher developed PKT had four constructed response items to assess students' knowledge of viruses. Students were asked what viruses looked like, how viruses function, how viruses cause disease, to draw a virus, and to describe nanometer and name things measured in nanometers,.

Beliefs Questionnaire (BELQ). The BELQ assessed students' ideas about scientists and their reactions to science. It asked: *What do scientists do when they are doing science, describe scientists as people, and have you ever had a scientist come to your class.*

Pre Opinion Questionnaire (PROQ). Students rated, on a six point Likert scale, their reactions to working with a microscope and indicated their degree of belief about how scientists work and what they do.

Post-Knowledge Test (POKT). The 6-item POKT asked 6 students were asked to describe the nM and AFM, different types of microscopes, adenoviruses, to list things measured in nanometers, and to draw a virus.

Post Experience Questionnaire (EQ). The 5-item EQ asked students to describe how the instructional experiences influenced their feelings about science, additional experiments they would have performed with the AFM, what scientist do when they are doing scientific research, and any new impressions they had of scientists.

Post Opinion Questionnaire (POOQ). The POOQ contained the eight reaction items from the PROQ and two additional rating items. They asked students to rate how much they had learned and how much the instructional experience had changed their views.

Pre- and Post Interview Questionnaire. The pre and post interview questionnaire contained questions that guided intensive interviews with the subsample. The items asked about the AFM and nM, adenoviruses, how big viruses were, and their perceptions of the learning experiences. Items were used to initiate interactions with the students; interviewers probed their understandings more deeply than with written response assessments. Also, students were asked to constuct and explain a clay model of a virus.

Equipment

The students used a Phantom nM device connected to a desktop computer to access, over the Internet, an AFM . A second computer connected to the internet provided two-way video-audio access to the scientist running the AFM.

Procedure

Pretesting. 1.5 months before the instructional activity, participants received an explanatory letter and permission forms. Two weeks later, participants completed the PKT, BELQ, and PROQ. *Instructional Activity.* The instructional activities occupied 5 science class periods. At the beginning, students were told that they would write a newspaper article that would be published in a Web newspaper. An activity packet was provided which gave directions for each activities described below and suggestions their newpaper article. On the first day, a participating scientist lectured on metric scale, the AF microscopes and how the nM/AFM provided magnified images and tactile feedback. For the next three days, students (divided into teams of four or five) completed two activities per period with each activity lasting for 20-25 minutes. The activities were: use of nM/AFM, use of a simulation of the AFM, interview a scientist, and writing, (described below). *Nanomanipulator/atomic force microscope.* In this activity, each student used the nM/AFM guided by a physicist. Each student controlled the nM to touch a virus and use the nM to make individual investigations such as moving viruses or trying to break the protein coat of the virus. The students were encouraged to talk to scientist running the AFM while one of their team members was using the AFM. *Simulator Activity.* The Simulator activities consisted of a mechanical model of the AFM. The model could allow a tip to travel across a stage and over a sample. A tracing was produced on a sheet of paper. Students made a model of an icosahedral adenovirus from a cut out cardboard sample and used the Simulator to trace it. This activity help students the scale of cells and viruses. The students were told that if a human cell were magnified 300,000 times it would be about the size of their classroom and an adenovirus magnified 300,000 times would be about the size of their softball-sized model. The students completed tracings of their model adenovirus. The tracing activity demonstrates how the AFM images only the top of objects. The scientist in charge asked probing questions to help students understand the AFM. *Interview a scientist.* Students had 2 opportunities to interview scientists including physicists, information scientists, and computer scientists. The instructional packet had suggested questions, but encouraged the students to be creative and to their interest. This activity gave students an opportunity to learn about scientists in different contexts and to provide a image of scientists that contradicted popular stereotypes. *Writing Activity.* In the writing activity, students planned and began writing their newspaper story. Students were provided with a possible outline, but were encouraged to be creative in their story. Students were asked to give readers a description of what they personally found worth noting about the experiences. *Post-Test Activities.* On the fifth day, students completed the post-assessment instruments (POKT, EQ, and POOQ) and their newspaper stories. *Individual Interviews.* The first two authors interviewed students in the subsample individually two weeks before the instructional week. Each interview took about 15 minutes. Interviewers audiotaped and took field notes. Post interviews were conducted similarly to the pre-interviews in the week after instruction. *Analysis.* The knowledge test, opinion questionnaire, and interview questions were analyzed by item for pre- and post-assessments. Interview tapes were transcribed and pre- and post-instruction item responses were placed in a matrix for comparison. Frequencies of responses for each item on the knowledge tests, opinion questionnaires, and interviews were determined and for open-ended items student responses were grouped into categories (described below). Videotapes of the clay models were categorized. These categories included: *presence of: angles, 2-dimensions (2D), 3-dimensions (3D), irregular edges, bumps, appendages, 20-sided, spherical and angled, cell-like, phage-like, rounded icosohedral, ball-shaped, and amoeba-like.* Students' responses to the beliefs questionnaire about science and scientists were compared to students' responses related to the learning experiences on the experience questionnaire and the post-interview transcripts to examine how the investigations influenced their perceptions of scientists and science. The newspaper stories were read and reread across individuals and categories of analysis were identified by the major areas addressed in the stories. The categories that emerged and were subsequently coded included references to or descriptions of: *the research team, feeling or manipulating the virus, the shape or texture of the virus affective reactions to the experience and changes in students' ideas or opinions..*

Results

The knowledge tests, opinion questionnaires, and interview questions revealed changes in students' knowledge of viruses, microscopy, nanometer scale, understandings of the nature of science, knowledge of science as a career, and understandings of scientists. The qualitative analyses of students' drawings, responses, and clay models also found important pre- and post-differences.

Knowledge of viruses

On each of the knowledge test questions that were parallel from pretest to posttest, students improved significantly and substantially on the: structure of viruses question -- 0% correct to 60% correct; how viruses cause disease question -- 0% correct to 32% correct. Prior to instruction most of the students typically represented viruses as similar to cells, amoebas, or paramecia. The results of the clay model virus task showed that students' concepts of viruses moved from conceptions of bumpy, round, 2D images, to conceptions that were more typically 3D, angular, 20-sided, and spherical with angles (like the isocahedral paper models made during instruction. The clay models and the drawings showed an increase in the number of dimensions represented. After instruction, 35% of the students' drawings were 3D, no pre-instruction drawing was. After instruction, about 16% of the drawings included the bumpy surface features of the adenovirus. The changes form 2D to 3D conceptions of viruses were noted also on the written pre- and post-knowledge tests. We coded description as 2D or 3D (88% interrater reliability). A chi-square indicated a significant change from 2D to 3D language from pre-test to posttest [$\chi^2(1)=18.5$, $p<.01$, $N=41$]. On the pretest, students described viruses as "circles" or "curvy lines,"; on the posttest references such as "dice," "spaceship," or "robot."

Knowledge of Scale

Responses were scored as correct, partially correct, or incorrect. Chi^2 indicated a significant increase from incorrect to partially correct or correct descriptions from pretest to posttest. ($\chi^2(1) = 29.4$, $p< .01$, $N=43$).

Knowledge of Microscopy

Prior to instruction students typically named only the light microscope (70%); a few named the electron microscope (20%). After instruction 50% also named the AFM. Students' post descriptions went beyond the naming to include how the nM and AFM operate and the impact of tip size on images produced. Tammy, one of the students explained the use of the nM and the AFM in her story: "(T)he nM... is a little box with a pen attached to it. The box is attached to a computer. When we walked in, we saw a purple bumpy surface on the computer screen. You then touched the pen to the surface by looking at the computer. Rapidly you start to feel the pen jump and vibrate as it makes you feel as if you are touching the virus." Darren wrote: "The nM is pretty complicated to explain. There was a colorful image on a computer screen. The image looked like a globe with the actual elevations on it. It was a flat surface with different lumps. We used a hand-held pen to move a point on the screen around. When you moved the point over the lump, which is an actual virus, you could feel the surface of the virus..."

Knowledge of Scientists and Science Careers

Students were asked during the pre-interview if they had met a scientist. 82% said no. Students also were asked to describe a scientist. Their pre-responses reflected the typical stereotypes scientists, boring old white men. On the posttest, students were asked if the activities had given them new impressions of scientists. 63% said "yes." Many students who said no also noted that they already had high opinions of scientists and the activities reinforced their positive impressions. Students who indicated a change in perceptions described changes in their feelings about science, science careers, and characteristics of scientists. For example, Fred wrote "Yes, they aren't just old men that sit in a lab all day."

erspectives of their work as well as the scientists' lives outside their research. Nearly all the students commented on scientists' lives outside of work.

Students' Affect For Science

Eight students noted that they had more positive feelings about science as a result of the experiences. Responses included: *"It showed me that there was more to these jobs than old men in white lab coats doing boring experiments; they showed it can be fun."* Sixteen students commented that after the instructional experiences their understandings of the nature of science careers had changed. For example: *"They have a fun, hard job to do. They are not all that boring after all." "I never knew that science can vary in meanings. Like people consider computers to be science when it doesn't deal with science at all." "I enjoyed my experience learning about viruses. It opened my mind to a possible new career path as a scientist and gave me a new outlook on viruses."*

Students were asked on the pre- and post- questionnaires to describe what they thought scientists do when they are doing scientific research. Twelve of the students' responses showed a change from a pre-conception of scientists as searching for answers to a post-conception of scientific research as a more dynamic and flexible process of inquiry. A recurring theme that emerged from the interviews and written reports was new understanding of the collaborative nature of modern science research. The stereotype of the isolated scientist working alone shifted to a concept of teams of scientists working together as noted by these students.

In summary, the investigations with the nM and the AFM influenced students' conceptual understandings of the morphology and 3-dimensionality of viruses, microscale, microscopy. Students' beliefs about science, science careers, and scientists were also altered as a result of the experience.

This study was exploratory in nature and the results should be viewed in light of the limitations of the study. It isn't possible to separate the impact of the technology from the influence of working alongside the university scientists. It is also highly likely that the mere novelty of participating in this type of unusual instructional experience would alter students' motivation and interests. The writing task was a rich source of information for the research but was generally disliked by the students. As a result, some of the students' wrote little and did not elaborate on their ideas.

Discussion

Students' understandings of virus morphology and dimensionality changed as a result of learning experience. Students' mostly depicted viruses as having 2D before using instruction and as 3D after instruction. These results suggest that the use of haptics as a tool for learning about morphology of invisible materials may be of benefit. The nM technology adds physical manipulation and an element of "hands-on" exploration to the study of nanoscopic objects. This study showed that use of an Internet-based nM/AFM technology in classroom was technically feasible. Further research is needed to examine how manipulation of nanometer sized materials contributes to conceptual understandings and how to scale up this technology to make it more widely available. The rapid development of Internet-based high quality 3D graphics and virtual reality software opens up new worlds to science teachers. The potential for students to visually and physically explore microworlds is within our grasp. The challenge for researchers is to develop new ways to measure how these technological innovations influence students' learning. Students also made gains in their understanding of microscale as a result of participating in these investigations. Scale is a difficult topic for students to understand and yet is a major theme that cuts across science disciplines (AAAS 1993). As a result of using the simulator and the nM/AFM, students began to develop understandings of the limitations of trying to visualize in 3D an object that is laying flat on a surface. The use of the nM to move, roll, and probe the viruses appears to have made a difference in the dimensional concepts students held of viruses.

Interviewing and working with scientists on the nM/AFM appears to have changed students' understandings of scientists and their work. Students were particularly interested in the normal lives that the scientists held outside of their work. They were surprised that the scientists actually had families, pets, and did normal things like go dancing and play in sports. These interactions with the scientists made science as a career seem plausible.

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The Internet science education environment (ROL)

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Paper deals with the ROL (Remote and Open Laboratory) – a component of the open educational and informational electronic supportive environment for science education of a broad scale of target groups (from pupils and teachers to technicians). The ROL on the Internet contains different kinds of materials (experiments, models etc.) and tools for teaching and learning science via network. A brief description of the content and ways users can work with the ROL is given. Some examples starting from " sharing ROL environment via the Internet" to the Web delivery of online courses and learning environment are presented.

ROL – history and brief description

The Internet based "Remote and Open Laboratory" (ROL) - is a part of the Laboratory for Computer Aided Physics Instruction at the Department of Physics Education, Faculty of Mathematics and Physics, Charles University in Prague. At the beginning (1996) the ROL was mostly oriented to initial teacher training. Now, thanks to increasing number of schools connected to the Internet the laboratory serves more and more in-service teacher training and classroom applications.

The ROL is focused mainly on support of experimental activities in physics, biology and chemistry, gives teachers and students possibilities to get familiar with methods of data acquisition and data processing, offers large number of experiments and models for studying and better understanding of different phenomena and systems behaviour.

The aim and idea of the ROL

The Remote and Open Laboratory's main aim is to give:

- supportive environment for teaching and learning experimental and modelling skills and for getting familiar with useful modern tools and techniques for experimenting and modelling
- learning environment with a set of well structured online courses with tutoring and with large amount of slightly structured learning materials in open learning area, both mostly oriented to initial teacher training (laboratory works), but also relevant to in-service teacher training
- flexible, easy and powerful tools for communication and desirable co-operation among students, users, teachers, experts and developers (using the Internet to share laboratory working desk)

Content of ROL

1/ Information sources and databases

The Remote and Open Laboratory contains large databases of physics, chemistry and biology experiments (including downloadable data), computer models, descriptions and explanations of many phenomena.

Experiments with computer measuring systems

This largest part of the Remote and Open Laboratory consists of more than two hundred experiments for computer measuring systems complemented with downloadable data and multimedia descriptions of experiment set-up. This database can be viewed by keywords, titles and areas, enriched with fulltext searching.

Most of the experiments was developed originally for the measuring system ISES [1] and cover the following areas: acoustics - musical instruments sounds and their frequency analysis, mechanics, optics, electricity and magnetism, electronics - semiconductors, and so called "mismatch" - e.g. a human heart and blood-vessel system measurements, etc.

The user can use the database in following two ways: If his laboratory is equipped with the software and hardware supported by Remote and Open Laboratory, he can launch an application, carry out the experiment described and, for example, immediately compare the results of their experiment with the downloaded data.

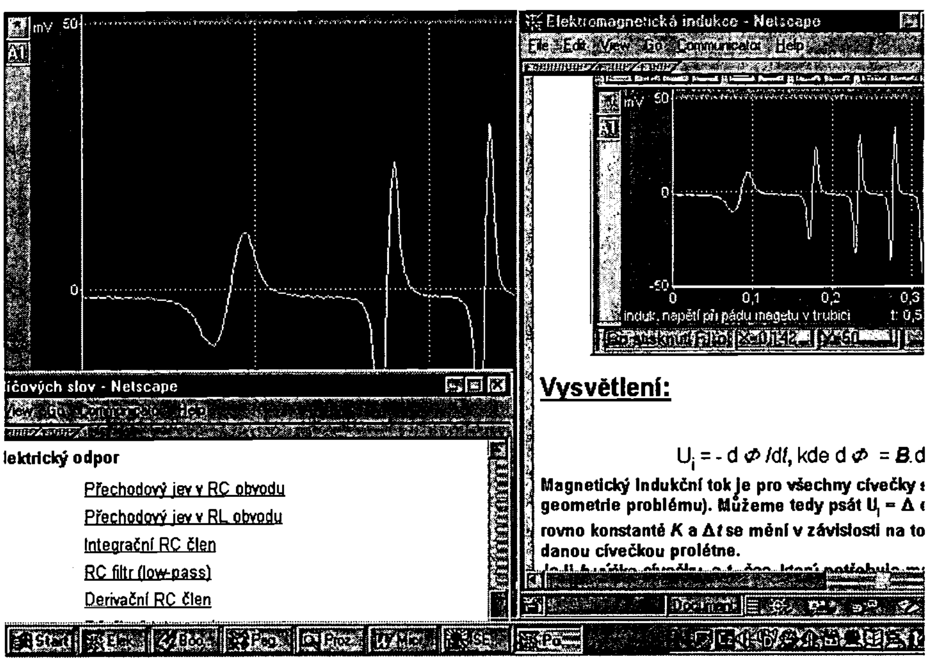


Figure 1: The database of computer aided experiments (left lower window), the description including images and downloadable data (right window), launched application (the background).

If the user's laboratory is not equipped with the measuring hardware, he can download data prepared for different kinds of application (e.g. ISES demo, spreadsheets like MS Excel, QuatroPro, etc) and work with the data in this environment.

Computer models

In the Remote and Open Laboratory a user can find sets of computer models and simulations, from the simplest to highly developed ones. These models are created in different modelling environments which allow users to choose and to reflect their modelling preferences, competence, skills or the tools they know.

The models and simulations were developed in different modelling systems - e.g. Interactive Physics [3], Famulus, IP Coach [4] and spreadsheets. Models are mostly ready to be used in schools by students or by teachers. Some of them are completed with commentaries, others are intended to be refined by teachers or students. Models are presented in many different ways and they are usually combined with questions to be answered. If users do not have the modelling system in which the model has been developed, they can use a spreadsheet or have a look at the model as a movie and continue studying the problem in a slightly different way.

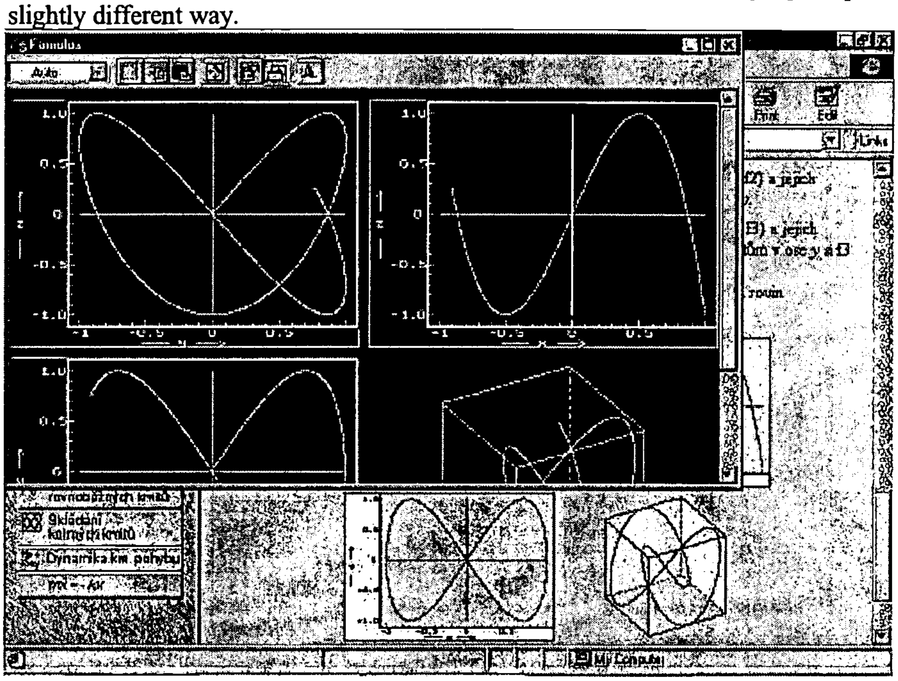


Figure 2: Living "3-D Lissajoux patterns" pop up as a running model from the WWW page specifically structured learning materials.

Experiments without computers

There a certain number of experiments in Remote and Open Laboratory which do not need any computer measuring system. These experiments are presented in form of hypermedia guides including video records, animations or series of pictures and schemes. Usually they are extended by questions and suggestions for further experimenting and complemented with brief remarks about how to perform and explain the experiment. This explanation is usually supplemented with useful data, additional knowledge and references.

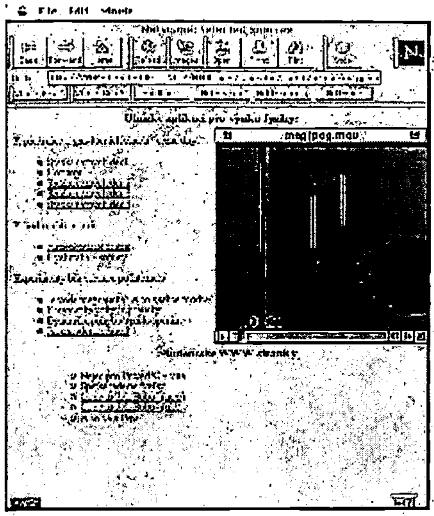


Figure 3: Web page with movie - recorded experiment on "Surprising magnetic behaviour of distilled water"

Technical and general information

The indispensable part of the ROL contains important information on computer measuring systems: technical details of hardware and software, recommendations, manuals, and guides.

2/ On line courses

The ROL offers different kinds of on-line courses mostly oriented to future teacher training and in service teacher training. These courses are offered as a part of combined courses [5] (together with face to face training) or delivered independently for different purposes (e.g. for "home preparation" of university students).

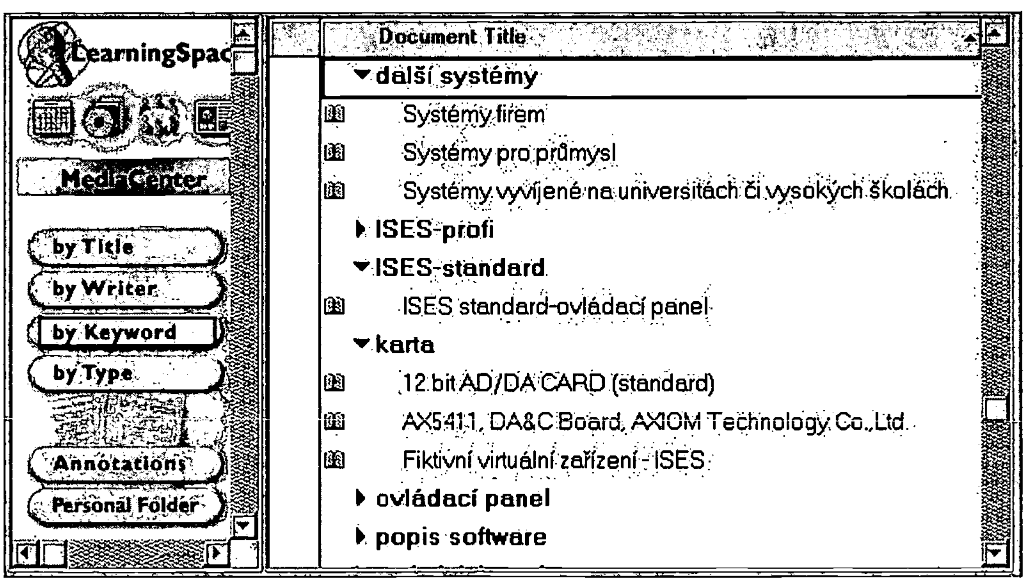


Figure 4: Part of course CAL (Computer aided laboratory) media room.

3/ Communication tools of the ROL

The ROL uses standard Internet communication tools for “off-line problem-sharing”: FTP, e-mail, Web forums, last both with attachments. We use the capabilities of videoconferencing tools, the Internet telephone , and chats for “on-line” consultations.

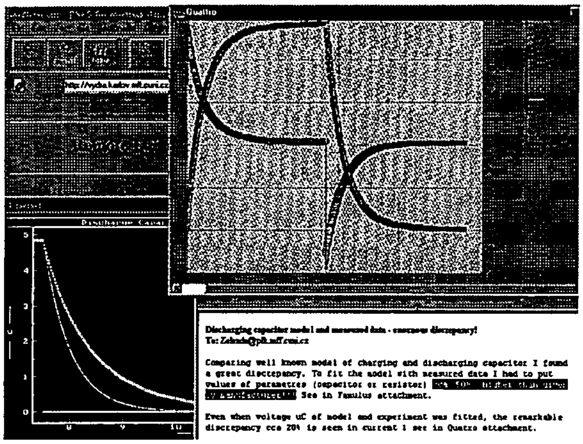
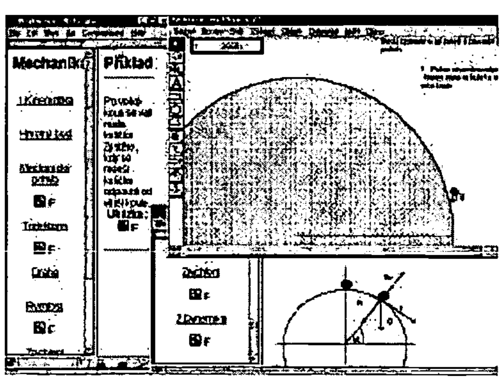


Figure 5: The user working with downloaded models “Charging and discharging capacitor - comparison of experimental data with models“ and performing the recommended experiment (using downloaded set-up of the experiment and different modelling environments Famulus, QuatroPro) found and emailed a severe problem. The ROL addressee can immediately rerun the whole problem situation –”shares the problem situation with the user: ”

The Remote and Open Laboratory in action

The Remote and Open Laboratory is able to become an open environment for learning , teaching and co-operation among users (students, teachers) and developers, providers (experts, students, teachers etc.). Simple examples of work in ROL learning environment follow.



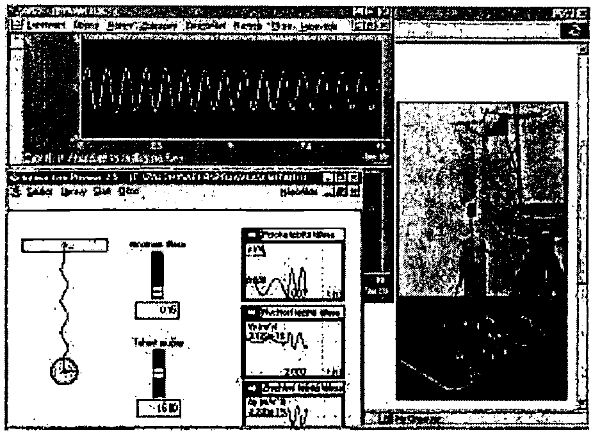


Figure 6: Example of the learning environment in the ROL (right frame – configuration and setup of the experiment, upper frame – experimental data obtained by system ISES, left lower frame – description and theoretical explanation, including simulations).

Figure 7: Example of learning environment in ROL (background window – content items and problems, lower right window- "a hint on the problem situation", upper right window – a simulation of the studied phenomena.

Users can change downloaded models and experiments, adapt them to different conditions or needs. They can also develop, verify and describe their own experiments or models and present them to other users in theRemote and Open Laboratory.

Users can simply ask authors and contributors the Remote and Open Laboratory for more information, send their comments or ideas via e-mail or other ROL communication channels.

Teachers can use their own modification of the ROL in the school LAN to distribute data or tasks to students via ROL environment. In the same way they can "open" school science labs to students, allowing them to learn science by exploring data, modelling, verifying hypotheses and looking for interpretations, whether the school labs are occupied or not.

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Meeting the Need for Technology Integration: Math, Science and Technology Integration for Pre-service Teachers

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Abstract
Historically, teacher education programs offered methods courses offered in isolation, neglecting the integrated manner in which many elementary classes are taught. This presentation focuses on the importance of curriculum integration in pre-service teacher education programs. The presenters explore the Math, Science and Technology (MST) integration block developed by the School of Teaching and Learning at the University of Florida for its Proteach II teacher education program with a focus on the technology integration course. The MST program goal is to develop the skills required by teachers to effectively create and implement an integrated curriculum.

Introduction
Historically, teacher education programs offered methods courses, such as science, math, reading, language arts, and social studies, taught in isolation. Although elementary educators often integrate subject matter, teacher-education programs have limited the inclusion of this skill in the coursework. Implemented in the fall of 2000, the School of Teaching and Learning at the University of Florida began the Math, Science and Technology (MST) Integration Block, providing pre-service teachers with opportunities to learn curriculum integration in a technologically connected environment.

Unable to conceptualize what curricular integration requires of teacher and student, pre-service teachers find it difficult to effectively integrate technology with multiple content areas. Carlson and Gooden (1999) state that "in order to become fully comfortable with use of educational technology, pre-service teachers need to actually see technology use modeled by their professors and their supervising teachers." This applies to all content areas. The MST block implements curriculum integration in a manner that allows pre-service teachers to benefit through both university learning and classroom activities. Specifically, the pre-service teachers are taught in the manner in which they are told to teach.

According to Carlson and Gooden (1999), technology mentoring is an essential component of pre-service development. Pre-service teachers also need better preparation in the use of technology (Carlson and Gooden, 1999), making them ready for what they will face in the 21st century classroom. By modeling effective and appropriate technology implementation, MST instructors offer students a vital component to the teacher education program.

The MST Block
Creating an integrated teacher education program offers many learning experiences for instructors and students. Bringing together departments that have taught independently elicits many challenges. How do instructors bring three separate courses together? How do you create a curriculum that focuses on the integration of the material yet accounts for the individual needs and requirements of the subjects? How do you maintain an integrated environment and still prepare your students to enter a classroom guided by standardized tests and isolated content? Answering these three questions is essential in creating a program

capable of providing pre-service teachers with the skills necessary to integrate content areas and technology.

Although the three courses are taught separately, content integration serves as the focal point for each class. In the integrated environment, students are provided with first-hand experience of how subjects can be integrated with technology serving as a tool to enhance the learning. Instructors teach about content and technology integration through unified lessons while maintaining the importance of the respective subject area material. Examples of lessons and experiences include trips to Camp Crystal Lake, an outdoor science education environment operated by the School Board of Alachua County. While visiting the camp, university students work with elementary school children as they complete water quality surveys , ecosystem investigations, and other camp activities. Math and technology are integrated throughout the traditional science curriculum. Activities include estimation, measurement, and calculation, followed up by entering the collected data into web-enabled database from wireless computers. Students and pre-service teachers take digital pictures as well as video tape of students participating in the lessons. The images and video are later combined into presentations.

The MST block provides an additional opportunity for student-teachers to experience curriculum integration in the elementary classroom setting. During the course of the semester, student-teachers are placed in elementary classrooms with the intention of observing integrated lessons involving math, science and technology. While in their field placements, the pre-service teachers observe how integration works (or in some cases does not work) and apply that to what they learn in the university classroom. These experiences are intended to extend the student-teachers' knowledge beyond the theoretical framework of the university setting.

During the course of the semester, the professors and graduate assistants met to evaluate and adjust the course material. In addition to these meetings, instructors (from math, science and technology) met to evaluate student projects. Although this proved time-consuming and difficult to schedule, the thorough feedback the instructors provided offered the students an opportunity for tremendous growth. While the feedback focused on the integration aspect of the assignments, comments specific to subject content reinforced the importance of maintaining the specific content of each subject. Although the student-teachers initially missed the value of the collaborative assessment, they understood its importance by the end to the semester.

Conclusion

Three times during the semester, students in the MST block had the opportunity to write reflective journals about their experiences. The first journals written by the students could best be characterized as tentative and uncertain about how they would benefit from the technology portion of the MST block. Students expressed concerns ranging from being unsure about their technical skills to being incapable of learning the technical skills necessary to integrate technology and teach students whose technical skills may likely exceed that of the teacher. By the end of the semester, students' attitudes changed dramatically. In their final journal entry, most students expressed surprise and satisfaction with how far they had come. Many students stated that they were looking forward to entering the classroom and providing meaningful learning for their students.

As today's pre-service teachers are prepared to teach in 21st century schools, education programs must ensure that pre-service teachers are able to meet the educational objectives while avoiding the lack of technological expertise that is the "norm" in today's teacher (Carlson & Gooden, 1999). If future teachers are to be qualified to present a technologically integrated curriculum that meets the ever changing demands of a standardized world, they must be trained through modeling and experience. The Math, Science and Technology block is determined to provide those necessary skills modeled in manner that allows the pre-service teacher to see its effectiveness. In its first semester, the MST block has taken huge strides in improving the way in which methods courses are taught. Although only time will tell how effective it will be, the MST block is on track to impact many pre-service teachers, making them ready for the 21st century classroom.

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Aiming a Better Understanding in Science Courses through Mathematical Reasoning

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Abstract: In this article we present a project which has the purpose of using mathematical based explanations to support the teaching of the sciences (chemistry, biology and physics) at the secondary level in Mexico. The article describes the structure of the worksheets developed and the pedagogical model followed within the classroom to ensure an efficient use of the activities. Spreadsheet models to be explored by the students accompany many of the worksheets. We will also show some of these spreadsheet models designed for this educational project.

Introduction

We can predict natural phenomena because it follows some ordered behavior. Behind this order, we find a few principles that can be formulated mathematically. A deeper understanding of science requires the use of these principles as mental tools. For example, diffusion can be better explained and understood using Fick's law about the net flux of particles being proportional to concentration gradient.

Thus, this project is based on the idea that the students can achieve a better understanding of some scientific phenomena if they are imbedded in proper mathematical formulations that will give them a more precise structure and the possibility of quantification.

In some countries like in UK, mathematical modeling is used as a strategy to teach math and science. In this didactical approach, we are interested in the construction of the math model as a tool to learn the surrounding mathematical and scientific topics.

The Ministry of Education of Mexico has being sponsoring, since 1997, a national program to teach mathematics and physics with technologies at the secondary level. Parallel to this educational project, there is an ongoing research project that has as its main purpose to investigate the impact of this technological implementation in students' learning, teaching practices and curricular transformation.

The project presented here was born as an extension to the previous project to cover the subjects of chemistry, biology and physics, but with the difference of stressing the math modeling approach and de-emphasizing the technological aspect. In this paper we will describe the materials that were designed for this educational project.

In each of the science courses, chemistry, biology and physics, we developed around 60 worksheets on different topics. About half of them can be used in the science classroom directly since they do not require any computational tool. The other half, guide the students to explore mathematical models constructed on spreadsheets. We will talk about both of these types in the following sections.

The activities developed for this project have the aim of complementing the normal presentation of subjects done by the science teachers in their classrooms. Although they have a mathematical content, the purpose of these activities is to learn scientific concepts and ideas and not math (although the students also learn math as an extra benefit).

In addition to the activities proposed to the science teachers, there are also computational tools to support them in expanding these mathematically oriented activities. For example, Figure 1 shows a prepared spreadsheet where the students can introduce any data very readily to obtain the corresponding graphs.

There are more graphing tools, like a pie chart graphing spreadsheet or a spreadsheet drawing automatically the least square approximation line to some given data.

Worksheets Requiring only Paper and Pencil

Within the classroom, we have used very effectively a teaching strategy that in part consists of coupling a math modeling approach with worksheet guidance.

An antecedent of this method is a collaborative Mexico/UK research project (Sutherland et al. 1996) aimed at investigating the role of modeling with spreadsheets across a range of subject areas (physics, chemistry, and biology). In this early research, the spreadsheet was introduced into the students' science classrooms to construct models, called by Mellar (et al. 1994) "artificial worlds". This activity helped the students to understand the scientific concepts behind the model.

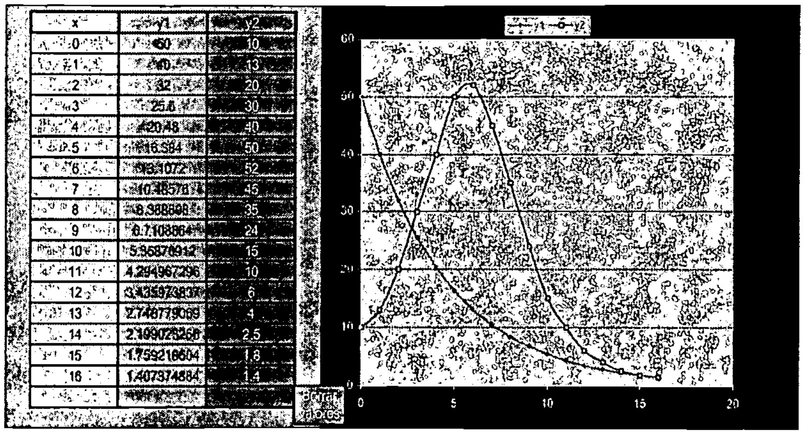


Figure 1: A graphing tool within a spreadsheet

In this new project presented here, we were not interested in the students constructing models but on the advantages of exploring and analyzing some aspects of a mathematical model to enhanced students' understanding of the scientific ideas related to the model.

For the design of the worksheets, we defined a structure that turns out to be very useful. In the next lines we give the sequence followed:

i. Posing a real situation as background.
ii. Asking some intuitive questions for the student to reflect on the problem.
iii. Analyzing the situation through questions and feedback.
iv. Expand on the analysis, giving questions about results, challenges and open questions.
v. Discussion and conclusions (it is important for the students to summarize their conclusions).
vi. Extra work (for fast thinking students).

The worksheets start with very directed tasks and progressively leaves the student with more freedom to try his own ideas.

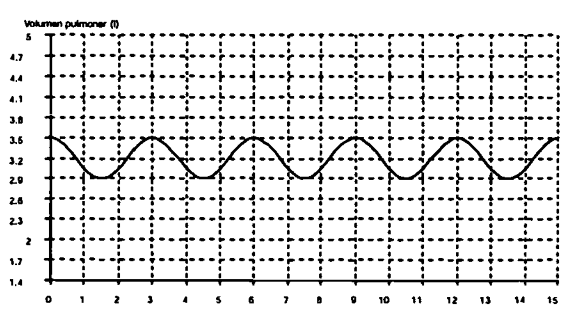
The worksheets designed fall into two different categories. About half of them described a scientific situation using mathematical ideas but no computational tools were needed. The other half were based on mathematical models constructed on spreadsheets. In the first type then some aspect of a mathematical model was analyzed through the use of graphs or tables. In the second type, the students explore the spreadsheet model.

To illustrate the previous points, the following is a worksheet of the biology series of the first type:

The breathing cycle.

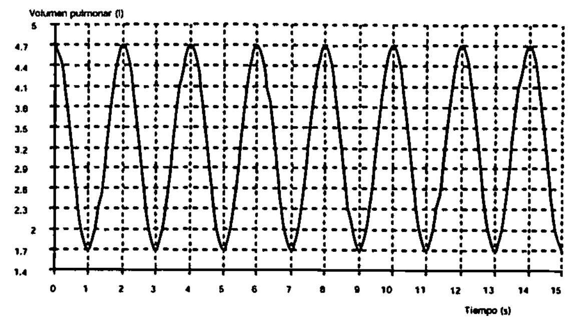
Observe the graph of the variation with time of the lungs' volume of a person (in liters) during rest. Note how the graph repetitively goes up and down. Explain why: _____ * *Show in the graph the intervals where the person is breathing in and breathing out.*

Which is the maximum volume reached by the lungs? _____ Which is the minimum volume reached? _____ Do they empty



* The actual lines in the worksheets are bigger so the students have enough space to answer. Here we reduce them for lack of space.

out completely? _____ How much air comes in and out during each breath? _____
Now observe the time axis to answer: How many seconds lasts each breath? _____
Note in the graph that there are 5 complete breaths in 15 seconds. According to this, how much time does a single breath lasts? _____ (Compare this answer with your previous one). How many breaths will this person take in a minute? _____
We obtained above that this person inhales 0.6 liters of air in each respiration and that he takes 20 breaths per minute. How many liters of air does the person inhale per minute? _____ The air contains 20% oxygen. How many liters of oxygen does the person introduce to his body per minute? ________ The air coming out of the lungs contains only 15% oxygen. How many liters of oxygen does the person take out of his body per minute? _____ How much oxygen does his body use per minute? ________ (this is 36 liters per hour).
Observe now the graph of the variation with time of the lungs' volume (in liters) of a person right after exercise. Show on the graph the intervals where the person is breathing in and breathing out.
What is the maximum volume reached by the lungs? _____ What is the minimum volume reached? _____ Do they empty out completely? _____ How much air comes in and out during each breath? _____ How many seconds does each breath last? _____



Note on the graph that there are 5 complete breaths in 10 seconds. According to this, how much time does a single breath last? _____ (Compare this answer with your previous one). How many breaths does this person take in a minute? _____
In this more intense respiration, the person inhales 3 liters of air in each breath and he takes 30 breaths per minute. How many liters of air does the person inhale per minute? _____ The air contains 20% oxygen. How many liters of oxygen does the person introduce to his body per minute? ________ The air coming out of the lungs contains only 15% oxygen. How many liters of oxygen does the person take out of his body per minute? _____ How much oxygen does his body use per minute? ________ (this is 90 liters per hour).
Compare the values obtained for the person at rest with the ones after exercise. Write down and explain the differences and draw some conclusions from these findings.

Worksheets to Guide Exploring Math Models in Spreadsheets

As we mentioned before, about half of the worksheets were designed to guide the students to work with prepared spreadsheets. Some of them have data about a specific topic or facilitated calculations. Others contained mathematical models for the students to explore.
In this section we will show some of the spreadsheet models with controls that were designed to support this project (we can only show here a static version of the screens. The dynamic power of these spreadsheets will be shown during the conference).
Some of the spreadsheets have the purpose of facilitating calculations, making it easier for the student to concentrate on the scientific content. For example, in the first two columns of a spreadsheet (not shown here), the student introduces the symbols and the number of atoms of the elements in a given formula. The program returns the molecular weight of the compound and the percentage participation of each element. Also using this spreadsheet, the students discover formulas if the percentages of the elements are given.
Figure 2 shows a simulation of the process of electrolysis (for the chemistry course). As the level of water is reduced, the amounts of hydrogen and oxygen increase accordingly. The students can take data and learn the relationships of mass and volume of these three substances (the control makes the effect of a dynamic process). Other spreadsheets for chemistry have reaction models, distribution of electrons in orbits for each element, etcetera.

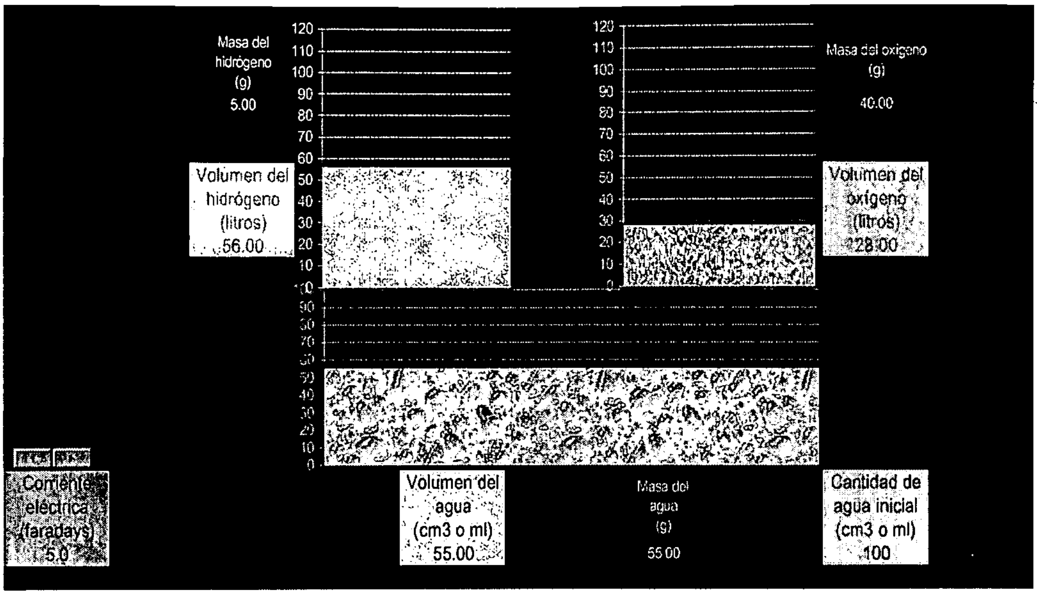


Figure 2: Spreadsheet modeling the process of electrolysis

Figure 3 shows a spreadsheet containing a simulation of diffusion in two dimensions (for the biology course). In it, we can start with any quantity of particles in each of the 100 cells and by pressing the F9 key repeatedly, we can observe the particles diffusing through the cells. On the left side of the screen, the diffusive constants in each of the four directions can be changed.

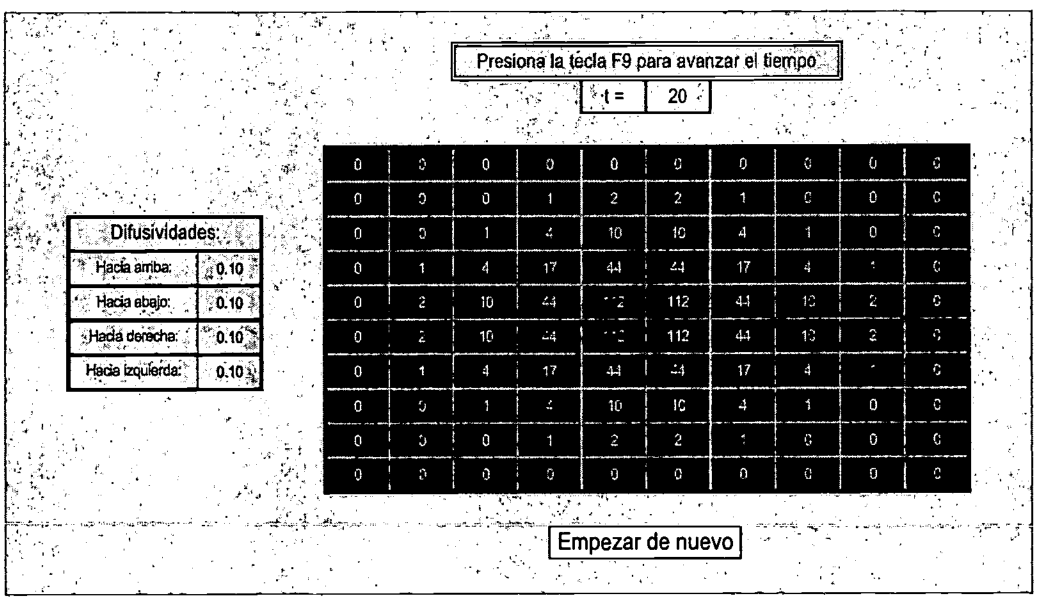


Figure 3: Spreadsheet modeling two-dimensional diffusion

Figure 4 shows a spreadsheet containing a mathematical model of two competing species (for the biology course). Each specie has a number of parameters that can be change through controls. The dynamic movement of the graphs allows the students to visualize the effect produced.

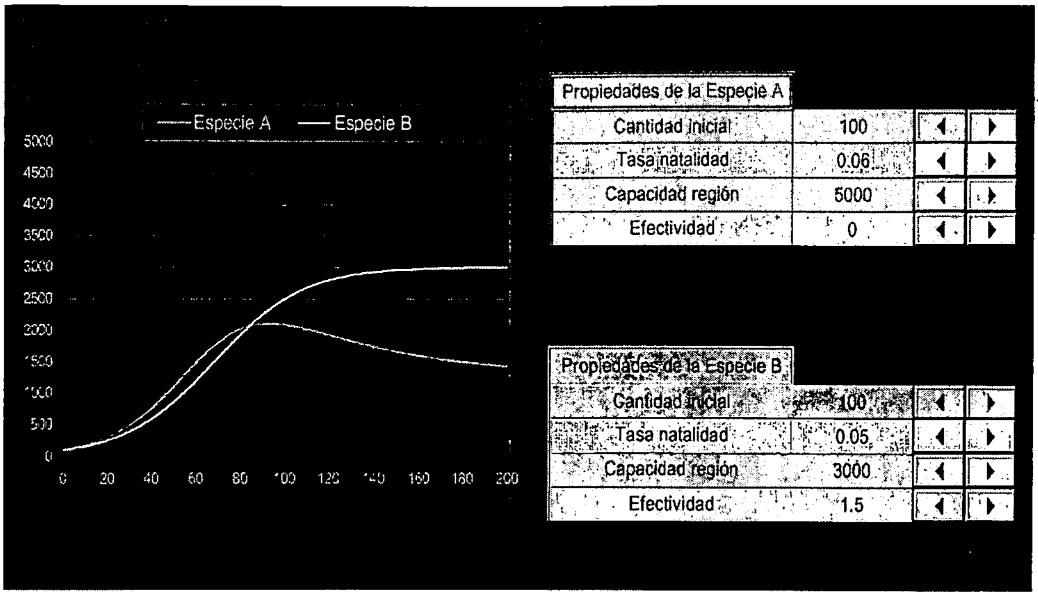


Figure 4: Spreadsheet modeling two competing species

Other spreadsheets for biology model populations in different ways, genetics, epidemics, nutritional data, etcetera.

Figure 7 shows a spreadsheet containing a simulation of radioactivity (for the physics course). Pressing the F9 key repeatedly, we can observe the atoms being disintegrated. The half-life of the material can be chosen and data can be obtained as a function of time.

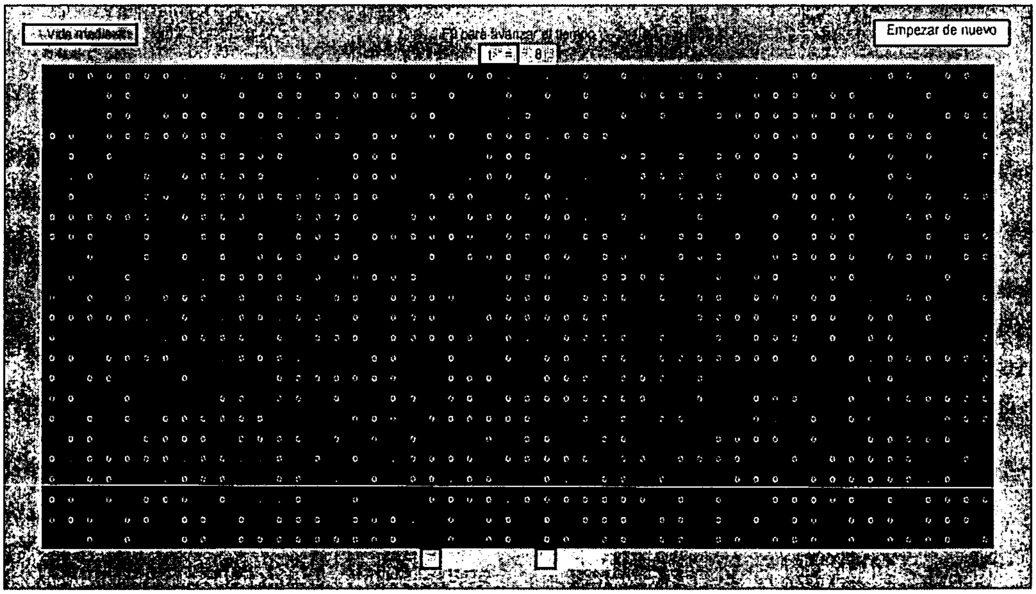


Figure 7: Spreadsheet modeling radioactivity

Other spreadsheets for physics model heat conduction, free fall or with air resistance, circuits, etcetera.

Pedagogical Model

The pedagogical model for this project was described in a previous article (Mochon 2000). Here we will mention only its main components:

- ✓ The work of the students is directed through worksheets to "discover" important ideas in the sciences.
- ✓ The students become the most important elements in the classroom, through active participation and reflection.
- ✓ Communication is crucial in the learning process of the student. Thus, the work is done in groups.
- ✓ The teacher in the classroom has the role of guiding the students to discovery and orchestrating the discussions.

As can be seen, the design of the worksheets is as important as how they are used. Our previous experience shows that the teacher is a very important component in this model. He should encourage the discussion between the students during and after the activity is done.

Conclusions

We have seen once again that the use of controls in spreadsheets has great potential to support the teaching in science, where mathematical models with dynamic graphs can give a visual image of the situation involved.
Although this has to be confirmed further by the classroom results, there is already data supporting the idea that an approach of quantifying the sciences through models, tables and graphs can be useful to improve the understanding of the concepts and ideas.
Finally we should stress that computational tools where the students act independently have a lower chance of success than those supported by worksheets that guide the students through the "right path" to discover relevant ideas. Also, an appropriate pedagogical model is needed.

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Revolution in Hand: Handheld Computers in the Science Classroom

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Abstract: Hand held devices, such as Palm Pilots, have the potential to revolutionize the science classroom. These small, inexpensive devices make it possible for science teachers to grade students' laboratory and group projects in real time. A team of science teachers and university educators will discuss what they have learned about these devices and their effectiveness as tool for learning and instruction.

Introduction

A Personal Digital Assistant (PDA) or handheld computer is a small hand held computer with built in applications such as word processing, spreadsheet, personal organizers, and calculators. Grade book and disciplinary programs expand the usefulness of the devices for busy educators. With a shift from teacher-centered to student-centered classroom environments, PDAs may play an important role in enhancing teaching and learning experiences.

Literature Review

While research on PDAs is in its infancy, it is useful to examine the literature relating to the use of laptops and PDAs in schools, as they relate to portability and ease of use. Of particular interest is the documented shift from teacher-centered to student-centered classroom environments in laptop schools (Stevenson, 1998; Rockman, 1998). Increases in both cooperative learning and project-based instruction were documented by Rockman (1998).

Pownell and Butler (2000) identified ways that PDAs can benefit educators. Pownell and Butler argued that PDAs are only effective when they support how teachers work and use information in their classrooms. Their web site, ***The Online Educator's Palm Web Site***, identifies four differences between PDA/handheld computers and desktop computers. One difference relates to portability and size. While laptops are smaller and more portable than stationary computers, PDAs are small enough to be carried in a pocket or a student's backpack. Like laptops, PDAs offer teachers and students portability (Bell, et al, no date; Byers, 1991; Concord Consortium, 2000) and on-the-fly note taking. They are also useful as field journals or in traditional lab settings (Berlanger, May 2000; Cooke, no date; Trotter, October 27, 1999). Accessibility is another area of comparison between laptops and PDAs. Handheld devices are considerably cheaper to purchase and to operate than laptops (Belanger, May 2000). Trotter (October 27, 1999) calls them "equity computers" because of their low cost and ease of use. A third category of comparison is mobility. Teachers are not restricted to a stationary computer and can access and retrieve information anywhere, anytime, including in the field or on fieldtrips to museums or historic places (His & Manus, no date). The fourth area of comparison relates to the adaptability of PDAs. PDAs can change the way educators use technology and the way they access information, particularly information on the Internet. (Pownell & Butler, 2000).

While research on the effectiveness of PDAs in educational settings is sparse, relatively few K-12 schools have had PDAs in place long enough to generate longitudinal studies of their instructional impact. Several groups are actively researching PDAs' classroom effectiveness. Among these groups is the Multimedia Portables for Teacher's Pilot in the United Kingdom. This project put 1,138 high-specification portable computers in the hands of practicing teachers in a range of schools. The program reported high levels of motivation and self-reliance (Fisher, 1999). The program concluded that the PDAs were flexible and adaptable and successful in providing a context for teacher professionalism to flourish (Fisher, 1999).

The Kentucky Migrant Technology Project, a division of the Ohio Valley Educational Cooperative, piloted a PDA program at Eminence Independent Schools in Eminence, Kentucky in 1999. One teacher and a group of eighth graders participated in the program. Preliminary findings included less teacher time spent photocopying tests and other papers and more efficient instructional time. Not only did the teacher use the PDA to beam tests and electronic texts to students' PDAs, but also the students used the devices as journals and as personal organizers. The PDAs' spreadsheet programs and the device calculators were used as well. Conclusions from the first year suggest PDAs are effective tools in the hands of teachers (Lifestyle Passport, 2000). The project is also piloting an online course using the devices, with course materials available for online download. Once downloaded to the desktop computer, the course can be beamed to an instructor's and the students' PDAs.

Other research efforts using PDAs are underway. The National Classroom Project (NCP) at the University of Mississippi (Cooke, no date) supports the use of PDAs as portable labs. One objective of the project is to test whether classroom sets of PDAs can be effective when wheeled from classroom to classroom. NCP literature suggests that PDAs will assist teachers in measuring student progress even as it allows them to conduct individualized re-mediation. Another group examining the effectiveness of the PDA in an educational setting is the Concord Consortium. Research conducted with second and fifth grades found that while both groups were comfortable with the technology, older students used the devices more effectively (Staudt, October 1999). Both groups "easily moved between note taking and data collection" (p. 1). The devices gave students "opportunities to connect questions and investigations to the data a real time setting that enhances "systematic investigations, critical thinking and cooperation" (Staudt, October 1999, p. 1). Additional research suggests that PDAs facilitate group work, the immediate analysis of data particularly during laboratory exercises or when conducting scientific investigations in the field rather than in the classroom (Belanger, May 2000).

Overview of the Study

The main objective of this study was to determine the feasibility of implementing the personal handheld devices for instructional use in the middle school science classroom. Three science teachers in a local middle school participated in the pilot program. They were selected for participation based on how they envisioned using the devices in their classrooms. The researcher used an interest inventory that allowed teachers to explain their vision of how the PDAs would assist their instructional purposes. Teaching experience varied from less than one year to 19 years. Technological comfort levels, as self-report on the pre-survey, ranged from a lack of comfort to very comfortable.

Discussion

Like laptops, PDAs may not be for every teacher. The ability to write lesson plans to incorporate the PDA may be beyond those teachers who continue to struggle with the integration of desktops and laptops into their classrooms. Yet without this integration, PDAs continue to function effectively as personal organizers. Indeed, it was popular with teachers who did not like using other forms of technology in their classrooms. Even with the reduced costs of PDAs, costs for many school districts will remain an issue. The cost of purchasing the devices, software, and providing adequate training may deter districts from these devices. However, what is certain is that these devices have a lower start up and maintenance costs when compared to laptops and desktop computers. It remains to be seen what additional research will reveal about the long-term impact of PDAs on effective teaching.

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Mining for Problem-solving Styles in a Virtual World

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Abstract: The Geology Explorer provides a multi-modal virtual environment that implements an educational game for teaching principles of geology. The game is a networked, multi-player, simulation-based, educational environment that illustrates our role-based pedagogical approach. This takes the form of a synthetic, virtual world (Planet Oit) where students are given an authentic experience and the means and equipment to explore a planet as a geologist would. Each student's experience includes elements of exploration of a spatially-oriented, virtual, world; practical, field oriented, expedition planning and decision making; and scientific problem solving (i.e. a "hands on" approach to the scientific method). Students assume a role and learn about real science by exploring in a goal-directed way and by competing with themselves and with other players.

In this paper, data are reported from a 1999 study, in which students enrolled in a freshman-level Physical Geology course explored the planet for credit. These data were collected in two forms: 1) a survey of student perceptions, positive and negative; and 2) a data mining analysis of student histories which reveals apparent categories of student problem-solving style. Planet Oit can be visited at http://oit.cs.ndsu.nodak.edu/

Introduction

The Geology Explorer (Saini-Eidukat, Schwert & Slator 1999; Schwert, Slator & Saini-Eidukat 1999) is a virtual world where learners assume the role of geologists on an expedition to explore a mythical planet: Planet Oit, which is designed to replicate the physical environments of Earth (and in the same orbit, but directly opposite the Sun). Learners participate in field-oriented expedition planning, sample collection, and "hands on" scientific problem solving.

To play the game, students are transported to the planet's surface and acquire a standard set of field instruments. They are issued an electronic logbook to record their findings and, most importantly, are assigned a sequence of exploratory goals. The students make their field observations, conduct small experiments, take note of the environment, and generally act like geologists as they work towards their goal. A scoring system has been developed, so that students can compete with each other and with themselves.

The Geology Explorer is being developed as a synthetic environment using the freely available Xerox PARC LambdaMOO (Curtis 1997; Bruckman, 1997), which is an environment for creating text-based virtual worlds, to simulate a portion of Planet Oit. Students armed with tools and instruments created as LambdaMOO objects land on the planet to undertake an exploration exercise. They are given an authentic geologic goal, e.g., to locate and report the position of potentially valuable mineral deposits. Accomplishing each of these goals entails mastering several geologic concepts and procedures, and demonstrates student mastery of the material. The first module involves mineral exploration, where students are expected to plan an expedition, locate mineral deposits, and survive the somewhat hostile virtual environment in order to report on it (future modules on hydrology, metamorphic facies, etc. are underway). The first version of the Geology Explorer is text-based; (Slator, Schwert, & Saini-Eidukat 1999); a graphical interface was launched in Fall, 2000.

Planet Oit is designed to emulate the geologic features and processes of Earth. The first version is based on a realistic planetary design, consisting of a single, super-continent composed of roughly 50 locations (Figure 1), arranged so as to be both diverse and coherent. A variety of Earth-like environments, ranging from tropical coastlines to volcanic calderas to glaciated peaks, allows for multiple geologic terrains to be explored. A museum of rocks and minerals is available at the landing site for use as a standard reference collection. Coordination of navigation on the planet is made possible by using directions relative to Earth-like geographic poles (North, South, etc.).

Implemented, as well, are almost 40 scientific instruments and geologic tools (streak plate, acid bottle, magnet, etc.), nearly 100 different rocks and minerals, and over 200 boulders, veins, and outcrops. In the text-based version, students use a command language, which allows for navigation, communication, and scientific investigation while on the planet. Command verbs dictate the student's application of instruments ("streak," "scratch," "hit," etc.) and senses ("view," "taste," "touch," etc.). Students can communicate, and therefore work, with one another through verbal commands. An on-line "user card" listing all these commands and functions is available at: http://oit.cs.ndsu.nodak.edu/oit/usercard.html.

Once the layout and artifacts of Planet Oit were implemented, the rules of the game were imposed over top. After being transported to the planet's surface, students are automatically assigned an initial exploratory goal and can acquire whatever equipment they wish. The goals are intended to motivate the students into viewing their surroundings with a critical eye, as a geologist would. Goals are assigned from a principled set, so as to leverage the role-based elements of the game by gradually leading students to more difficult and interesting goals.

In order for a student to achieve a goal (and therefore earn points), they must address a multitude of tasks identical to those faced daily by field geologists. These include the selection and use of proper field tools, navigation across the planet to the correct region, and interpretation of the tests applied to the problem. As each goal is satisfactorily completed, the student is automatically assigned new goals requiring progressively higher levels of expertise and decision-making. Through this practical application of the scientific method, students learn how to think, act, and react as geologists (see Duffy & Jonassen 1992). This is a particular strength. Student progress is tracked in terms of goals achieved -- and students have a self-paced, anytime/anywhere learning experience.

Classroom Context

Physical Geology at North Dakota State University is a large-enrollment (400+ students in one large lecture section), 3 semester hour course. Aside from lecture, the course content is augmented by slides, a set of course lecture templates, a textbook, and a web resource site that includes self-quizzes, photographs, course news, and links to related resources. Testing is by multiple-choice exams, with students submitting their results on optical scan sheets. Nearly 100% of the students enroll in the course to complete either general education science requirements or specific course requirements within their majors. Because the class is so large in enrollment, it demonstrates the obvious impracticality of field-training each student to think and behave as a scientist, and as a geologist.

In the Fall semester of both 1998 and 1999, the Geology Explorer was incorporated into the Physical Geology curriculum. Data were gathered with a view toward 1) answering several questions about student use of technology and 2) student perceptions of, and satisfaction with, the Planet Oit simulation using an on-line evaluation questionnaire.

The primary goal was to investigate the effect on the student experience with Physical Geology as consequence of introducing the Geology Explorer prototype as a supplementary resource to classroom instruction for a non-major introductory course. To do this, we implemented tracking routines on Planet Oit in order to get statistics for time-on-task, correlations for computer literacy and attitudes towards technology, effect on final grade. We anticipated that these data would lead to a classification by learning style.

The Student Experience

In the Fall, 1999, 81 students completed a Geology Explorer assignment, scoring the required 500 points, and then completed an on-line follow-up evaluation form. This form is web-based and requires identification information (e.g. name, student ID number, and e-mail address), and is composed of 35 questions about the Planet Oit experience (the full form is on-line at http://oit.cs.ndsu.nodak.edu/~mooadmin/cgi-bin/oitform.html).

In the post-test evaluation, 82.8% of the students said they somewhat agreed or strongly agreed they had learned something from the game, and only five students (5.4%) disagreed or strongly disagreed that they had learned something. At the same time, only 9.7% somewhat or strongly disliked the concept of game, and 62.4% thought they might like to play the game again. Meanwhile, the students perceived the game to be at an appropriate level of difficulty, with only 8.6% describing the game as much too complex, and 0 students believing it was much too simple.

For the 81 students who completed the assignment and the post-test evaluation, the average actual time on task was 3.47 hours with a range from 0.83 hours to 8.04 hours (while the average estimated time on task was 5.2 hours with a range from 1 to 12.5 hours). Of this group, 11 (13.6%), underestimated time spent on the planet, 12 (14.8%), overestimated their time on task by 25% or more, and 58 (71.6%), accurately estimated the time they spent on the planet.

Learning Style

Through the course of the experiment, and by interacting with students both off- and on-line, we came to believe that identifiable learning and problem-solving styles were being employed by the students. Some students appeared to take an analytical approach: frequently referencing the on-line help, conducting sequences of experiments, and making diagnoses leading to their scoring points in a deliberate fashion. Other students seemed to take a pattern-matching approach: exploring far and wide in search of outcrops that seemed to match the description of what they were looking for, and then scoring points with relatively few experiments. There was also a small but noticeable group taking a straight "brute force" approach, simply visiting location after location and identifying everything there, one after another, as their goal, eventually succeeding after many tries. One monument to this approach was a student in 1998 who made 1,244 guesses on the way toward obtaining just five correct answers.

To investigate the nature of the apparent trends, an analysis was conducted using logging data to count the number of "reports" (i.e. guesses), the number of locations visited, and the number of experiments conducted (e.g. hit, scratch, streak, etc.), for the same 81 students who had completed the game and the evaluation survey in 1999. These data are summarized in Table 1.

	Reports	Moves	Experiments
average	42.6	139.2	73.8
st. dev	38.2	83.1	63.2
min	5	19	0
max	238	518	301

Table 1: Student Reports, Moves, and Experiments in 1999

Using these values for average and standard deviation, we developed a classification of behaviors by looking for combinations of either much higher or much lower than average activities in terms of reports, moves, or experiments, or combinations of these. These data are summarized in Table 2. There are a total of 24 clusters, each marked with a code, which represent the three significant categories.

The values in Table 2 indicate that a wide range of approaches are supported by the Geology Explorer, a testament to the user-centered and user-controlled nature of the simulation. Further, almost half of the students can be classified as consistently efficient, not only economizing on their problem-solving effort, but doing so across all three dimensions.

Meanwhile, over half were above normal in one or more dimension, with 17 making excessive reports (code "R," the "brute force" approach); 19 making excessive movements around the planet (code "M," the pattern matching approach), and 22 making more than the normal number of experiments (code "E"). Note that three students were excessive on all three dimensions, and only two students were within 1/2 standard deviation on all three.

Consistently normal or below normal activity		Consistently normal or above normal activity		Mixed problem-solving activity	
rme	10	-ME	5	-Me	4
r-e	8	--E	4	rM-	2
r--	5	R-E	4	r-E	2
-m-	5	R--	3	RmE	2
-me	4	RME	3	---	2
--e	4	RM-	3	Rm-	1
rm-	4	-M-	2	-mE	1
		rmE	1		
		R-e	1		
		Rme	1		
Total (49.4%)	**40**	**Total (29.6%)**	**24**	**Total (21.0%)**	**17**

Table 2: Learning / Problem-Solving Styles

Note: R = many reports; r = few reports; M = many moves; m = few moves;
E = many experiments; e = few experiments.
Example: "-Me" means normal reporting, many moves, below normal experiments (where normal is within one-half standard deviation from the mean).

Discussion

We can only speculate, at this point, what these data mean. We would seem to be seeing a great deal of apparent variability in student style which could point to basic differences, or which might simply be a function of pre-conceived notions on the part of the students as to how interactive software games usually work. That is, a certain number of students might be tempted to "game" the system -- i.e. devote their energies toward learning to "beat the game" rather than learning the geological content the game is meant to convey.

Gaming the system in more-or-less constant concern in efforts of this type and a problem that we, as designers, must be constantly vigilant against. However, it must be recognized these issues are not strictly confined to computing media. Students are resourceful, and there is a long history of anecdotal accounts of students, for example, "cracking the code" of lab samples in order to pass a test. Anyone who has taught laboratory sections for any length of time has similar stories on this theme.

We can make only preliminary claims, at this stage, to a definitive classification of student problem-solving categories. For example, above normal "M" in Table 2, indicating movement and exploration more than 1/2 standard deviation above the mean, might not directly indicate the "pattern matching" strategy mentioned above, but it could simply indicate a high degree of curiosity in some students. Alternatively, it could mean (modesty forbids our promoting this alternative), that our virtual environment is so exciting and filled with wonders that students are exceedingly engaged and feel compelled to see everything they can (19 students were coded "M," we note, over 23% of the total).

By the same token, 22 students were "excessive," if that's the right word, in terms of code "E," for experimentation in Table 2. This is hard to criticize on any level, as experimentation is, in one sense, what we hope to teach. Perhaps these students were repeating experiments because our logging procedures were too inaccessible and they re-did experiments rather than refer to their logbooks. If so, this is a failing of the software that we must try to address.

Lastly, we find that 17 students made excessive reports. This was the indicator that led us to this data-mining investigation in the first place: the intuition that some students (in these data, 21%) were taking a "brute force" approach to their assigned goals. Is this supported? We suspect so. But there are many open questions, the primary of which is how to encourage these students (if we're right in this supposition), to be more analytical in their approach. One aspect we would like to track in the future is the effect of our software tutors in terms of steering the gamers, and the truly overwhelmed, towards more deliberative strategies.

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Integrating Mathematics, Science, and Technology Education Goals: An Interdisciplinary Approach

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Abstract: Reform documents in mathematics, science, and technology increasingly call for meaningful integration of technology in K-12 classrooms. Simultaneously, schools are being held more and more accountable for increased content at lower grades by both the reform documents and the popular press. Middle school models call for more focus on the student as independent learners and less focus on specific "school-based disciplines" or classes. One approach to addressing these concerns is through interdisciplinary units. In this paper, an interdisciplinary middle school unit on weather is briefly described as a model that addresses the multiple concerns related to (1) meaningful integration of technology, (2) increased accountability, and (3) less focus on historically independent mathematics, science, and technology classes.

Mathematics, science, and technology educators include the use of technology as a common goal in their most recently developed standards. The National Council of Teachers of Mathematics *Principles and Standards for School Mathematics* (NCTM, 2000) suggests a framework for the types of technology-based activities and content that should be taught. Similarly, the National Research Council's *National Science Education Standards* include suggestions for science education reform in technology-based content and professional development. Finally, the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), administered through the International Technology Education Association and funded by the National Science Foundation and the National Aeronautics and Space Administration, identifies the development of technological literacy as the major goal for technology education. A technologically literate citizenry has the ability to "use, manage, assess, and understand technology" (p.7). It is only by inspecting and integrating technology-based activities that include mathematics, science, and technology education goals will a technological literate society be possible.

In addition to this change, these same organizations assert that a more in-depth study of each discipline's content at earlier and earlier grades. This is especially true in the middle grades. To address these issues, the National Middle School Association calls for more focus on the student as an independent learner, developmentally appropriate teaching, and a more integrated approach to teaching and learning in general. One approach to addressing these concerns is through interdisciplinary units. This paper will discuss (1) the need for interdisciplinary teaching, (2) how interdisciplinary planning, teaching, and learning can occur between the mathematics, science, and technology disciplines via technology-based interdisciplinary unit, and (3) other content themes for interdisciplinary development.

The Need for Common Goals and Integrated Assessments

Mathematics

The National Council of Teachers of Mathematics *Principles and Standards for School Mathematics* (NCTM, 2000) Technology Principle states 'technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). In particular, "when technological tools are available, students can focus on decision making, reflections, reasoning and problem solving." (p. 24) While "technology is not a panacea for teaching computational strategies, teachers should use technology to enhance their students' learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well – graphing, visualizing and computing." (pp. 25 – 26) Calculators, databases and spreadsheets provide opportunities for these types of experiences to occur.

The *Principles and Standards for School Mathematics* additionally suggest in each of its process standards (Problem Solving, Reasoning and Proof, Communication, Connections and Representation) that "solving problems that arise in mathematics and in other contexts" (p. 52) are crucial to students better understanding their world. More specifically, "school mathematics experiences at all levels should include opportunities to learn about mathematics by working on problems arising in contexts outside of mathematics." (pp. 65 – 66) Thus, creating a method of demonstrating that "the link between mathematics and science is not only through content but also through process." (p. 66)

Science

According to the American Association for the Advancement of Science (AAAS, 1993) scientifically literate people should understand the interdependence of science, mathematics, and technology. Science instruction should include mathematics and technology as tools for observing, thinking, experimenting, and validating. This merger of mathematics and technology into scientific inquiry holds promise for a scientifically literate society. Technology is one way of defining the human experience. Paleontologists use the technology of tool making as one of the chief indicators of emerging human culture. Technology allows us to interact, shape, or more fully understand our environment. The distinction between technology and science blurs as technology becomes more sophisticated. Modern scientific research requires computers for data collection, analysis (statistics), and display. Technologies shape science as they develop, providing motivation and direction for theory building. For example, knowledge of subatomic particles increases with the expanding technology to control collisions between smaller, faster particles and to detect smaller particles as a result of these controlled collisions.

The *National Science Education Standards* grew from the work of the AAAS and several other groups dedicated to the improvement of science instruction. As with mathematics, it is our belief that rich technology- based instruction is integral in nurturing the development of students as active science inquirers. The science and technology standards " establish connections between the natural and designed worlds and provide students with opportunities to develop decision making abilities (NRC, 1996, p. 106)." Using databases, spreadsheets and calculators will assist students with their developing scientific inquiry skills.

Technology Education

The International Technology Education Association *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), states "technology is created, managed, and used by societies and individuals, according to their goals and values" (ITEA, 2000, p. 7). It has the potential to improve the human situation or damage it. Technology has the potential to save or destroy lives. "The promise of the future lies not in technology alone, but in people's ability to use, manage, assess and understand it" (ITEA, 2000, p. 7). The major goal of Technology Education is to develop a "technologically literate" citizenry. A technologically literate citizenry has the ability to "use, manage, assess, and understand technology" (ITEA, 2000, p. 7). In order to be technologically literate one must understand that technology has consequences. These consequences or "impacts" affect individuals, society, and the environment (ITEA, 2000).

In order to gain technological literacy and minimize the negative impacts of technology students must gain an understanding of "the universals of technology." (ITEA, 2000, p. 10) These include the knowledge, processes and contexts of technology (ITEA, 2000). The development of technological literacy goes hand in hand with the development of both scientific and mathematical literacy. Technologists use math and science, scientists use math and technology, and mathematicians use science and technology. Together these three disciplines have moved society toward new horizons. A technologically literate society will help the scientists and technologists of the future make wise decisions for the benefit of all.

Planning an Interdisciplinary Mathematics, Science and Technology Unit

Individually and in common, these mathematics, science and technology reform documents describe a classroom environment where students are involved in hands-on manipulations that subsequently lead to minds-on engagement. Technology is used because it increases learner's ability to interact with and learn from their environment. Interdisciplinary units are a mechanism for integrating hands-on, multi-discipline, technology-based activities. Mauer (1994) describes four methods of developing interdisciplinary units: correlated, multidisciplinary, interdisciplinary, and integrated day. In a correlated unit, teachers apply the same scope and sequence to their respective courses but make minor adjustments in the time the different elements are taught (p. 3). A multidisciplinary approach consists of designing a course whose purpose is to integrate the content area of different disciplines into a single course of study based on the study of specific themes (p. 4). An interdisciplinary approach centers on organizing curriculum around broad themes which by their design must contain most subject areas (p. 4). An integrated day approach uses the entire school day as an integrated learning experience (not subject based) (p. 4). Regardless of the approach implemented, all true interdisciplinary units have a "curriculum organized around broad themes which by their design must contain most subject areas" (p. 4).

Effective interdisciplinary units incorporate eight characteristics (Erb & Doda, 1989; Mauer, 1994). While each of these characteristics (Figure 1) is expected in all classrooms, when taken as a whole, these characteristics describe and multi-layered approach to teaching and learning, where diversity in the daily routine is valued.

1. A wide variety of instructional objectives (Bloom)
2. Important Theme
3. Balanced Activities (teacher-centered and student-centered)
4. A Wide Variety of Student Learning Activities (hands-on, lecture, technology, etc.)
5. An exciting culminating activity
6. Develops new skills
7. Applies/develops same skills across disciplines
8. Motivating

Figure 1 Characteristics of Effective Interdisciplinary Units

The development of an interdisciplinary unit is a five-step process (Figure 2) (Erb &Doda, 1989). The net result of this process is a unit that begins with a central theme and is refined through more and more specific goals and objectives so that ultimately a variety of subject-specific activities reinforce all objectives and the common theme.

1. Central Theme
2. Instructional Goals (Broad)
3. Content Objectives (Math, Science, etc.)
4. Student learning activities
5. Implementation Plan

Figure 2 Era & Doda's Five Step Planning Model

An Interdisciplinary, Internet-Based, Middle School Unit

The authors have selected the central theme of weather to demonstrate how an interdisciplinary, Internet-based, middle school unit addresses the variety of concerns previously described. A typical unit on weather includes the broad science topics of hydrology (the water cycle) and meteorology (the atmosphere, weather phenomena and their effect, and factors that cause weather). The science processes of describing, recognizing, investigating, interpreting, and forecasting are explicitly stated. Further, the concepts of relationship, composition, structure, effect, and interaction are fòci as well. Implicitly, students are to measure weather phenomena; analyze, interpret, and display the data; and diagram the relationships inherent in the study of weather. Mathematics processes that support the learning of weather include, collecting and organizing data along with reading, interpreting, comparing, and analyzing data. Specific technology-based problem-solving skills include the use of scientific calculators and computer skills to solve problems, to discover patterns and sequences, to investigate situations and draw conclusions along with the use of computer software and applications to research, investigate, and analyze data using charts, tables, graphs, or other presentation forms.

Several years ago a unit of this sort would have been restricted to local measurements with locally purchased—or even locally constructed—instrumentation with TV weather reports used to supplement student data gathering. The World Wide Web (WWW) has dramatically changed the potential of this learning experience. Today, a well-constructed unit would be expected to include additional data not previously accessible. Two broad instructional goals that would encompass these additional features would be: (1) collect and use weather data to visualize weather phenomena, including local and Internet sources; and (2) collect and use weather data to make weather-related decisions, including local and Internet sources.

The Georgia Quality Core Curriculum (Georgia QCC found on-line at http://www.glc.k12.ga.us/qstd-int/homepg.htm) was developed to specify the broad competencies for all students in Georgia public schools from kindergarten through high school. Competencies are organized by subject matter and grade. The national standards in mathematics, science, and technology education—along with other resources—were used to frame the development of the Georgia QCCs. The following eighth-grade Georgia QCCs were utilized to develop the interdisciplinary mathematics, science and technology education weather unit.

Science

16. Describes the water cycle and its relationship to the movement of surface and subsurface water.
18. Describes the composition and structure of Earth's atmosphere.
19. Recognizes and investigates weather phenomena and their effect on the Earth's surface. Interprets weather maps and make forecasts.
20. Describes atmospheric factors which interact to cause weather: heat energy, air pressure, winds, and moisture.

Math

3. Uses scientific calculator and computer skills to solve problems, to discover patterns and sequences, to investigate situations and draw conclusions.
4. Uses computer software and applications to research, investigate, and analyze data using charts, tables, graphs, or other presentation forms.
46. Collects and organizes data, determines appropriate method and scale to display data, and constructs frequency distributions; bar, line and circle graphs; tables and charts; line plots, stem-and-leaf plots, box-and-whisker plots, and scatter plots.
47. Reads, interprets, compares, and analyzes data in frequency distributions, diagrams, charts, tables, and graphs (bar, line, circle, stacked bar, double line, and multiple bar), and makes predications or conclusions based on this data.

Exploratory Technology (Grades 6-8)

6. Utilizes tools, materials, and processes to solve technical problems involving the application of science, mathematics, and inventiveness.
9. Solves a given problem using the inductive and deductive processes of the scientific method.

In general, all ten of the Georgia QCCs under Exploratory Technology support the learning of mathematics and science as integral parts of society. Specifically, two standards explicitly point out the interrelatedness of technology, mathematics, and science. The first includes the use of tools, materials, and processes to solve technical problems involving the application of science, mathematics, and inventiveness. Hands-on, minds-on science is built upon individuals observing and manipulating their environment, typically utilizing tools, materials and processes. These observations lead to inferences and meaningful learning takes place. A simple visit to any manipulative-based mathematics classroom will show how the use of materials and tools support cognitive processes in concept development.

Just as mathematics and science consider problem-solving a "foundational skill," technology educators include the idea of inductive and deductive problem-solving as essential. This manifest itself in a study of the tools, materials, and processes of science and mathematics contained in the previous standard. Typical topics of study within a weather unit might range from the history of weather measurement tools to the instruments used today from a simple rain gauge to Doppler radar. Also inherent in this standard are the effects on individual include decisions about dress or activities, effects on society include early warning for tornadoes, and mans effects on the environment -- which might include weather phenomena related to impacts of specific technology such as CFC-free air-conditioning.

A Brief Look at the Structure of a Weather Unit

The major advantage of any interdisciplinary unit -- and this weather unit in particular -- is the broader understanding inherent when the somewhat artificial boundaries of school-based subjects are rejected in favor of complete conceptual development. Five multi-day "projects" drive the study of weather. Projects are listed below with specific limited examples of WWW sites that make each project more student-directed.

(1) set-up their own weather station that monitors local weather,
    a. Description of surface weather observation techniques - http://www.nemas.net/edu/observations/index.htm
    b. An extremely large selection of weather dot com sites - http://www.weather…..com/
    c. Miami Museum of Science - Weather Tools - http://www.miamisci.org/hurricane/weathertools.html
(2) explore the history of weather measurement tools,
    a. Weather Ref Desk - http://www.refdesk.com/weath1.html
    b. The Weather Vane Home Page - http://www.denninger.com/
(3) explore the water cycle utilizing data taken at their local weather station and weather sites,
    a. The Weather Channel - http://www.weather.com
    b. CNN Weather http://www.cnn.com/WEATHER/
(4) determine what weather instruments are being used today to forecast weather, and
    a. The Weather Channel - http://www.weather.com
    b. CNN Weather http://www.cnn.com/WEATHER/
(5) analyze data using the visualization power of spreadsheets.
    a. Sources of real data include the National Oceanographic & Atmospheric Administration - http://www.noaa.gov , specifically found via the NOAA's National Geophysical Data Center (NGDC) - http://www.ngdc.noaa.gov/ngdc/ngdcsociety.html (NOTE: Data is available through multiple sources at this site, http://www.ngdc.noaa.gov/paleo/pubs/mann1998/frames.htm contains six centuries of global climatic data that could be analyzed by students, as an example.)
    b. Visualizing weather related phenomena - http://covis.atmos.uiuc.edu/covis/visualizer/surface.html

Additional Topics

It is important to note that not all individual concepts or objectives lend themselves to fully interdisciplinary units. However, teachers and students who are familiar and competent with interdisciplinary units will naturally be able to *integrate* other skills into any topic. A brief list of topics that are suitable for interdisciplinary units in the middle school follow.

1. Using Machines, simple to complex
2. Using energy
3. Using matter
4. Electronics
5. Structures, natural to manmade
6. Aerospace
7. Force and motion
8. Changes over time
9. New technologies, lasers to fiber optics
10. What things are made of, atoms to molecules to ecosystems

In conclusion, the authors believe that interdisciplinary middle school units hold special promise when attempting to simultaneously address the multiple concerns related to (1) meaningful integration of technology, (2) increased accountability, and (3) less focus on historical math, science, and technology classes that are expressed in the reform documents for mathematics, science, and technology education's. Especially when these concerns are multiplied by the concerns inherent in the middle school reform movement.

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The Design of Instructional Technology to Help Students Connect Phenomena to Scientific Principles

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Abstract: When technology is used to support student inquiry, learners can develop mental models that are initially based upon their intuitive knowledge of the phenomena. Technology can support this collaborative development by giving them the opportunity to visualize the connections between their experiences with phenomena and the corresponding abstractions (e.g., mathematical equations) for a particular scientific principle. This visualization process is optimized when they interact with resources that provide the visual images and the corresponding verbal rules (i.e., heuristics) that scientists use to solve scientific problems. This process is especially effective when the level of abstraction is intermediate between the concrete instances of a phenomenon and the higher order abstractions that represent it. The author recommends that pre-service and in-service science education programs use technology to help students truly understand the connections between phenomena and the underlying scientific principles.

This paper describes how instructional technology can be designed to help students make meaningful connections between phenomena and scientific principles. Conversely, traditional science instruction separates the study of phenomena—in the laboratory—from the study of the underlying scientific principles—in the lecture room. Three types of technology can help students build procedural-to-conceptual bridges across this large curricular gap: (1) *microcomputer-based laboratory* (MBL) experiments give them the opportunity to predict, observe, and explore the effects of experimental parameters (e.g., pH, etc.) upon the outcome (i.e., the dependent variable); (2) *computer-simulated experiments* (CSE) allow extension of MBL learning opportunities to include a wider range of phenomena; and (3) *multimedia learning modules* (MLM) can help them apply scientific principles by practicing their problem-solving skills within a real world context. These three technologies can provide the scaffolded support that students need to design experiments and to discover scientific principles.

Visualization of Phenomena and MBL Experiments

MBL experiments have been shown to be one of the most effective types of technology used in teaching science topics (Berger et al. 94). An MBL is a system that couples a data-gathering device to a microcomputer. The microcomputer records the incoming information from a sensor (e.g. pH probe), and then organizes it into a recognizable pattern (e.g., a graph). MBL experiments can help students simultaneously visualize a phenomenon and its graphical representation (Nakhleh & Krajcik 93, Suits 00). Students need these visual experiences because scientists use visual imagery (Mathewson 99) as mental tools when they attempt to understand and solve complex problems. Technology can shift instruction away from the primacy of verbal thinking and towards the integration of visual and verbal thinking (Collins 91). Students can use it to connect multiple representations of phenomena and to enhance their understanding of principles (Kozma & Russell 97). The goal should be to help them construct meaning through the use of manipulatives, visualizations, and internalizations, which enhance mental pictures and lead to further abstractions (e.g., mathematical equations). Thus, with the support of MBL technology, students can enhance their conceptual knowledge (Nakhleh & Krajcik 93). Overall, MBL experiments can help them organize their observations of phenomena (concrete level) into a coherent set of interrelated principles (abstract level).

Intermediate Level of Abstractions and Interactive CSE

An interactive CSE can fully engage the decision-making processes of students while extending the range of phenomena that can be explored. CSE's use models of scientific phenomena and data from real experiments to allow students to determine the experimental conditions and hence to design experiments. Upon running the experiment, they receive feedback about the experimental outcome. If the outcome does not meet their expectations, they can change the experimental conditions and rerun the experiment. In addition, an interactive CSE enables the student to create idealized simplifications for scientific systems and to transform abstractions into concrete manipulative representations (White 93). This transformation allows them to see dynamic representations of phenomena that are connected to more abstract representations. Thus, they can relate and apply their formal knowledge to their everyday situations (White 93). This "intuitive knowledge" is a flexible and generative type of knowledge (diSessa 00) that could be used as the building blocks to construct a conceptual network of knowledge.

The instructional design of interactive CSE's is most effective when represented at an intermediate level of abstraction (ILA) (White 93). These ILA's enable students to interpret the model's behavior in terms of simple conceptual and process abstractions. They derive these abstractions from their everyday experiences. Instructional design decisions should begin with a model at a low level of complexity and then help students use causal reasoning to visualize a simple mechanism for their model. Other design decisions should make learning (White 93): (1) *understandable and meaningful* by building on intuitive notions of causality and mechanism; (2) *transferrable* by allowing the mapping of ILA's to different real world situations; and (3) *linkable* because their models can link different levels of abstraction (e.g., iconic and symbolic) and different perspectives (e.g., microscopic and macroscopic). These designs should feature a "vast repository of capabilities that we can tap" so that designers "have a much easier time building learning environments that capitalize on that competence (p. 98, diSessa 00)."

Scaffolded Student Knowledge and MLM's

Interactive MLM's can be designed to give students practice at solving problems in an enriched learning environment that allows visual experiences within a real-world context. Students often work quantitative problem solving exercises without understanding the underlying principles for those exercises. In addition, the feedback they receive is often delayed or uninspiring. Conversely, an MLM can show a movie of an expanding automobile air bag (Suits & Courville 99) as the "real-world feedback" that students receive based upon their calculated quantity of solid sodium azide (via the gas law equations) needed to properly inflate the bag. These enriched "drill and practice" problems can increase both student interest and "on task" attention to the problem-solving process. Initially students are given full support (e.g., feedback, help, and cues) so they can attain a particular level of competence; however, this support is faded so they can extend and apply their problem-solving skills.

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Life and Death of the Lymphocytes a Didactic-Pedagogic Game for teaching Immunogenetics

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Abstract Individuals are potentially capable of generating antibodies to all antigenic stimuli. Aminoacid sequencing has revealed a curious and unique fact among proteins, a high diversity (variable) amino-terminal region, responsible for antigen recognition associated to a relatively constant carboxi-terminal region responsible for biological functions. As the presence or absence of immunoglobulins during maturation will determine the fate of the lymphocyte we elaborated this game which follows some rules of Role-Playing Games. Genetic rearrangement, lymphocyte differentiation and repertoire selection are present in the game and were topics of our immunology course where students had most difficulty. Their first reaction in doing this activity was of disbelief, they were reluctant in starting and presented childish reactions, but as they did, they asked the questions we expected during classes. The game is used, with success; in continued-education programs for high-school teachers where Molecular Biology, Genetics and Immunology are the themes. This type of activity renders learning a more pleasant process.

Introduction

All individuals are potentially capable of generating antibodies to any antigenic stimuli. The antibody is a glycoprotein composed of four polypeptide chains, two light and two heavy chains, kept together by sulphate bridges forming a three-dimensional "Y" shaped structure called monomer. Each chain contains a series of repeated homologous units, each with approximately 110 amino acid residues, which fold independently into a common globular structure, called domain. The heavy chain has twice the molecular weight of the light chain, presenting four domains while the light has only two. Within a monomer, the chains are paired, each pair composed by one light and one heavy chain and chains with the same weight are identical to each other. Immunoglobulins (Ig) can also be presented in a polymeric form, joined by another glycoprotein, the J chain, synthesised by the same cell. The most common polymeric forms are the dimmers and pentammers, although other intermediary multiples exist.

Amino acid sequencing analysis of the Ig has revealed a curious and unique fact among the proteins - a high diversity at the amino-terminal region of the chains associated to a relatively constant carboxi-terminal region. The amino-terminal region, of both chains, called the variable region, is responsible for antigen recognition. The carboxi-terminal end, the constant region, is responsible for the biological functions of the Ig's - interaction with the organism's structures such as cells and enzymatic cascades. Having in mind that Igs are present on the membrane of B-lymphocytes as clonal receptors and that the presence or absence of these receptors, during maturation, will determine their fate (life or death), we explored the programmatic content of our basic Immunology course with the game **"LIFE and DEATH of the Lymphocytes"** which we here propose.

Genetic rearrangement, lymphocyte differentiation and repertoire selection, are the topics of the course present in the game. The game permits the comprehension of probabilities of cell survival and therefore of the repertoire selection and is based on probability calculus and combinatory analysis and follows some of the rules of Role-Playing Games (RPG), where each player participates as an actor. Before the presentation of the rules of the GAME we will make some considerations on the concepts of Ig isotypes and idiotypes. And next we will approach the problem of the generation of Ig diversity and some considerations on ontogeny of these cells.

ISOTYPES - The carboxi-terminal region, although denominated constant region, presents 5 different variants for the heavy chains and two for the light chains. The heavy chains are called *mu, delta, gamma, epsilon* and *alpha* while the light chains are called *kappa* and *lambda*. The variations of the heavy chains determine the classes or isotypes of the Igs giving rise to the Ig classification: IgM, IgD, IgG, IgE and IgA, respectively. Technological progress has permitted further classifications, and some isotypes are subdivided and are designated by their corresponding symbol to which a number is added, for example IgA1, IgA2. Any heavy chain can be associated to a Kappa or lambda light chain.

IDIOTYPES - The idiotype, which corresponds to the variable region, is related to the individual variation of each Ig molecule, that is to say, to the capacity that each one has in interacting to a different set of antigens. The association of any one of the estimated 10^{14} different idiotypes to a constant region in the same molecule rendered an interesting genetic problem formulated by Dreyer and Bennet, for the first time, in 1965:

"...The paradox results of the observation that one extremity of the chain behaves as if it was the product of an only gene while the other as if it was the product of thousands of genes..." (Tonegawa, 1983)

What type of genetic duplication would have happened during evolution that produced mutations only at one of the extremities? To solve this paradox Dreyer and Bennet proposed that the genetic material that codes the variable extremity of the polypeptide chain would combine, during the B lymphocyte differentiation, with the gene segment that codes the constant region. This visionary hypothesis came to be proven, two decades later, with the classic work of S. Tonegawa and collaborators, which rendered them a Nobel Prize in Medicine (Tonegawa, 1983)

GENERATION OF DIVERSITY - Although the V region diversity is calculated as being approximately 10^{14} idiotypes, sequence variability is not evenly distributed. Within the variable region there are 3 segments of higher variability designated hypervariable regions flanked by regions of lower variability denominated framework regions. During the process of molecular folding the hypervariable segments are joined and are the segments that will have direct contact with the antigen.

A cluster of multiple gene segments called V_H, D, J_H and C_H for the heavy chains, and V_κ, J_κ and C_κ for the kappa chain and V_λ, $J_\lambda$and C_λ for the lambda chain codes each chain. Each one of these three gene clusters is located on a different chromosome. Of all gene segments used to encode the variable region, the V segments participate encoding the largest number of amino acids. According to the degree of homology these gene segments are grouped in families, both in the human and mouse system. Each species presents a number of different families.

The recombination diversity is possible because of the number of germline V, D and J segments in the heavy chain and V and J segments in the light chain. The fact that the heavy chain presents an extra group of gene segments, the D segments permits a greater variability compared to the light chain. Assuming that these gene segments are rearranged in a completely random mode (which is not true), and that there are no restrictions in the rearrangements (what is, also, not true) it is possible to generate 10^7 different variable regions. This potential repertoire can still be increased by a series of molecular events during the rearrangement process, such as nucleotide deletion, by exonucleases, and nucleotide addition by the enzyme Deoxinucleotidil Terminal Transferase (TdT).

As the absolute number of segments of each region varies between species and have not been determined we will use figures frequently found in the literature and depicted in our game. Let us see:

Considering the rearrangements of the heavy chains

200 (segments V_H) x 10 (segments D) x12 (segments J_H) = 200 x 10 x 12 = $2,4 \times 10^4$ possibilities

Considering the rearranges of the light kappa chain

200 (segments V_κ) x 12 (segments J_κ) =200 x 10 =2.4×10^3 possibilities

Considering that heavy and light chain recombination are independent events the combination of the heavy chain possibilities with the light chain possibilities

$2,4 \times 10^4$ (heavy chain) x 2×10^3 (light chain) = $(2,4 \times 10^4) \times (2,4 \times 10^3) = 5,76 \times 10^7$

Each V, D and J segment is flanked by a rearrangement signal, a special sequence which consists of three parts: a highly conserved heptammer, a non-conserved spacer sequence either 12 or 23 nucleotides long and a relatively conserved nonammer. The spacers of the V_K, J_λ e D genes have 12 base pairs, while the spacers of the V_λ, J_K V_H, e J_H genes have 23 bp. A striking feature of the spacers is that the lengths correspond either to one or two turns of the DNA double helix. The relation of 12 and 23 bp in the spacers has to be respected, so that the recombinase, can fit in the small and large groves of the DNA.

As soon as two segments have been joined by the recombinase, the endonuclease, acts on the double strand DNA. While the endonuclease cuts the DNA at the corresponding position at the beginning of the heptamers, the recombinase maintains the cut extremities juxtaposed. If the cut ends are bordering perfectly, ligase acts and makes the final repair of the DNA and the recombinase can detach. The intervening segment that was cut is lost and is degraded. However, the cut extremities are not always juxtaposed. When this occurs it is necessary to repair the DNA in order to become functional. The enzyme that repairs the DNA that is being maintained united by the recombinase is TdT. This enzyme inserts nucleotides *de novo* at the 3' end of the junctional regions, without the need of a complementary DNA strand. After this, polimerase, a DNA repair enzyme, which now has a template to guide the addition of the new nucleotides, adds them starting from the 5' terminal, allowing the ligase to complete the final repair of the double strand and recombinase may detach. These N inserts are only seen at the joining sites of the heavy chains. The apparent absence of this type of repair of the light chains is explained by the absence of this enzyme in the later developmental stages of the cell, when the recombination of the light chains happens.

These processes of addition and removal of nucleotides explains the presence of sequences that are not found in the germ line gene segments as in the third hyper-variable region of the Ig which does not exist in the germinal sequence. It is generated randomly by the V_H/D and D/J_H junctions. The D gene segments are Open Reading Frame codons permitting nucleotid insertions or deletions that are not multiples of three, as any of the 3 reading frames are allowed.

It is calculated that the diversity generated by the enzymatic activity has the same order of greatness of the diversity generated by gene segment recombination. This means that for each possible gene combination, for example, $V_{10}D_2J_3$ there may exist 10^7 variations. Let us see how. Considering the random insert of 1 or 2 nucleotides a general change of the molecule due to alteration of the reading frame; 3 nucleotides the addition of 1 amino acid. Considering that 20 amino acids exist 1 amino acid insert x 20 = 20 differences while a 6 amino acid insert (20^6) will lead to 6.4 x 10^7 different molecules.

ONTOGENY OF THE LYMPHOCYTES - During onotgeny, gene rearrangements occur in a pre-determined order. The first cluster to rearrange is the heavy chain gene segments and within it the D/J rearrangement occurs first. Then finally the VDJ segment is rearranged to the constant region. At this point the first polypeptide chain can be produced and exported to the cell membrane. If a productive rearrangement has occurred and the membrane protein receives a stimulus a series of events will be triggered simultaneously; allelic exclusion of the other heavy chain gene cluster and the rearrangement of the first light chain gene clusters. If not then the second allele is rearranged. Now at this point, after the rearrangement of the second allele, if the cell has not produced a functional heavy chain it dies of apoptosis. On the other hand if a productive rearrangement has occurred and the protein is stimulated on the cell membrane the light chain is rearranged. The cell has 4 chances to produce a light chain 2 in the kappa gene cluster and 2 with the lambda gene cluster. The first to produce a productive rearrangement will induce an allelic exclusion event in order not to further rearrange genes. In summary there should only be one productive rearrangement for the light and one for the heavy chain. As soon as the cell has a full antigen receptor it leaves the bone marrow to populate the secondary lymphnods.

The Game - The life and death of the lymphocytes

After the lectures where we approached the themes "Lymphocyte receptors: from genes to proteins" and "Aspects of the ontogeny of Lymphocytes." We presented, to the students, the game we here propose. which consists of steps where we simulate the developmental stages of a lymphocyte. To determine the several options of each stage we propose to use dices. There are at least two possible ways of playing the game in order to demonstrate the lymphocyte development: **Individually** - each student follows the rules simultaneously. After 15 rounds each player compares the results obtained by the rest of the group. **In groups** - make groups of 4 or 5 students, each player waits his/her turn to play and the group accompanies the evolution of the ontogeny of every lymphocyte (each student).

Material necessary for the game

4 RPG dices (20, 12, 10 and 4 faces, one of each) called D20, D12, D10 and D 4, Scissors (representing the exonucleases), Glue (representing the repair enzymes), models of each DNA strand, rules and Game tableau

Observations

1. Before the beginning of the game each player will have to construct the strands of the heavy chain germ line DNA simulated in paper. To play with the light chain as well an adaptation will have to be done removing the D

segments (cyan) and substituting the heavy chain gene segments (green) to the kappa segment (due to lack of space we have not included them here. When all players have their DNA's prepared the game may begin

2. Although, in our model, we represent the five constant region gene segments of the Igs, the rules of the game don't contemplate the class switch, because it would imply in a much more complex and too long a game, which would turn it into a very tiring one. We are now elaborating a game that contemplates the interactions of the lymphocytes involved during the immunological activity.
3. For the light chains we only include one of the light chain gene clusters, there is a second group of gene segments located on a third chromosome. In other words we could still have another two chances to survive, if it were the case. Again we could continue but, to simplify the game, this rearrangement is not included.
4. It would be very complicated to include all the molecular details of the recombination in this model. When the students prepare the model of the simplified DNA strand, it already measures approximately 2 meters. To insert the details of the rearrangement signals (leader sequence, palindromic segments, spacers, etc.) these strands would be at least four times as long rendering them unworkable.

Results using this game with Students of the School of Medicine at UFF

Before we elaborated the game these were the topics in the programmatic activities of our regular immunology course where the students had most problems in learning. Their first reaction in doing this type of activity is of disbelief. They are reluctant in starting the activities, giggle and present other childish reactions but as they start to go through the steps of the game they start asking the questions we would expect during classes.

We have used the game, with great success, to work with high school teachers in continued education programs where Molecular Biology, Genetics and Immunology are the central themes. Using this type of activity renders the learning process a more pleasant one. This game can also serve as the starting point for other events where the generation of biological diversity occurs, not only at the cellular level but, also, of the organism or even of populations

The game

This game is a model of the steps (in summary) that occur during the ontogeny of lymphocytes. It is not intended to be exhaustive but a didactic model in order to make it easier to understand the lymphocyte development. The instructions of the game were planned for the B Lymphocyte but they can be applied for the T lymphocyte once they have been adapted taking into account the distinctiveness of these cells.

Rules of the game

We will consider that each participant is a lymphocyte progenitor cell committed to the development of a B cell. To survive, the indispensable condition is to have a clonal receptor on the plasma membrane. To play and try to survive, everybody will have to repeat the steps described below.

Before starting the game it is necessary to prepare a model of the DNA that you inherited from your parents. For this, get the sheets that contain the light and heavy chain strands, cut the strands and where indicated glue the ends in order to simulate the strands of germ line DNA (enlarge the models supplied here).

Have at hand the dices, scissors, glue and a pencil to accomplish the next stages and the tableau to write down the result of each stage, permitting the final analysis of the events (as a suggestion add more line to permit 15 rounds)

Let's start

1. The game starts with the recombination of the heavy chain of the B cell receptor (BCR). To know which allele will be used first used toss any dice
   PAIR the maternal allele will be used. **ODD** the paternal allele will be used
2. Toss the D12 dice (representing the "J" segments) and D10 (representing the "D" segments) to know which DJ combination you will have.
3. Join the selected gene segments, obtained with the dice, by making a loop in your DNA and then cut out the intervening segments and make the repair of your strand. For example, if you obtained with the dice the segments D1 and J 3; you will cut and drop everything that is in this interval in order to put D1 nest to J3.
4. Now roll your D20 and D10 dice to know what segment "V" you will have. The number obtained with the D20 represents the first two numbers, and D10, the last (i.e., D20=17 and D10=3, the chosen "V" segment is 173).

5. Make a loop in your DNA strand to join the chosen "V" segment to the "D/J" already rearranged segment. Cut out the intervening DNA and make the repair. To have a functional gene you will still need another rearrangement step (stage 8). But before let's see if your rearrangements are functional ones.
6. Throw any dice.
   ODD - means that your enzymes united the several segments in an appropriate way.
   PAIR - means that some repair error has occurred and that the enzyme TdT, entered in action inserting 1 to 12 nucleotides in one of the junctions.
7. To know how many nucleotides were inserted throw your D12, and, to know in which junction, roll any other dice.
   ODD - junction D/J   **PAIR** - junction V/D
8. And finally, to know which nucleotides were inserted use your D4, attribute a number for each of the four nucleotides and determine the sequence your TdT will provide as a template for polymerase to repair the DNA **1** - A (Adenine); **2** - C (Cytosine); 3 - G (Guanine); 4 - T (Thymine) **Don't forget to write these results on your tableau**
9. A new, non-random, rearrangement occurs at this point. Join your rearranged VDJ segment to the μδ segment of the constant chain. Make a loop in your DNA to join the respective segments and perform the repair.
   Let us see if your enzymes accomplished the repair appropriately producing a functional gene. Play any dice.
   FIRST ALLELE
   PAIR - means that your rearrangements were accomplished in an appropriate way; therefore, you (the lymphocyte) can now transcribe and translate your membrane protein. Proceed to stage 10
   ODD - means that an error happened in your rearrangements. Therefore, in order to survive, you will have to repeat the steps from 1 through 9 using this time your second allele for the heavy chain.
   <u>OBS - If you didn't prepare two DNA strands and have already understood the mechanisms of rearrangement and repair of your germ line DNA, just play with the tableau from here on.</u>
   SECOND ALLELE
   ODD - you die because you have already used both alleles and didn't produce a heavy chain. Without it you won't have the clonal receptor, without which, the lymphocyte doesn't survive.
   PAIR -, you now can proceed for the stage 10.
10. Having produced a heavy chain and expressing it on the cellular membrane associated to the pseudo light chain you have to receive a stimulus from the environment to continue surviving. To know if you continue to live, throw your D12.
    FIRST ALLELE
    Numbers 1 - 4 you have to repeat steps 1-10, for insufficient stimulus;
    Numbers 5 - 12 you survive, therefore these stimuli are adequate. Go to stage 11.
    SECOND ALLELE
    Numbers 1 - 4 you die, for insufficient stimulus;
    Numbers 5 - 12 you survive, therefore these stimuli are adequate. Go to stage 11.
11. Since you are a survivor, now you will have to rearrange your light chain, because without it you won't have the complete BCR. For this throw your D10 (representing the segments "J") and then your D20 and D10 (representing the "V" gene segments) to know what VJ combination you will have.
12. Make a loop in your DNA and cut out the intervening sequences to join the respective gene segments obtained in the dice and make the repair.
13. Make a new loop now to join the rearranged VJ segments with the constant region of the light chain. Cut out and repair your DNA to join the gene segments.
14. Play any dice -
    FIRST ALLELE
    ODD - means that an error occurred in your recombination. Therefore to survive, you will have to repeat the steps from 10 to 14, using this time your second allele for the light chain.
    PAIR - means that your recombination was accomplished in an appropriate way; therefore, you the lymphocyte can now transcribe and translate your membrane protein. Proceed to stage 15.
    SECOND ALLELE
    ODD - you die, once you have already used both alleles for the light chain and didn't produce a functional gene, without which you won't have clonal receptor and, therefore, you (the lymphocyte) will not survive.
    PAIR - you now can proceed for the stage 15.
15. Having completed all rearrangements, both heavy and light chains, in a functional way, you (the lymphocyte) can now express your complete clonal receptor (BCR) and leave of the bone marrow and migrate to any secondary lymphoid tissue. You are winner!
16. To conclude, let's see how many survived. And what are the differences.

Tableau for the game

Instructions

1. Write down the chosen allele in which the first recombination will occur, then the chosen **V, D, J** segments determined by the dice on the corresponding line
2. If an ERROR occurred indicate at which rearrangement point and how many nucleotides were inserted by TdT.
3. In the column Final Result write down which cells leave the bone marrow and for those who die at which stage this occurred
4. To be able to study the populations of cells produced by the bone marrow let's put together your results and those of the rest of the group or class. Now let's analyze
   - Which is the survival rate?
   - Among the survivals how many used the same gene segments?
   - Among these, how many did not need to repair the DNA at the recombination sites?
   - How many repaired the DNA? The number of nucleotides was the same? And at the same recombination site? Are the same aminoacids be inserted?

Cell	Allele	V	TdT	D	TdT	J		Allele	V	J		final Result
1	M							M				
	P							P				
2	M							M				
	P							P				
3	M							M				
	P							P				
4	M							M				
	P							P				
5	M							M				
	P							P				

Use this plate as original for enlarging and photocopying

✂ Glue the next segment here

V1 V2 V3 V4 V5 V6 V7 V8 V9 V10 V11 V12 V13 V14 V15 V16 V17 V18 V19 V20 V21 V22 V23 V24 V25

✂ Glue the next segment here

V26 V27 V28 V29 V30 V31 V32 V33 V34 V35 V36 V37 V38 V39 V40 V41 V42 V43 V44 V45 V46 V47 V48 V49 V50

✂ Glue the next segment here

V51 V52 V53 V54 V55 V56 V57 V58 V59 V60 V61 V62 V63 V64 V65 V66 V67 V68 V69 V70 V71 V72 V73 V74 V75

✂ Glue the next segment here

V76 V77 V78 V79 V80 V81 V82 V83 V84 V85 V86 V87 V88 V89 V90 V91 V92 V93 V94 V95 V96 V97 V98 V99 V100

✂ Glue the next segment here

V101 V102 V103 V104 V105 V106 V107 V108 V109 V110 V111 V112 V113 V114 V115 V116 V117 V118 V119 V120 V121 V122 V123 V124 V125

✂ Glue the next segment here

V126 V127 V128 V129 V130 V131 V132 V133 V134 V135 V136 V137 V138 V139 V140 V141 V142 V143 V144 V145 V146 V147 V148 V149 V150

✂ Glue the next segment here

V151 V152 V153 V154 V155 V156 V157 V158 V159 V160 V161 V162 V163 V164 V165 V166 V167 V168 V169 V170 V171 V172 V173 V174 V175

✂ Glue the next segment here

V176 V177 V178 V179 V180 V181 V182 V183 V184 V185 V186 V187 V188 V189 V190 V191 V192 V193 V194 V195 V196 V197 V198 V199 V200

✂ Glue the next segment here

D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 J1 J2 J3 J4 J5 J6 J7 J8 J9 J10 J11 J12

✂ Glue the next segment here

CHμ1 CHμ2 CHμ2 CHμ2 CHδ1 CHδ2 CHδ3 CHδ4 CHγ1 CHγ2 CHγ3 CHγ4

✂ Glue the next segment here

CHε1 CHε2 CHε3 CHε4 CHα1 CHα2 CHα4 CHα4

Model of the gene segments of the heavy chain

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