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ABSTRACT

This paper provides an overview of five innovative projects involving network learning technologies in the United States: (1) the MicroObservatory Internet Telescope is a collection of small, high-quality, and low-maintenance telescopes operated by the Harvard-Smithsonian Center for Astrophysics (Massachusetts), which may be used remotely via the World Wide Web; (2) the Teaching Teleapprenticeships Project at the University of Illinois is exploring frameworks for learning that use electronic networks to create apprenticeship-like, asynchronous or synchronous learning environments for teacher education; (3) the Learning Through Collaborative Visualization (CoVis) Project at Northwestern University (Illinois) utilizes advanced technologies and innovative pedagogical approaches to help make the teaching and learning of science more like the practices of scientists; (4) the Knowledge Integration Environment (KIE) Project at the University of California at Berkeley has developed a model to foster Web-mediated learning; and (5) the Global Learning and Observation to Benefit the Environment (GLOBE) program is a major Internet-based international science education program aimed to enhance students' understanding of earth systems and to promote science and mathematics learning and environmental awareness. After a brief overview of each project, features common to these projects are discussed, followed by a consideration of challenges to be faced as innovative pedagogies and network technologies are used to support educational improvement and reform. Contains 10 references. (Author/DLS)

Lessons Learned and Lessons to Be Learned: An Overview of Innovative Network Learning Environments

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Abstract: This paper provides an overview of five innovative projects involving network learning technologies in the United States: (a) MicroObservatory Project, (b) Teaching Teleapprenticeships, (c) Learning through Collaborative Visualization (CoVis), (d) Knowledge Integration Environment, and (e) GLOBE. Each of these projects has an explicit research orientation that allows for principled ways to consider the successes and failures of the respective projects. After a brief overview of each project, features common to these projects are discussed, followed by a consideration of challenges to be faced as innovative pedagogues and network technologies are used to support educational improvement and reform.

The purpose of this paper is to provide an overview of selected innovative projects that use electronic computer networks in the United States. It should be stated at the outset that such a paper can only be a snapshot of what might be described as one of the largest educational experiments in history. Beginning in the early 1980s, many in the United States became concerned about declining educational achievement (The National Commission on Excellence in Education, 1983). Since that time, numerous initiatives have been implemented to improve the quality of K-12 education in the U.S. A common aspect of many of these initiatives has been the utilization of computational and communication technologies to support systemic and curricular reform [Honey and McMillan 1994; Hunter 1992; President's Panel on Educational Technology 1997]. However, there have also been cautions against assuming that technologies in and of themselves will substantively enhance educational outcomes and effect reforms [Educational Testing Service 1997].

Yet there is no denying the fascination in the U.S. with computer and network technologies, in particular the World Wide Web. Nearly all universities and businesses now are "on the Internet" and have Internet "addresses" (i.e., URLs, universal resource locators). As of 1997, sixty four percent of the schools in the U.S. have a connection to the Internet [Educational Testing Service 1997]. Also, there have been national initiatives, such as the *Goals 2000: Educate America Act* (signed into law in 1994), that have promoted the applications of technology, including networking, at the pre-college level. Other national programs have aimed to form cooperative partnerships between the U.S. federal government, states, local communities, individual schools and school districts, and private companies to help foster the use of technologies at the K-12 educational levels.

Yet what do we know about the ways educational technologies mediated by electronic networks may be used to achieve substantive educational outcomes? What are the lessons that have been learned? And what are the lessons still be learned? This paper will provide an overview of what is know about these questions based on selected projects involving schools and electronic networks in the U.S. The first portion of the paper provides a survey of exemplary educational networking research projects. The second section of the paper considers these projects more generally in terms of their underlying learning and theoretical frameworks, research issues, and general lessons learned.

EDUCATIONAL ELECTRONIC NETWORKS: SELECTED INNOVATIVE CASES AND PROJECTS

There are quite literally thousands of schools in the United States which are now using network resources in a variety of interesting and creative ways--far too many to be systematically considered. Five projects are discussed in this paper which utilized computational and communication technologies in educationally innovative ways: (a) MicroObservatory Project, (b) Teaching Teleapprenticeships, (c) CoVis, (d) Knowledge Integration Environment, and (e) GLOBE. Also, each of these projects has a research orientation that allows for principled ways to consider the successes and failures--the lessons learned and to be learned--of the respective projects. Given the limitations of space, these projects will be generally discussed in terms of their goals and major findings. For more detailed information, the reader should consult the references and Web sites for these projects.

MicroObservatory Internet Telescope

Astronomy is a popular science among the nations' youth and adults. However, the opportunity for learning astronomy by doing original research with professional grade instruments has been extremely limited for most students. In 1992, the MicroObservatory telescope network became the first generation of remote astronomical scientific instruments available on the Internet [Sadler, Gould, and Brecher in press]. The MicroObservatory is a collection of small, high-quality, and low-maintenance telescopes operated by the Harvard Smithsonian Center for Astrophysics. A Macintosh computer through an Ethernet communications protocol controls each telescope. The MicroObservatory Web site allows the user to control one of these special telescopes from his or her desktop. This makes the experience of high quality astronomical observations available in real classrooms rather than just from relatively inaccessible mountain observatories. The MicroObservatory user can schedule real-time use or program delayed observations and network delivered digital photographs.

The MicroObservatory has been used remotely in ten high school classrooms throughout the US. Experimental use has also been extended to introductory astronomy courses at the college level. Participating teachers use the MicroObservatory to demonstrate daytime observations during class periods, or download images taken by MicroObservatory telescopes. Students often work collaboratively to initiate their own astronomy investigations using the MicroObservatory telescopes over the Internet. For example, students found Comet Hale-Bopp to be an exciting object to observe during the spring of 1997. Students recorded the comet's shape and brightness over time and, some downloaded images from other students to make short movie of the comet. Similar to professional astronomers, students must write proposals to obtain time on the telescope for observations, and work with other users to analyze the images collected. Overall, student use of the MicroObservatory network of telescopes has indicated students can in fact conduct interesting scientific activities in a manner similar to research scientists.

Teaching Teleapprenticeships

The *Teaching Teleapprenticeships Project* at the University of Illinois has been exploring frameworks for learning that use electronic networks to create apprenticeship-like, asynchronous or synchronous learning environments for teacher education [Levin and Waugh in press]. A variety of frameworks for *Teaching Teleapprenticeships* (TTa) have been integrated into learning activities in many different preservice and inservice education courses. These frameworks include question answering and asking, collaborations, student publishing, utilization of Web resources, and project generation and coordination. For example, in the "question answering and asking" framework, undergraduate biology students were engaged in extra-credit course assignments as mediators to answer pre-college students' science questions. A suite of telecommunication software (e.g., Eudora, Gopher, Newswatcher, and Netscape) and a laptop computer were provided for each participating preservice education student.

The main features of the TTa approach include: (a) preservice or inservice students receive a "tele-field experience" for participation in a K-12 classroom as a "teaching teleapprentice," (b) students practice answering the kinds of questions they will be faced with when they are teaching K-12, (c) pre-college students interact with a diverse set of advanced learners (i.e., the teaching teleapprenctices in the project) in a manner that was found to be scaleable, and (d) undergraduates receive support in their mediator roles from their university instructor and graduate assistants. Network technologies allow novice teachers to start as "legitimate peripheral participants" [Lave and Wenger 1991], and then to gradually take on more central roles in networked-based projects. Students in the TTa Project were able to learn in meaningful and contextualized ways (i.e., school related) supported by multiple mediators (e.g., practicing teachers, fellow students, scientists, education faculty), while serving as valued mediators themselves to pre-college students. Other aspects of the TTa Project have investigated the nature of the mediator roles for learners and teachers as important factors for the successful use of new distributed learning environments and ways to integrate teaching teleapprenticeship frameworks into supportive and sustainable institutional structures.

Learning Through Collaborative Visualization (CoVis)

The Learning through Collaborative Visualization (CoVis) Project at Northwestern University and SRI International was one of the four initial NSF-funded National Networking Testbeds for Education [Pea 1994; Pea, Edelson, and Gomez 1994]. The CoVis Project has investigated how students can acquire scientific understanding mediated by scientific visualization software in collaborative environments, and how to support project-enhanced learning of science in a community that extends beyond the classroom. The central goal of the CoVis Project is to utilize advanced technologies and innovative pedagogical approaches to help make the teaching and learning of science more like the practices of scientists. The CoVis Project provides students with collaboration and communication tools that include: desktop video teleconferencing, shared software environments for remote, real-time collaboration access to the resources of the Internet, a multimedia scientist's notebook, and scientific visualization software.

The initial classroom uses of the CoVis Project started in 1992 with 296 grade 9-12 students in Chicago area. Students in the CoVis Project primarily study atmospheric sciences with some environmental science emphasis. For example, they may use tools such as *Weather Visualizer* and *Climate Visualizer* to investigate the progress and changes of major hurricanes through animations based on visible and infrared satellite data. Student activity logs are recorded in the *Collaboratory Notebook* and may be shared among a group of collaborators. Through a diverse suite of communication technologies, students engage in dialogs with practicing scientists in "teleapprenticing" relationships (Levin et al., 1987; Riel, 1992). The ongoing assessments of the CoVis Project investigate issues such as scaling, culture diversity, equity of access, sustainability, attitudes toward science and technology, and pedagogical improvement related to the use of networking technologies for remote collaboration.

Knowledge Integration Environment (KIE) Project

The World Wide Web is a complex resource that presents significant challenges to teachers to use in educationally powerful ways. In contrast to the focus of the CoVis project on network-mediated, collaborative data visualization, Dr. Marcia Linn and her colleague at University of California at Berkeley have developed a different model to foster Web-mediated learning. In the Knowledge Integration Environment (KIE), middle and high school students not only look for information on the Web, but also analyze evidence and provide scientific explanations about real world phenomena and problems. Research involving KIE has investigated the use of on-line scaffolding and guidance, student search strategies on the Internet, individual and collaborative sense-making of science evidence, on-line discussion tools, and reflection for science learning. KIE research findings suggest that students' performance in searching relevant sites improved through collaborative search activity and using the design library that contained pre-selected sites related to student project areas. Given that information found on the Web is often very complex and ill-organized, an "advanced organizer" approach was developed for KIE to provide key ideas about the Web content and sources with the intent of helping students become more critical in interpreting evidence and more successful in applying evidence to their projects. Overall, the KIE research to date has demonstrated that providing specific types of scaffolding and support to students as they utilize Web resources for inquiry projects can enhance student learning of scientific knowledge.

The GLOBE Program

The *Global Learning and Observation to Benefit the Environment* (GLOBE) program is a major Internet-based international science education program that was enunciated by Vice President Al Gore on the Earth Day April 22, 1994 [Means & Coleman in press]. GLOBE aims to enhance student's understanding of earth systems as well as to promote science and mathematics learning and environmental awareness. Through the GLOBE program, K-12 students around the world use the Internet to collect environmental data, perform measurements, exchange data, and interact with scientists and with other students. Students also use software developed by NASA to visualize the data they have collected from ongoing research investigations being conducted by practicing scientists. GLOBE participants come from more than 3,500 schools in 50 countries.

Empirical results of GLOBE activities for the past three years are being collected largely through electronic surveys. On-site observations and interviews at selected sites conducted by SRI, International researchers are also being used to supplement the survey data. Students are asked to reflect on their involvement in GLOBE activities and their attitudes and beliefs about technology, science, and measurement issues. Teachers are surveyed concerning the ways in which GLOBE activities are implemented in their classrooms, the challenges posed by setting up the program, and their strategies for dealing with problems. Participating scientists provide comments on the quality of various types of student-collected data and the ways in which the data support the scientists' investigations. Recent evaluations of this large scale, ongoing project suggest students are quite motivated by the authenticity of their participation in GLOBE research and the use of state-of-the-art technology [Means & Coleman in press]. Significant learning outcomes have also been found related to student performance on taking measurements, sampling principles, and data interpretation. Overall, the GLOBE program is a very interesting and important project in terms of the large implementation scale, the use of innovative learning approaches and activities, and the significant learning outcomes being documented.

LESSONS LEARNED

The previous sections have primarily described the features and learning activities associated with selective exemplary educational network learning projects. In this section, we consider general issues related to the use of educational networks that have emerged from these projects.

The projects described above reflect a wide range of ways that electronic educational networks may be used. The MicroObservatory, CoVis, and GLOBE projects scaffold students to be involved with scientific projects in ways that are qualitatively similar to professional scientists. The KIE project also involves students in projects, but provides ways to support students' critical and thoughtful use of Web-based resources as part of project activities. And the Teaching Teleapprenticship project focuses on teacher education, and utilizes various network resources to support collaboration and apprenticeship learning mediated by the network.

There are also other general features shared by these projects in a "family resemblance" manner. These include:

- employ a constructivist framework for learning and teaching;
- involving students in authentic activities and tasks;
- involving students in "tele-apprenticeship" collaborations with peers and adult practitioners and experts;
- promoting intrinsic motivation;

- enhancing student generated inquiry questions and interest in independent learning;
- changing the teacher's role from information provider to facilitator and mentor;
- scaffolding higher order student engagement in problem-solving and inquiry activities;
- providing technological support for teachers and students to facilitate productive learning activities;
- developing scientific software to be integrated into curriculum for advanced activities;
- providing asynchronous and synchronous activities in different places and time (removing physical constraints); and
- providing equitable access to network learning technologies.

There are many nuances in terms of how these features are instantiated in the different projects discussed in this paper. For example, the ideas of "teleapprenticeship" are implemented differently in the Teaching Teleapprenticeships Project and the CoVis Project. Overall, these various projects should be regarded as model cases of innovative and generally successful approaches to using the technological affordances of nationally and globally interconnected electronic networks in educational contexts. However, the full value of these projects is not just in detailing their successes, but in learning from the difficulties and problems they encountered, which we consider next.

Lessons to Be Learned

Internet technologies provide ways to interconnect people around the world in ways and on a scale that has never before been possible. Combining these technologies with innovative ways to improve and reform education thus represent significant challenges to teachers, students, schools, school systems, and national educational systems. In this section, we discuss some of these challenges and issues.

Based on the projects discussed in this paper, there are several areas that need further research in applied contexts (i.e., real classrooms) to address. For example, many of the projects were mainly science oriented due to funding priorities for research in the United States. How may these technologies and learning approaches be adapted and used in liberal arts and social science domains? Also, most of these projects were assessed using innovative learning outcome measures or qualitative methodologies. How will it be possible for traditional large-scale quantitative standardized assessment methodologies to measure that types of learning outcomes associated network learning projects? If so, how? If not, what are the implications for large-scale assessment methods? These projects primarily employed open-ended student directed learning activities involving electronic networks (e.g., CoVis, MicroObservatory). How can teachers meet curriculum content requirements and national standards, particularly at the high school level, with primarily student directed learning activities? These projects involved tens to hundreds to thousands of schools, yet there are over 100,000 schools in the U.S. alone. Will it possible to "scale-up" to hundreds of thousands of globally distributed schools? Finally, the successes reported in these projects were associated with a constructivist learning framework and educational epistemology. How can constructivist based network learning approaches be implemented in school situations which may be employ an "instructivist" approach teaching, learning, and assessment?

Given the relatively short period of time these technologies have been available in the schools, it is certainly understandable that there are not "definitive" answers to these and other questions related to how emerging network technologies can be infused into the educational activities of our children. However, it should be stressed that there are many who feel that the research and experiences to date concerning the educational efficacy of network learning environment technologies warrants continued implementation concurrent with continued research investigating questions of learning efficacy and implementation [President's Panel on Educational Technology 1997].

Conclusion: Learning New Lessons

Clearly there is much that has been learned in the research oriented U.S. educational network projects to date. This continues to be a time of rapid development with respect to the cluster of computational and communications technologies that comprise the Internet. Higher connection speed with the Internet II, faster and less expensive computers, new programming paradigms with network-based languages (e.g., Java), desktop video conferencing, Web-based digital video and audio, virtual reality (VRML) simulations--the list is seemingly endless and ever changing. The pace of technological change at this point in history is certainly a challenging issue to be confronted by those who are interested in exploring the emerging possibilities of network learning environments.

One major lesson of these projects, though, is that technology per se is *not* the most important issue. Of course, each of these projects has had to grapple with the complexities and the frustrations of implementing their respective models of learning mediated by technology. But the main lessons to be learned from these projects relate to the constructivist pedagogical and curriculum innovations they employ, and how the computational and communication technologies may be used to help facilitative those innovations. More research and practical experience is certainly necessary as the task of educational improvement and reform mediated by technology continues. The true challenge is to continue learning new lessons.

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