The Internet and K-12 Mathematics and Science Reform

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Abstract

Current efforts to improve United States K-12 mathematics and science education include the use of a variety of high performance computing and communication technologies. This paper examines the background, current status, and direction of this trend.

1 Introduction

Within a few years, global economics, politics, and technologies will become as important to our individual and collective lives as local economies, politics, and technologies. The slogan "Think Global ... Act Local" will become as universal as Coca Cola and MS-DOS. In response to these and other changes in society, formal education will experience a metamorphosis. We will build a global schoolhouse. Since imagining a global schoolhouse is the first step in building it, teachers, students, parents, and interested citizens everywhere need to rise to the challenge of reinventing education.

Dream with us a moment as we step into an intermediate school classroom that has integrated the best practices of the old and new educational paradigms. As you walk into the room, students are actively engaged in a variety of learning centers. The teacher is available to answer questions, to promote inquiry, to summarize and synthesize ideas, and to lead. All teachers in this school are themselves life long learners who love sharing the adventure and rewards of learning with others. Today the students are learning about weather. Let's walk around to see what is going on.

At one station, students are using CU-SeeMe Desktop Videoconferencing from Cornell University <http://magneto.csc.ncsu.edu/ Multimedia/CU-SeeMe/cuseeme.html> to speak with a Florida Explores <http://thunder.met.fsu.edu/explores/ explorestext.html> meteorologist. She is helping the students set up a closed environmental system (terrarium) that models the Earth's atmosphere. She will use the model and the scientific method to guide the students through an investigation of the water cycle. Another group of students has gone to the media center to gather books and articles from the automated library system and CD-ROM reference materials explaining how to build their own weather instruments.

At the weather satellite receiving station, incoming, real-time satellite images of hurricanes, tropical storms, and large weather fronts are converted from analog to digital form and investigated using image display and analysis software. Used with Blue-Skies <http://cirrus. sprl.umich.edu/Weather_Underground.html>, an interactive program for browsing, viewing and reporting dynamic weather information in graphic and text format , these images help students to understand and make predictions of future weather events.

At another station, local weather observations and measurements gathered by students in ground-truthing experiments are compared to satellite images. Today, students are collecting data from the weather instruments on their indoor/outdoor weather station and recording it in their project journals. The journals contain their observations, data, graphs, hypotheses, conclusions, and final reports. In their journals, we see a seamless integration of science, mathematics, geography, language arts, and computer technology. In their faces, we see the future.

We stop to talk with some students about what they are learning. They speak excitedly about the new friends they hope to make as they share their data and ideas with students, teachers, and scientists around the world. For instance, they will soon take an "electronic field trip" to Antarctica with NASA scientists. On the "trip", they will learn about the ozone hole over Antarctica and its relationship to global ozone fluctuations. Their world is both smaller and more personal than that of their parents. They are becoming citizens of their community, their nation, and their world.

Another group of students takes your hand to show you their new "game." CliMoMan <http:// nebbs.nersc.gov/ climate/climoman.html> acts as a interface to the Oregon State University climate model simulator running on the National Educational Supercomputer at Lawrence Livermore National Laboratory. Using CliMoMan, students manipulate parameters that are known to have some influence on the development of weather and observe the consequences in the model.

As you reflect on what you see happening, you realize these students are being transformed into young scientific researchers as they apply their newly developed skills. They have already made the most important discovery of all, that learning is an exciting life long adventure.

Thinking about the global schoolhouse in an institutional sense is much more difficult than considering the exciting technologies available for the study of weather. How much of the local schoolhouse should we carry into the global schoolhouse? As students begin to sense their rights, responsibilities, and opportunities as individuals, will they also commit their talents and energies to building strong local, national, and global communities? What roles should formal education play in promoting and supporting life-long learning for all citizens?

2 The Local Schoolhouse

Around 1920, a young Georgian emigrant named George Papashvily stepped onto American soil for the first time and walked directly to the employment office, confident that he was ready for life in the new world. When the clerk asked what he could do, Papashvily [1] replied "I am a worker in decorative leathers particularly specializing in the ornamenting of crop handles according to traditional designs." "My God!" the man said. "This is the USA. No horses. Automobiles. What else can you do?" Papashvily was not deterred. His father had apprenticed him in a second trade as precaution against just such a circumstance. "I am also a sword maker. Short blades or long; daggers with or without chasing; hunting knives, plain or ornamented; tempering, fitting, pointing -". "My God! A crop maker. A sword pointer." exclaimed the clerk. Shortly thereafter, Papashvily began his career in America as a dish washer. His autobiography, Anything Can Happen, is hilarious. His life was hard.

This year, millions of young men and women will enter the work force with skills as irrelevant and outdated as George Papashvily's were in 1920. As much as we may sympathize with these young people, there are larger issues at stake than their individual futures, issues that threaten the stability and prosperity of entire nations. In a global economy, the most critical factors determining the success of any venture will be talent, information and capital. Corporations lacking the necessary talent at every level of their organization will not be able to compete. Nations lacking competitive corporations will not grow economically. At the same time, meaningful public discourse on the environment, natural resources, community and economic development, health care, and education cannot take place if the electorate is incapable of understanding the arguments. More than ever before, every citizen needs to be mathematically and scientifically literate and technologically competent.

3 A Nation at Risk

In 1983, Terril Bell, United States Secretary of Education, stated:

> Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science and technological innovation is being overtaken by competitors throughout the world ... The educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people [2].

Secretary Bell's concern was well founded. A series of international comparisons of educational achievement [3] - [6] made it clear that United States students were at best average when compared to the students of other industrialized nations. While students in other countries were learning to apply mathematics in a variety of contexts, United States students continued to labor over 19th century shopkeeper mathematics, paper and pencil arithmetic. Not surprisingly, the older students got, the less they regarded mathematics as intrinsically interesting or potentially useful. As a result, few students continued their study of mathematics past the minimum required for high school graduation. Fewer still were prepared for college level mathematics. Two reports were particularly influential in describing this problem and in stimulating a systematic response from the mathematics education community, The Mathematics Report Card: Are We Measuring Up? [7] and Everybody Counts: A Report Card to the Nation on the Future of Mathematics Education [8].

In 1989 the National Council of Teachers of Mathematics (NCTM) published its Curriculum and Evaluation Standards for School Mathematics [9], the first comprehensive response to the challenges leveled at K-12 mathematics education. The Standards and subsequent NCTM publications redefine the objectives of school mathematics, teaching and assessment practices, and the role of students in mathematics classrooms. The central thrusts of these changes are to connect the various components of school mathematics to one another, to other disciplines, and to the real world in order to make the student an active participant in his or her mathematics education. As in all paradigm shifts, full implementation of these changes will take years; but meaningful progress is being made at the national, state, and local levels to explain the changes to students, teachers, and parents as well as to develop on-going professional development opportunities for mathematics teachers.

The situation with regard to science education is comparable. According to the United States Department of Education, only seven percent of high school seniors are prepared for college-level science courses [10]. One doesn't need to look far for explanations. In the 1990-1991 International Assessment of Educational Progress study, United States thirteen-year-olds scored thirteenth out of fifteen countries in science achievement, but placed first in the amount of TV watched each day [11]. In the United States, there is a pervasive attitude that science is a difficult, somewhat esoteric, and impractical area of study, pursued by an elite with a natural gift for it [12]. This idea is a cultural and economic time bomb ticking in our society. The time has come for education in the United States to make the transition from the 1890s objective of science for some in some grades to the 1990s goal of science for all in all grades [13].

With a $4 million grant from the National Science Foundation, the National Science Teachers Association (NSTA) is developing and testing a systematic response to these problems in its Scope, Sequence, and Coordination (SS&C) reform project [14]. In the SS&C project, each of the four basic science subjects -- biology, chemistry, physics, and earth/space science -- is taught every year. By emphasizing the scientific process and utilizing modern scientific technologies, this project seeks to motivate students to continue their science education through high school and college.

Working together, NSF, NCTM, NSTA, colleges and universities, state offices of public instruction, and other organizations and agencies have forged powerful new partnerships to address the crisis in mathematics and science education. Real progress is being made. Unfortunately, the positive results obtained so far have touched only a small portion of the teaching profession and their students. Serious attempts to scale these improvements from the project level to systemic reform await the development of an implementation strategy that will not be frustrated by layers of state and local government, the educational bureaucracy, or its characteristic financial limitations. The National Infrastructure for Education (NIE) Program of the NSF is the first step in the development of a technological and human infrastructure capable of developing and delivering mathematics and science education reform materials and training at a systemic level.

4 The National Infrastructure for Education

"The NIE Program aims to hasten the development of a widespread high performance electronic communications infrastructure in support of science, mathematics, engineering and technology (SMET) education reform, and to help lay a foundation on which strategies for the appropriate use of technology in support of increased student achievement can be developed. NIE's goal is to build synergy between technology and education researchers, developers and implementers so they can explore networking costs and benefits, test self-sustaining strategies, and develop a flexible educational networking infrastructure that will be instrumental in the dissemination, integration and application of technologies to speed the pace of educational innovation and reform" [15].

In 1994, NIE grants for planning (see Table 1), multi-year projects (see Table 2), policy studies (see Table 3), and supplements to existing projects (see Table 4) totaled $13.8 million. These awards reflect the breadth of approach taken by the NIE in fostering a K-12 telecommunications infrastructure.

Table 1: Planning Grants

William Beldham, PA $98,165	Planning for Regional Technology Initiative
Thomas Clark, ME $96,248	Discovering Community Networks
William Coberly, OK $99,776	Metropolitan Tulsa Education Network
Norman Dodl, VA $99,824	Planning for Virtual Schools in Electronic Villages
Pamela Keating, AK $101,343	Coming into the Country: Pioneering K-12 Internet Access Across Alaska's Interior
James Laffey, MO $96,020	Planning Grant for the Development of NIE Most (Missouri Supporting Teachers) Electronic Support System to Promote Problem-Based Learning Using a Computational Science
William Lamb, OR $99,924	Developing Oregon's Technical, Human and Organizational Networking Infrastructure for Science and Mathematics Education
Kam Matray, CA $112,000	The Ultimate Electronic Field Trip ... from abyss to Andromeda
Shirley McBay, FL, GA, IL, MD, NY, VA $100,000	Expressway to Quality Mathematics and Science Education for Low Income Minority Communities
John Shacklett, CA $91,690	Morse High School (San Diego) NIE Planning Grant
Josef Stagg, WI $93,136	The Virtual Community: A Telecommunication Model for the Inner City
David Thomas, MT $105,807	Development of a Rural Networking Infrastructure in Support of Systemic Change in Mathematics and Science Education: The Network Montana Project
Frank Watson, VT $99,000	Vermont Technology Alliance
Michael Williamson, MA $86,395	WhaleNet - Interdisciplinary Curriculum
Judith Yoho, PA $50,000	Keystone Community Network

Table 2: Multi-year Projects

Ann Billings, ME $927,800	A Community of Learners Network
Alan Feldman, MA $2,835,229	Enabling Widespread Telecollaboration
Edward Friedman, NJ $2,901,234	NIE Testbed Within the Context of Statewide Systemic Reform in MST Education
Carrie Heeter, MI $461,568	A Digital Learning Center for Microbial Ecology for K-12 Education
Paul Helfrich, PA $3,511,089	The Science Learning Network
Martin Huntley, MA $2,231,881	Toward Universal Participation in the NII - Phase II of the National School Network Testbed
David Lassner, HI $2,152,673	HERN - Hawaii Educational and Regional Network
Bernie Manning, PA $3,170,565	Common Knowledge: Pittsburgh - Creating an Urban Research Laboratory
Roy Pea, IL $3,539,105	The CoVis Testbed: A National Science Education Collaboration.
Philip Sadler, MA $1,312,897	Micro Observatory Net

Table 3: Policy Studies

Victor Bunderson, UT $49,728	Differentiated Staffing in Global Village Learning Communities
Robert Kozma, CA $99,986	A Community Learns On Line: Planning Activities to Explore the Use of Interactive Cable for Education
Karen Buller, NM $96,069	Electronic Pathways Alliance: A Native American Think Tank
Charles Warlick, TX $218,315	Role of State Networks in Educational Reform
Charles McClure, NY $102,529	Policy Issues in Assessing the Role of Public Libraries in the NII

Table 4: Supplements to Existing Awards

Jack Buchanan, TN $263,304	Memphis Educational Computer Connectivity Alliance
Kerry Davidson, LA $564,000	Integrating Educational Needs with Networking
Wallace Feurzeig, MA $523,000	A Distributed Multi-Server Architecture for Scalable Educational Applications
Gerhard Fischer, CO $374,907	Mastering High Functionality Systems by Supporting Learning on Demand
Louis Gomez, IL $301,858	Augmenting the Collaborative Visualization (CoVis) Network
John Klensin, MA $63,281	Network Start-Up Resource Center
Robert Panoff, IL $553,157	An Affiliates-Based Educational Infrastructure Testbed
Perry Samson, MI $623,261	The Weather Underground: Application of Computer Technology to Science in Michigan Secondary Schools
Michael Staman, IL $152,000	Networking Native Americans and Education Futures
Robert Tinker, MA $187,535	Alice: A Collaborative Infrastructure supporting Educational Use of NREN - Phase I

5 The Network Montana Project

The Network Montana Project (NMP) planning grant <http://victor.math.umt.edu/home.htm> is developing an infrastructure that:

- Builds and maintains a state-wide coalition of partners from academia, government, and the private sector responsible for directing a wide variety of K-16 educational networking activities;
- Supports and enhances a number of nationally significant systemic mathematics and science education reform projects;
- Integrates multimedia network-based materials and delivery systems into mathematics and science instruction to enhance access and usability of many scientific resources;
- Investigates adaptations of educational and informational telecommunications required to serve populations with special needs including those that may be visually or hearing impaired;
- Develops a workable community networking model that is feasible in a low population

density environment, promoting teleliteracy for rural citizens to enhance their involvement with lifelong learning, entrepreneurship and local/state governance.

The technological and human infrastructure of the Network Montana Project will:

- Create a variety of on-line forums (listservs, conferencing tools, and so on) where teachers, librarians, school administrators, researchers, government officials, and leaders in the private sector meet to exchange information, identify opportunities, develop proposals, and solve problems. NMP will conduct on-going research and development activities on the structure and support of these forums and their contributions to the reform of mathematics and science education, to the development of community networking, to populations with special needs, and to general public awareness of NMP and K-16 networking.
- Work with systemic reform projects in Montana on the development of guidelines for email use. NMP will develop and test a variety of models for steering participants to appropriate points of contact and for handling routine correspondence.
- Develop and deliver on-site and distance learning courses for participating teachers, librarians, administrators, and students.
- Identify, develop, test, and disseminate curricular materials that make use of modern multi-media technologies, information and computational resources available on the Internet, remote mentors, and models of cooperative and collaborative teaching and learning involving the use of Internet communications.
- Create on-line information resources, CD-ROMs, and print materials focused on various aspects of the NMP agenda.
- Maintain a help-line service for servicing NMP partners.

The Network Montana Project will generate new knowledge about the development and use of educational networks in rural settings and the value of high performance computing and communication in K-16 mathematics and science education. The principal findings and products of NMP research will be published on WWW information servers created for this purpose.

6 From Home Room to Home Page: Current Events in K-12 HPCC

New WWW sites spring into existence every day as professional organizations, educational institutions, governmental agencies, and research institutes hoist their flags in cyberspace. Of particular importance to K-12 mathematics and science teachers are WWW sites that disseminate critical professional information, provide access to powerful computing resources, offer on-going professional development opportunities, and facilitate reform efforts through collaborative programs and projects. The following sites illustrate the variety of offerings currently available to K-12 mathematics and science teachers.

Meeting Places and Information Marts

- Hotlist of K-12 Internet School Sites <http://toons.cc.ndsu.nodak.edu/~sackmann/k12.html> points to a number of K-12 schools with WWW home pages.
- Geometry Forum <http://forum.swarthmore.edu/> is an electronic community focused on the teaching and learning of geometry. Located at Swarthmore College and funded by the National Science Foundation, The Geometry Forum uses a variety of Question-Answer formats to encourage teachers and students to explore geometrical ideas. On-line software archives, research papers, and curricular materials plus weekend and summer workshops provide teachers with valuable information and professional growth opportunities.
- Geometry Center <http://www.geom.edu> at the University of Minnesota provides access to a variety of high performance mathematical modeling tools that run interactively through Web browsers.
- Joint Education Initiative <http://jei.umd.edu/jei/jei.html> is funded by NSF and located at the University of Maryland, College Park. JEI offers image processing workshops for teachers, a newsletter, CD-ROM sets created by cooperating scientists and K-12 teachers, and on-line databases oriented to remote sensing and the earth sciences in K-12 education.
- Cornell Theory Center Math and Science Gateway <http://www.tc.cornell.edu:80/Edu/MathSciGateway/> provides a wide range of educational services including links to resources in mathematics and science for educators and students in grades 9-12
- NCSA Education Program Home Page <http://www.ncsa.uiuc.edu/Edu/EduHome.html> points to mathematics and science education computational and information resources on the Internet and explains how computers and computer networks may be used to enhance K-12 education.
- NWREL - Science and Mathematics Education <http://www.nwrel.org/same/samehome.html> is one of the ten regional consortia that are part of the National Network of Eisenhower Regional Consortia and Clearinghouse, sponsored by the United States Department of Education.
- AskERIC Virtual Library <http://ericir.syr.edu/> located at Syracuse University is sponsored by the United States Department of Education. A wide variety of information

resources including the ERIC database, lesson plans, and information on Newton's Apple, the Discovery Channel, and the Learning Channel are available.

- Educational Resources on the Internet <http://sunset.tamu.edu/~dawn/edu.html>
- NASA K-12 Internet Initiative <http://quest.arc.nasa.gov/>
- NASA Spacelink <http://spacelink.msfc.nasa.gov/>
- NASA On-line Educational Resources <http://www.nasa.gov/nasa_online_education.html>

Electronic Field Trips

- SeaWiFS: Studying Ocean Color From Space Project <http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/LIVING_OCEAN.html> includes a Teachers Guide with Activities.
- Views of the Solar System <http://www.c3.lanl.gov/~cjhamil/SolarSystem/homepage.html> is an educational tour of the solar system. It contains images and information about the Sun, planets, moons, asteroids, comets and meteoroids found within the solar system. Statistical information of the planets and satellites can be browsed through lists sorted by name, radius and distance.
- Live From Antarctica <http://quest.arc.nasa.gov/livefrom/livefrom.html> allows students and teachers to ask questions of the scientists in Antarctica and respond to their challenge questions. It also provides links to international research centers where students can find full color pictures of penguins (127k), and see computer images of the ozone hole (80k) from current data . Live From Antarctica supports classroom learning with a Teacher's Guide.
- Fractal Microscope <http://www.ncsa.uiuc.edu/Edu/Fractal/Fractal_Home.html> is an interactive tool designed by the Education Group at the National Center for Supercomputing Applications (NCSA) at the University of Illinois, Urbana-Champaign for exploring the Mandelbrot set and other fractal patterns. An increasingly popular topic among high school teachers and students, fractal geometry is a natural setting in which to explore the relationship between mathematical concepts and their representations in computational systems. Fractal Microscope is used with NCSA imaging tools such as DataScope and Collage.

7 Integrating Mathematics, Science, and Technology

Two years ago David Thomas visited a one-room elementary school in rural Montana. It was spring and a few of the children had horses tied up outside. Inside, he showed the students images of Mars taken by cameras onboard the Viking spacecraft. Bright and inquisitive, the children began asking questions such as, "How big is that crater? How long is that mountain range?" They were surprised when Thomas told them to answer their own questions the same way a scientist would, by measuring Mars with a scientific visualization tool. Over the next hour the class took an interest in and gained ownership of their investigation of Mars. They became explorers, first posing questions, then devising strategies to answer their questions, and finally interpreting their findings. For those students, seeing was more than believing. It was motivation and engagement, insight, satisfaction and pride. They loved being scientists!

Following this experience, a formal classroom activity was drafted and sent to Stephanie Stevenson for further development. Shortly thereafter, she and her fourth grade drop-out prevention students volunteered to pilot test and revise the activity for use at the intermediate grade level. Stevenson focused the lesson by asking her students, "What is the largest volcano in the solar system?" That question launched an investigation that integrated skills and concepts from mathematics, science, technology, language arts, and geography. Students began their search for information in the school media center's automated card catalog and the CD-ROM version of Grollier's Encyclopedia. The search produced no answer; but armed with reference books, the students returned to the classroom. They learned that volcanoes occur along the edges of tectonic plates; they learned there are several different kinds of volcanoes; and they learned that the largest volcano on Earth is Mauna Loa in the Hawaiian Islands. Still they found no answer to the question "What is the largest volcano in the solar system?"

"Do you think anyone on our modem would know, Mrs. Stevenson?" a student asked. The students sent the question to Kidsphere, an Internet discussion forum where educators and students share information and activities (To subscribe to Kidsphere send an email message to kidsphere-request@vms.cis.pitt.edu). Within hours, several scientists responded to the students' question, informing them that Olympus Mons on Mars is the largest volcano in our solar system.

Stevenson then introduced her students to the scientific visualization tool NIH Image 1.55 [16] and a collection of Mars images taken by the Viking spacecraft (see Figure 1). Over the next few weeks, Stevenson and her students developed and tested a version of the activity Measuring Mars: A Visit to Olympus Mons that took into account the academic background and interests of fourth grade students. About this time, a draft of a second activity entitled Measuring Global Sea Surface Temperatures was completed. Stevenson and her students again volunteered to act as partners in the development of this activity (see Figure 2).

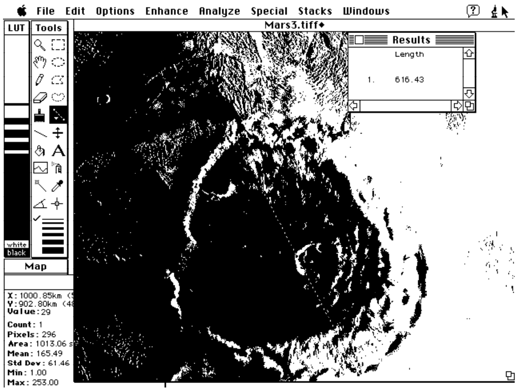

Figure 1
Measuring Mars: A Visit to Olympus Mons

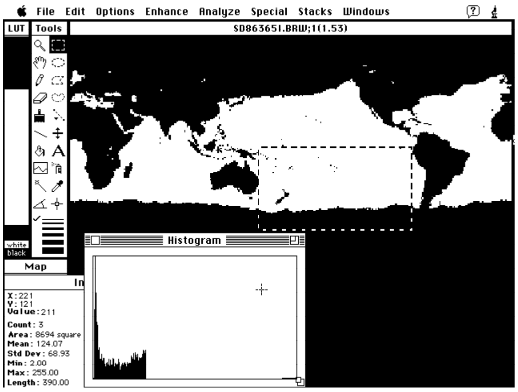

Figure 2
Measuring Global Sea Surface Temperatures

We have never seen a technology so appealing to students of all ages as scientific visualization. What is more important, we have never used a technology that evoked such a flood of genuinely insightful and thoughtful questions and comments. Students who normally confine their questioning behavior to clarification issues suddenly start making conjectures and suggesting possible means for gathering relevant information and testing hypotheses. This use of a powerful visualization tool, real scientific data sets, and the Internet appears to appeals to all students, even such students as Mrs. Stevenson's who have been identified as "at risk."

The Measuring Mars and Global Sea Surface Temperature activities have been described in an article [17] <ftp://mathfs.math.montana. edu/pub/ thomas/html/article.html>, and additional materials are under development. Curriculum products such as these may be used to link students and teachers to scientific data products published by NASA and other agencies on CD-ROMs and on WWW information servers. However, publication is not enough to guarantee usage. Teachers need to be trained to use the technologies effectively.

8 Teacher Training Projects

At the 1995 Secretary's Conference on Educational Technology <http://www.ed.gov/ TechConf/1995/> [18], United States Secretary of Education Richard Riley stated, "Schools and students have changed significantly in recent years, but teachers are still at the heart of instruction. If, as a nation, we expect to prepare all students for the 21st century, we must provide teachers with ongoing opportunities to be the most informed, the most capable, and the most inspiring classroom leaders possible." At the same conference Molly Merry, Colorado's 1995 Teacher of the Year, asserted that it is critical that teachers spend time throughout their careers updating their teaching skills and knowledge of how children learn. Today's teachers can improve continually through ongoing professional development that:

- Offers a long-term strategy to improve teaching and learning based on the best available research and practice in teaching, learning and leadership;
- Focuses on teachers as central to overall school reform, yet includes all members of the school community;
- Respects and cultivates teachers' intellectual capacities and enhances their skills and knowledge in pedagogy, content and leadership;
- Involves teachers in planning and commits ample time and resources for change in the classroom; and
- Is evaluated by its impact on teacher effectiveness, student learning and leadership, with the school community serving as a guide for future professional development efforts.

Currently, the educational community is exploring various models for developing and delivering Internet based professional development opportunities to K-12 teachers. The authors have some personal experience with the following programs.

- University of South Florida's Learn From a Distance (LFAD) <gopher://madonna.coedu. usf.edu:70/00/ dlinfo/about> program administrator, Lara Kiser, states that, "As a society, we tend to think of the "average" college student as young, single, childless, living on or near campus, and having the benefit of external financial support. This image does not reflect the diversified community of college students in the nineteen-nineties. Currently, the college population is also composed of working parents, full-time employees, and commuters who must drive several hours to attend classes. The educational system must respond to the changing needs of "real" students by developing alternative methods of delivering instruction. These methods must enhance the students ability to receive instruction and develop professionally." The LFAD program is responding to the needs of today's adult students in several ways. LFAD has been offering five or six courses per semester via telecommunications since the Spring of 1992. LFAD has an average enrollment of 70 students per semester and is reaching educators from as far away as Miami, Pensacola, Daytona, and Puerto Rico. For additional information email lfad@madonna.coedu.usf.edu.

- The Florida Information Resource Network (FIRN) <http://www.firn.edu/> operated by the Florida Department of Education electronically links all of Florida's public education entities to computing resources serving public education. Included in this mission is an on-going effort to provide a variety of professional development services for Florida's K-12 teachers. The FIRN Gopher Server now has a category called "Best of K-12 on the Internet" in the "Other K-12 Educational Resources" section. Teachers may search this area for current and upcoming Internet projects and new Hot Topics for discussion. FIRN also announces satellite and cable delivered telecourses for K-12 teachers from Distance Learning Associates (DLA), Florida Remote Learning Services (FLRS), Florida Public TV, and Discovery Communications (Elementary School, Assignment Discovery, Ready-Set-Learn, and Teacher TV). For additional information, call (904) 487-0911 or email go4adm@mail.firn.edu
- The Mathematics Learning Forum and the Bank Street College of Education offer four on-line professional development courses on NCTM-based mathematics instruction: Talking and Writing Mathematics, Classroom Discourse (K-4), Teaching Probability (5-8), Cooperative Learning: Working in Groups (K-4), and Fractions: Exploring Equivalent Forms (5-8). The forums are hosted by a graduate faculty member of Bank Street College and focus on the "how" of mathematics instruction, providing on-going support to teachers as they implement reform in their own classrooms. During each eight-week forum, teachers engage in on-line discourse with colleagues as they plan, revise and implement activities with their students, view videotapes of students and teachers in a range of school settings and discuss topic-relevant readings. Enrollment is limited to ten participants. A computer and modem or telnet access is required. Courses may be taken for graduate credit, inservice credit, or personal enrichment. For additional information, call 212-807-4207 or email nross@ confer.edc.org
- Montana State University's National Teacher Enhancement Network Project is developing and delivering distance learning courses to a nationwide audience of K-12 mathematics and science teachers under a grant from the National Science Foundation. Participants log on to the MSU computer network from home or work using 800 dial-up service or telnet. The Network provides teachers with high quality graduate science and mathematics education courses team taught by university faculty and cooperating K-12 mathematics or science teachers. It also enhances professional networking nationwide between science teachers and active research scientists. Course topics are selected based on input from science and mathematics teachers, identified needs from national surveys and reports, and current events taking place in science and technology. A variety of courses are offered each semester. Courses already developed include Snow Science, Water Quality, Relativity, Images of Earth, Food Safety, Genetics, and Visualization and Communication Tools for Mathematics and Science Teaching <ftp://mathfs.math.montana.edu/pub/thomas/ courses/main.html>, taught by David Thomas. For additional information, call (406) 994-6550 or email zxs7001@msu.oscs.montana.edu

9 Conclusion

The human and technological resources of the Internet cry to be harvested by teachers and students of all ages. Providing reliable, affordable access to those resources will take creative thinking and commitment on the part of technologists, teachers, parents, and many others. One of the functions of any scientific conference is to facilitate imaginative discussion among creative individuals. Teachers in touch with technology can imagine a compelling global schoolhouse. Parents and members of the Internet Society can imagine an educational system spanning the world that offers a life time of learning. Our colleagues and neighbors need to hear what we think the Internet can mean to teachers and life-long learners of all ages. We must lead the discussion. The imagining must begin with us. It is time for the discussion to begin in earnest.

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