DOCUMENT RESUME

ED 350 992 IR 015 807

AUTHOR	Tinker, Robert F., Ed.; Kapisovsky, Peggy M., Ed.
TITLE	Prospects for Educational Telecomputing: Selected Readings.
INSTITUTION	Technical Education Research Center, Cambridge, Mass.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	92
CONTRACT	MDR-9153955
NOTE	164p.; Papers distributed to participants attending the Consortium for Educational Telecomputing Conference (Cambridge, MA, April 18-19, 1991). For the proceedings of the conference, see IR 015 813.
AVAILABLE FROM	Technical Education Research Center (TERC), 2067 Massachusetts Ave., Cambridge, MA 02140 ($15).
PUB TYPE	Collected Works - General (020) -- Viewpoints (Opinion/Position Papers, Essays, etc.) (120) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	*Computer Networks; *Educational Change; Educational Cooperation; *Educational Innovation; Educational Technology; Electronic Mail; Elementary Secondary Education; *Government Role; International Communication; *Private Sector; School Restructuring; *Telecommunications
IDENTIFIERS	National Research and Education Network; *Telecomputing; Texas Education Network

ABSTRACT

The purpose of this collection of readings was to stimulate debate on the role of educational telecomputing in school reform and restructuring, and how efforts from the public and private sector can coordinate to bring about these changes. The 14 papers are entitled: (1) "Linking for Learning: Computer-and-Communications Network Support for Nationwide Innovation in Education" (Beverly Hunter); (2) "Networking for K-12 Education: Bringing Everyone Together" (John Clement); (3) "A Developer's Perspective on Telecomputing" (Candace L. Julyan); (4) "A Publisher's Perspective on Telecomputing" (Monica Bradsher); (5) "The Network Science Experience: Learning from Three Major Projects" (Cecilia Lenk); (6) "Building Electronic Communities: Success and Failure in Computer Networking" (Margaret M. Riel and James A. Levin); (7) "Electronic Communities of Learners: Fact or Fiction" (Sylvia Weir); (8) "Alice: Telecommunications for Education" (Patricia Parker); (9) "Considerations Underlying the Architecture of a State Public School Telecomputing Network" (Glen L. Bull, Cameron M. Harris, and Harold Cothern); (10) "TENET: Texas Education Network" (Connie Stout); (11) "Networking the Future: We Need a National 'Superhighway' for Computer Information" (Al Gore); (12) "IGC (Institute for Global Communications) Networks and Education" (Bill Leland); (13) "International Telecomputing" (John Foster); (14) "Introducing Telecomputing to Soviet Schools" (Boris Berenfeld). (ALF)

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Funding was provided primarily by the National Science Foundation, grant # MDR-9153955. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

CONTENTS

PREFACE

Prospects for widespread implementation of computer-based telecommunications—telecomputing—in pre-college education are favorable if educators and policymakers articulate a strong position now, as the fragmented telecommunications debate swirls around the country. There is no doubt that telecommunications technology will improve tremendously in the next few years, creating what many observers think will be profound changes in our society. Part of this impact will be on education. Some of the changes in education are, in fact, already occurring, and you will read about programs, services, networks, and software, as well as issues and obstacles, in the following pages.

This collection of readings was put together primarily because of TERC's belief that educational telecomputing can play a central role in school reform and restructuring, and that states, provinces, communications companies, and other major organizations must coordinate their efforts to bring about these changes. To promote such efforts, TERC organized the Consortium for Educational Telecomputing Conference. Held on April 18-19, 1991, in Cambridge, Massachusetts, and funded by the National Science Foundation, the Conference draw together more than 50 delegates from 32 states and 2 Canadian provinces.

The Conference was designed to be short and intense in order to attract important decision-makers and planners, and participants met in five Working Groups to discuss, debate, and achieve agreement on a number of critical issues.[1] To provide introductory concepts and thought-provoking ideas and to stimulate debate, a set of papers was commissioned and distributed to participants. We present these papers here, slightly revised and updated for timeliness, in the hope that they will provoke lively discussion and lead to thoughtful decisions related to educational telecomputing.

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1 Published as *Consortium for Educational Telecomputing: Conference Proceedings* (1992), R.F. Tinker and P.M. Kapisovsky, eds. Cambridge, MA: TERC.

Linking for Learning: Computer-and-Communications Network Support for Nationwide Innovation in Education[1]

by Beverly Hunter

Introduction

Thousands of educators across the United States, supported by citizens in all walks of life, are working to reform our educational system. Leaders in all sectors seek an educational system more flexible and responsive to constantly changing needs of learners of all ages. This great challenge requires new kinds of collaborations across previously separate institutional boundaries and among individuals whose work was previously isolated from one another.

Computer and telecommunications technologies can support these collaborations and help provide more equitable access to expertise, information, and tools. Fortunately, the National Research and Education Network (NREN) is being developed now, just at the time when educational reformers are beginning to see the need for computer and communications support. The recent report, "*Grand Challenges: High Performance Computing and Communications*" by the Committee on Physical, Mathematical and Engineering Science of the Federal Coordinating Council for Science, Engineering, and Technology clearly calls for the participation of both educational and research instutions in the NREN:

> The vision of the National Research and Education Network (NREN) is of an interconnection of the nation's educational infrastructure to its knowledge and information centers. In this system, elementary schools, high schools, two and four year colleges, and universities will be linked with research centers and laboratories so that all may share access to: libraries, databases, and diverse scientific instruments such as supercomputers, telescopes, and particle accelerators.
> (FCCSET 1990, p. 18).

The NREN is part of the Federal High Performance Computing and Communications Program. The HPCC Program is driven by the recognition that unprecedented computational power and capability is needed to investigate and understand a wide range of scientific and engineering "grand challenge" problems. These are fundamental problems whose solution is critical to national needs. We have an opportunity now to

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1 Reprinted from *Journal of Science Education and Technology*, Volume 1, Number 1, by permission of Plenum Publishing Corporation.

design and build the networks in ways that help meet the educational problems whose solution is equally critical to national needs.

This paper describes some of the efforts of the National Science Foundation to support the work of educators and technologists in building national communications-based infrastructures in education. The paper:

- explains educational needs and technological opportunities that motivate this work.
- characterizes the current status of educational networking.
- identifies challenges to be met in laying the foundation for a national network to serve all learners and teachers.
- sets forth goals to be met over the next few years.
- explains one Federal agency's strategies for achieving those goals.

This plan was developed in consultation with, and builds upon the strengths of, the technological, scientific, and educational communities working with and supported by the NSF. It builds upon current and past successes in building telecommunications networks such as NSFNET and regional academic networks for scientific research and higher education, the successful model of supercomputer centers, and the associated network applications to scientific research. The plan builds upon NSF's current and historical role in fostering curriculum reform, pedagogical innovation, and teacher enhancement; encouraging scientist participation in science education; advancing the state of knowledge concerning effective learning and teaching; advancing the state-of-art in technology applications to learning and teaching; and championing excellence in education.

Computer Networks and Grand Challenges

Our society is changing more rapidly than in the past, and the problems we must address are more and more complex. Throughout business, industry, government, and scientific enterprises, people are inventing new ways of organizing their work so they can more effectively meet continually changing challenges and solve complex problems.

Some of these complex problems, called "Grand Challenges" in science and technology, are described in the Federal High Performance Computing Program report issued in September 1989, and in the *Grand Challenges* report of the Federal Coordinating Council for Science, Engineering and Technology (1991). Consider, for example, how computer-and-communications networks help scientists meet the "grand challenge" of understanding the earth's biosphere:

> In order to predict the directions and consequences of changes in the state and condition of the biosphere, detailed scientific models are required, which in turn are constructed from massive amounts of experimental and computational data. Experimental information is derived from satellite and ground based sensors. By the late 1990s, the sensors will have the resolution required to provide data in support of much more accurate and informed decision making on issues such as pollution and global warming. Because the sensors will generate terabytes of data each day, which will be combined with local data sets on the ecosystem, major improvements in the capability for collecting, analyzing, distributing and archiving data are necessary. The effort of constructing valid scientific models which describe the dynamics and underlying processes of the biosphere will involve interdisciplinary teams of experts from the geophysical, life, physical, computer, and computational sciences. They will work together (through distributed computer systems via telecommunications networks) to construct computational models which will validate our empirical understanding of the biosphere, and help predict how worldwide activities affect the global ecosystem. Computer and computational scientists will develop the advanced software technology and algorithms for handling massive amounts of data and working with high resolution, coupled models of the earth's atmospheric-biospheric-oceanic interactions. Efforts in software development and experimentation will predict how local current conditions may impact future global conditions allowing the linking of ecosystem models to global climate models. The result of this collaborative effort will be a much deeper understanding of our environment and the impact of human activities upon it. (FCCSET, 1991 p. 52).

At the same time that scientists are engaged in this long term research, economic and political decisions are being made that must be informed by whatever current scientific understanding can provide. America's citizens must comprehend scientific processes and understandings as they emerge. Thus, closer links are needed between the scientific and the educational world than in the past. This is one reason why it is so important for educators, learners, and scientists to be interconnected on the same networks. The Federal government's *U.S. Technology Policy* (Executive Office of the President, 1990) includes education and training as a major element:

> Revitalize education at all levels including not only the training of scientists, engineers, and the technical workforce, but also educating our population to be sufficiently literate in science and technology to deal with the social issues arising from rapid scientific and technical change. Achieving such a goal will require a broad-based approach involving business, academia, and educational organizations, as well as Federal, state, and local governments. (p. 5).

Meeting Grand Challenges Requires New Collaborations

Current efforts at reform and restructuring of education aim towards changing what the education system does, not simply improving what it is already doing (e.g. Bank Street, 1990). While many important individual reforms are aimed towards changing what happens in classrooms, the more general thrust is towards restructuring the overall educational system to make it more functional for and responsive to needs of lifelong learners in the information age.

The educational reforms apply not only to school children and how they learn, but to all participants in the educational system. Creative ideas and energies for reform and innovation are initiated from all quarters in our decentralized educational system — from teachers, parents, business people, district superintendents and staff, school boards, college faculty, governors, state legislators, teachers' unions, foundations, educational researchers, staff of federal and private funding agencies, staff of science museums, television and radio producers, publishers, and many other sources.

Just as the "grand challenges" in scientific research involve collaboration among geographically disparate institutions, disciplines, and individuals, so the grand challenges of educational reform require new kinds of collaborations across previously separate institutional boundaries and among individuals whose work was previously isolated from one another. Educational researchers are teaming with classroom practitioners to form action research collaboratives. Industry scientists and engineers are serving as mentors for teachers and high school students. Parents and teachers are networking with school board members. Interdisciplinary experts at supercomputer centers are working with high school teachers. Professors and graduate students in physics are working with inner city science teachers and their students to test new ideas about how computer-based simulations and visualization tools can make complex ideas understandable to students. Children and adults are collaborating with and learning from their peers in diverse schools all over the world.

In mathematics education, a broad coalition of mathematicians, mathematics educators and researchers, teacher educators, teachers, curriculum developers, state and local educational administrators, are collaborating in the implementation of the NCTM mathematics education standards, which represent a significant change in the way mathematics education will be conducted throughout the country. In science education, closer linkages among research scientists, teachers and learners enable all to participate in methods, tools and content of current scientific investigations. The AAAS Project 2061 (1989) is undertaking the challenge of achieving a new consensus on fundamental concepts needed by all Americans. Such agreement would free teachers and students to investigate and understand fewer, powerful ideas in more depth rather than covering an ever-increasing amount of required facts and content.

Computer-communications networks can be designed and used to help these diverse individuals and groups form new kinds of virtual communities to facilitate the reform and restructuring processes, in a manner analogous to the collaborative processes of contemporary science described above, and in ways that mirror the innovative work styles in modern business and industry. As the Office of Technology Assessment of the U.S. Congress found in its study of distance learning:

> Distance education makes feasible the linking of all levels of education — elementary, junior, and senior high to higher and continuing education. This fact has great significance because of the widespread current interest in restructuring many aspects of education. Distance learning networks that link universities, schools, and informal learning institutions, such as museums and public libraries, lead not only to expanded services but to new relationships. (Congress, 1989, p. 7).

Educational Reform Opportunities Provided by Computer-Communications Networks

We have a window of opportunity. The national and international telecommunications infrastructure is being engineered and deployed at the same time as new structures are sought for education. The telecommunications infrastructure can be engineered and deployed in such a manner as to support not only specific desired reforms in education, but indeed the very processes of making those reforms.

Illustrative challenges and trends in education, with some of their implications for computer-communications networks, are highlighted in Table 1. This collection of ideas about some of the challenges and trends in educational reform is intended to illustrate reasons why some educational reformers want to take advantage of computer-communications networks, as well as to suggest some of the considerations that need to be taken into account in the design of networks and networked communities.

NSF History in Computer-Communications Networking

The NSF has been supporting scientific research and educational innovation through the use of computer-communications networks since the late 1960's. The following are a few examples of research and educational networks projects and programs over past decades:

- 1968 — Thirty regional computer networks were established, beginning in1968, to develop both research and educational applications. They were the forerunners of the mid-level networks that form a key part of today's NREN infrastructure.
- 1968 — Dartmouth formed a league of secondary schools networked to Dartmouth's timesharing computer.
- 1970 — After several years of NSF-supported research and development, the University of Illinois began building the national and now international network of 3,000 educational stations using the PLATO system.
- 1969 — Stanford began delivering mathematics instruction to low-income students in Mississippi, Kentucky, and California via computer networks.
- 1981 — CSNET was established to facilitate research and education in computer science and engineering.
- 1984 — NSF began establishing supercomputer centers and designing a network (NSFNET) to provide access for grant recipients to the centers. A standard protocol (TCP/IP) was chosen for networking, that would make it possible for users of different networks to be interconnected.

Table 1: Some Educational Challenges and Their Implications for Design of Computer Communications Networks

Educational Challenges and Trends	Implications for Educational Telecommunications
Meet needs of increasingly multi-cultural populations. Numerous efforts are underway nationally; but schools vary widely in their access to expertise and new resources.	• In all educational projects, take advantage of telecommunications to speed access to new instructional materials , methods, and teacher collaboration opportunities. • Ensure inner-city & rural communities have access to network resources. • Apply internet standards to ensure interconnection of network communities.
Reform instructional methods and curriculum and restructure schools to better meet needs of diverse students and information-age society.	• Support reform and restructuring efforts of teachers & ed institutions, by providing access to: research on teaching & learning; experiental know-how; -alternative instructional materials and learning methods.
Forge closer linkages among school, community, industry, and home; essential to restructuring and contextualized learning.	• Build local network connections & organization to facilitate parent involvement, business partnerships, community organization linkages.
Quantitative & scientific inquiry skills, problem formulation, information handling are high priority goals for all learners.	• Design network communities to enable learners and teachers to access expertise, tools, and data they need as they develop skills and understanding to address real, complex problems.
Collaborative learning is increasingly desired goal and classroom method. Shift from competitive or individual to collaborative modes of learning presents major challenges.	• Engineer the network projects, software, and structures to support collaborative learning (e.g. computer-supported cooperative work). • Design school LANs and district infrastructure to support collaboration.

These few examples illustrate several points. The NREN structure is built in part upon the regional networks that from their beginnings over two decades ago have had both research and educational purposes. Current efforts in educational networking can take advantage of a long history from a variety of models of networking. Adoption of TCP/IP standard protocols has made it possible to create interconnected networks on a large scale.

Currently, the Foundation is extending the capability and reach of the NSFNET and integrating it with networks of other agencies involved in building the NREN. The NSF has the lead responsibility of coordinating the other agencies involved in deploying the NREN. At the same time, NSF is supporting basic research on network architectures and management; protocols; fiber optic networks; and communications technology. Another critical component is a wide range of network information services.

Table 1: continued

Educational Challenges and Trends	Implications for Educational Telecommunications
Constructivist views of learning are influencing design of new curricula and pedagogies, but transmissionist assumptions are very deeply embedded in school culture.	• Design network software, resources and virtual communities to meet needs of learners and teachers engaged in actively constructing knowledge and solving real problems.
Computer-and communications technology is changing the methods and content of scientific research, but curricula and teacher knowledge will need continual updating.	• Need for curriculum, tools and materials development using advanced computational techniques. • Take advantage of networks to facilitate collaborations among scientists, technologists and educators, to help update teachers' knowledge of new scientific tools, methods & findings. • Provide teachers & students with access to tools and data, such as visualization software, modeling tools, scientific databases, distributed computers.
Assessment of student learning should be based on quality of students' understanding, products, and portfolios rather than multiple choice tests; but testing system is deeply entrenched.	• Design network activities and structures such that students have real audiences and meaningful feedback for their work. • Build mechanisms for quality control and assessment of student work into network communities and activities.
Action research by teachers is becoming more valued as teachers take innovator roles; but new support structures and incentives must be built in to the system.	• Facilitate teachers' collaboration, feedback, and access to each other's findings.
Recent research provides valuable guidance for improving learning and teaching, but gap between research and practice is wide.	• Enable closer linkage between educational researchers and practitioners.

Present Network Support for Educational Innovation

Today, thousands of teachers and students throughout the U.S. and the world are involved in hundreds of projects supported by computer-communications sometimes in conjunction with related technologies, including satellite telecommunications and instructional television. The projects are testing new models for the conduct of learning and teaching and for certain aspects of educational restructuring.

Table 2 provides a selection of examples of current operating network projects for eight educational purposes.

The nation's experience with educational network projects such as those listed in Table 2 is helping to inform its goals, strategies, and plans for building the national communications infrastructure for educational and research purposes. Hundreds of the

Table 2: Purposes for Using Computer-Communications Networks in Education, with Selected Example Networks

Educational Purpose	Examples — Operating Network Projects
Professional Collaborations among Educators/Teachers	• Chief State Science Supervisors' Network (NSF) • National Education Association School Renewal Network • FrEdMail (NSF)
Students' Collaborative Investigations	• NGS Kids Network (NSF) • TERC Global Change Network (NSF) • FrEdMail (NSF)
Students' and Teachers' Access to Scientific Expertise	• InSite (Indiana) (NSF private sector partnership) • TeleApprenticeships (U. Illinois) (NSF)
Students' and Teachers' Access to Information (libraries, databases)	• National Geographic Weather Machine • NASA Spacelink
Students' and Teachers' Access to Computing Resources (machines, software)	• Superquest (NSF) • Big Sky Telegraph (Montana)
Collaborative Development & Electronic Delivery of Instructional Materials	• Curriculum Resources for Earth Science Teachers (Maine) (NSF) • Engineering Education Coalitions (NSF)
Teacher Education & Enhancement	• Teacher Link (U Virginia) • Beginning Teacher Network (Harvard) • BSCS Science Teacher Enhancement Network (NSF) • Educational Network for American Natives (U New Mexico)
Electronic Publishing of Students' Products	• AT&T Long Distance Learning Network • Associated Student News Network (U. Alaska)

teachers and other educational innovators involved in such projects have provided and continue to provide input to planning related to this topic. The NSFNET itself is an enabling technology that makes possible this collaborative planning process between Foundation staff and the field.

The following are just a few of the outcomes and lessons that have been learned from such projects:

- Elementary school children and their teachers can participate productively in scientific research on matters of national and international consequence (e.g., "acid rain"), in collaboration with distant learners and scientific advisors.

- High school students and their teachers can conduct high quality scientific investigations with the aid of supercomputers, associated visualization software tools, and access to scientific advisors.

- Children write better when they have real audiences for their compositions. The networks provide a convenient mechanism for children to publish their work to disparate audiences, often in other countries.

- Computer communications networks provide a mechanism through which private industry can make substantive contributions of expertise directly to students and teachers in schools, conveniently and at acceptable cost.

- Computer communications networks can support professional collaborations and rapid diffusion of knowledge among educational leaders.

- Teachers are more likely to plan curriculum, discuss innovative instruction methods, exchange ideas, and support one another if their students are engaged in a compelling online classroom project.

- Effective network learning activities require clear purposes, careful planning and ongoing labor-intensive support, and these requirements must be taken into account in project staffing and budgets as well as in the development of network mechanisms to charge for their services. Some networks projects have been unsuccessful, mainly due to lack of such purposes, planning, and support.

Past and current experience of teachers and learners involved in educational telecommunications projects provides valuable information about not only the potential benefits but also the obstacles to be overcome if productive use of such networks is to be possible for everyone. Some of the lessons learned in this regard are identified in the growing literature in this field (e.g., see Harasim, 1990).

The following are some of the most pressing of the obstacles to productive use of the telecommunications network in support of educational reform:

- There does not yet exist consensus among all the stakeholders (Federal agencies, State and local education agencies, private industry) as to the overall network architecture, its governance and financing.

- There is very little at present in the way of local school and school district communications infrastructure — e.g. telephones, local area networks, desktop computers. This is an obstacle to equitable and collaborative teacher and student participation in projects and activities. In colleges, universities, research laboratories, and private industry, it is more commonplace for workers, teachers and learners to have access to telephones, desktop computers, and local area networks.

- Teachers and students in few schools enjoy full Internet access and functionality. Typically, a teacher participating in a network project is involved in a particular network community or service that is isolated from other networks. The need for a coherent national communications infrastructure is becoming more obvious as more and more separate networks get established.

- Currently available computer software that enables a person to interact on the networks is difficult to learn and use.

- Few of the people with technological expertise in networking have an understanding of the educational applications and reforms. Conversely, few educational leaders understand the technology. The cadre of people who understand how to build and manage productive online communities and learning activities needs to increase quickly if the technology is to be deployed productively for educational purposes

- School curricula and instructional methods are not designed to take advantage of extensive resources such as electronic libraries, data bases, and software that are accessible through the Internet. Most of the information resources that are accessible through the Internet are not in a form that is usable by teachers and students.

- There are some compelling examples of successful and productive network applications in education, but many more models are needed.

Building National Telecommunications Infrastructure for Educational Reform

The mission and capabilities of the National Science Foundation suggest two appropriate and interconnected roles for this agency in building the national telecommunications infrastructure to support education. These roles include building both the educational and the technological foundation for nationwide networking for learning and teaching. In both roles, the NSF provides intellectual leadership, coordination with other agencies and stakeholders, and financial support to teams of educators and technologists from a wide range of institutions who initiate and conduct the actual work.

Building the educational foundation

One of the NSF's roles is to create, and advance our understanding of, new paradigms for education made possible by computer-communications networks. The NSF supports hundreds of high-quality teams to conduct educational research, applications of advanced technology, instructional materials development, informal science education, teacher preparation and enhancement, private sector partnerships, undergraduate curriculum, and many kinds of systemic change projects. These projects involve learners, teachers and experts at all levels of education and among all kinds of institutional settings including elementary, secondary and vocational schools, state and local education agencies, postsecondary institutions, science centers and museums, television producers, community-based organizations, industry, research laboratories, professional societies. Because of its twin missions of supporting scientific research as well as education, the NSF fosters linkages between children and teachers in classrooms and research scientists.

When such diverse innovative projects incorporate and study the effectiveness of a computer-communications component, they can contribute to the building of a coherent national support system for education in the following ways:

- They create new "virtual communities" made possible through online collaborations of experts in various disciplines, teachers, students, curriculum developers, teacher educators, teachers-in-preparation, professional societies, state education agencies, and others involved in science education. Such online communities enable more teachers and students to participate in federal, state, and industry supported education projects or scientific research areas such as global change research.

- They have a common interconnection via the NSFNET/Internet, which already interconnects scientists and engineers in higher education and industry. The innovative educational networking projects add to the number of teachers and students having access to the National Research and Educational Network and to each other.

- They add to the repertoire of educational resources and innovations on the NREN. As learning goals, curricula and classroom practices are changing, educators and students will need access to resources such as instructional materials, software, research reports, assessment methods, problem sets, data bases, digital libraries, specialized instrumentation, remote sensors and computational facilities.

- They make such resources more accessible to students and teachers. Providing rapid and widespread access to such resources should significantly multiply the impact and benefits of investments in educational innovations.

- They will contribute to the accumulating base of know-how and vision of new paradigms for learning and teaching.

A major purpose of these educational projects is to advance our understanding of factors affecting the effectiveness and productivity of new educational structures and processes, such as effective ways of organizing group projects, support and incentives for scientist-teacher collaborations, organizational arrangements for innovations such as online mentoring, teleapprenticeships, peer collaborations, virtual classrooms, student participation in scientific research projects.

Building the technological foundation

The second of the Foundation's roles is to support research and development of computer software, standards, and user services to support educational applications of the NREN. In this role, the Foundation builds on its current leadership in high performance computing and the NSFNET. The Foundation supports development of technology and services such as those needed to:

- enable non-technical educators and scientists to use network resources without extensive training;
- assist students and teachers in locating, accessing, retrieving, and manipulating data from large data bases;
- assist learners and teachers in locating communities, projects and resources on the network;
- teach teachers how to use online resources in the classroom;
- provide low-cost, easy-to-use connections to the networks.

The Foundation's research, development, and innovation roles in this national effort complement roles of other agencies and stakeholders. Through the Federal Coordinating Council for Science, Engineering and Technology, the Foundation coordinates with other federal agencies involved in building the National Research and Educational Network. Through its State Systemic Initiatives and other programs, the Foundation collaborates with state and local education agencies that play a key role in implementing local and state communications infrastructure. Through its NSFNET programs, the Foundation works closely with the mid-level networks organizations and private industry firms that play a key role in providing the needed technological base and expertise for building the networks.

Goals and Timetables

A reasonable goal is to have in place by 1995, the intellectual, technological, educational, and organizational foundation necessary for productive and efficient use of computer-communications networks for education on a nationwide scale. Essential elements of this foundation include:

- High-quality models and proof-of-concept projects of effective, compelling network applications for a wide range of educational purposes.
- Measures and models of educational and economic benefits, how-to-do-it, costs, performance parameters, and financing.
- Participation in educational innovation projects by learners of all ages; teachers, experts and decisionmakers from all geographic regions; rural, suburban, and urban locations; institutional and organizational settings including public and private sectors.

- Consensus among stakeholders on an explicit national plan for connecting educational and community institutions to the Internet/NREN. This must include local, state, and national infrastructure, and involves clarifying roles of public and private stakeholders.

- Software, hardware and know-how available to communities, schools and districts for building their local communications infrastructure in ways productive for educational reform.

- Software tools for creating and managing productive educational applications accessible to educators.

- Substantial numbers of educational and technology leaders who are knowledgeable about the state-of-art, visions, and prior research.

- Educational networking communities enjoying full access to NREN resources (i.e Internet compatibility).

- Technical support for networking available to educational institutions at all levels.

- Accounting mechanisms enabling for-fee educational services and products to be made available through the NREN.

- Network management infrastructure to enable very large scale participation in the NREN.

This foundation for productive educational change with support of computer-communications technologies will enable state and local education agencies and other stakeholders to complete the implementation of a full-scale national networking system in a cost-effective manner. In this way the nation as a whole will avoid enormous costs of duplicative development and uncoordinated approaches, and use the technologies in the most productive ways available to support reform and improvement in learning and teaching nationally.

Strategies for Building the Foundation

To achieve the above goals, many research, development, and knowledge dissemination efforts need to be undertaken. In the NSF's program for Applications of Advanced Technology, priority is given to accomplishing the following in the context of such projects:

Knowledge dissemination

If educators and technologists are to visualize, formulate, and implement productive projects involving telecommunications, they need to become knowledgeable about the technological, sociological, and pedagogical opportunities and constraints. There is need for understanding of the following:

- NSFNET, the connected Internet, and TCP/IP protocols: concepts, resources, access, connections, operations;
- local (school, school district, community) communications infrastructures needed to enable school- and community-wide participation in innovation and take advantage of wide-area networks;
- characteristics of productive network communities and participant structures;
- design of effective learning activities to take advantage of telecommunications and the resources on NREN;
- teacher-specific education to use computer communications to enhance their teaching practice and professionalism.

Creating educational networking know-how

Research, development and proof-of-concept activities are needed to advance the state-of-art in educational networking. The following are examples of areas of need:

- Identification of factors in design and management of virtual communities that contribute to successful functioning of community (e.g. what should be the nature of the interactions; how should leadership be provided; how should learning activities be organized; how should tasks get defined; what response obligations are expected;
- Identification of factors (pedagogical, technical, administrative, curricular) affecting design of effective collaborative learning activities;
- Creation and testing of models for development, production, distribution and support of instructional materials;
- Identification of factors contributing to successful participation of experts in educational network activities — e.g. industrial mentor programs; teleapprenticeships.
- Identification of incentives for vendors of instructional materials and software to participate in online dissemination mechanisms;
- Development of evaluation and monitoring criteria and mechanisms for networked learning activities and network communities;
- Creation and testing of models for effective participation of home, community organizations, in educational activities;

- Measurement and characterization of effects of widespread network access — intended and unintended

- Establishment of mechanisms to continually update the field re learnings from research and development activities; network mechanisms for this.

Software development:

Prerequisite to the conduct of large-scale projects are a number of advances in software, such as:

- software to support productive functioning of various kinds of online educational communities;

- software to support productive functioning of the NREN for educators and students: e.g. tools to enable educators to easily locate and extract relevant information; integrated tools for access, information filters, file transfer, project management, database access; standards for tool development; visual modeling facilities for science and math education;

- software to support productive functioning of local communications infrastructure for schools and school districts, whole-district models, schoolwide models, network management tools;

- software to support collaborative work among distant learners;

- integration of local and long distance communications capability into existing and new educational software applications such as simulations and database software;

- software to support physically handicapped participation in network activities;

- standards for user interface in network applications.

Connections; NREN infrastructure

Progress is needed on several fronts in deploying the NREN infrastructure in preparation for large-scale participation of educators and students in the network:

- a variety of technical and organizational mechanisms for connecting educational institutions, community organizations, and existing educational networks to the NREN (e.g. schools located in remote areas);

- explicit national plan for connecting educators and educational institutions to NREN (e.g. roles of State Education Agencies and school districts);

- creation, update, and access to directories of network services and communities;

- accounting mechanisms for paying for services on networks;
- technical support infrastructure for educational users of networks;
- experiments with contributions of a wide range of media, e.g. video conferencing, wireless networks, coupling learning environments with video; virtual laboratories; simulation of instruments.

To provide maximum benefit to educational reform and the building of telecommunications infrastructure, projects have the following characteristics:

- Have *educational grand challenges* as the central focus. For example, TERC/NGS Kids Network provides a compelling example of how elementary school children can do science and contribute to scientific investigations, in collaboration with other children and scientists on the network.
- Build upon current knowledge about *learners' and teachers' needs*, learning processes, effective learning environments, and change processes in education. Much more is known about effective teaching and learning than is currently implemented in educational practice. Networks can help to bridge this gap.
- Not only create and operate, but more importantly contribute to our understanding of, *new organizational arrangements* in education, such as those involving collaborations among scientists, educators, teachers and students in higher education and elementary/secondary schools, and those involving connections between industry and schools.
- Contribute to the building of local, state, or national telecommunications infrastructure for education. Serve teachers and students most in need of new mechanisms for access to expertise and materials, due to geographic, cultural, physical disability, or other barriers. State-wide and regional efforts that can ultimately contribute to national infrastructure are critical, as are national projects that serve "virtual communities" with common needs.
- Be compatible in design with current and evolving NSFNET, Internet and NREN plans and standards.
- Take into account and build upon *prior research, development and experimentation with educational networks and online education*. Over the past decade several dozen online education R&D projects have been documented to the extent that others can learn from their experiences. For example, Margaret Riel and Jim Levin have written several papers describing the factors contributing to success of online communities (Riel & Levin, 1990; see Riel & Levin's "Building Electronic Communities: Success and Failure in Computer Networking").
- Produce knowledge about network communities and activities, that can be disseminated to others who are planning similar work.

Conclusions

The Grand Challenges in education are as difficult, complex, and important to society as the scientific and technological Grand Challenges the NREN is intended to support. Many different groups seek to create a new educational system more flexible and responsive to changing needs of learners of all ages. Just as the grand challenges in scientific research require network support for collaboration among geographically disparate institutions, disciplines, and individuals, so the grand challenges of educational reform require new kinds of collaborations across previously separate institutional boundaries and among individuals whose work was previously isolated from one another.

We have a window of opportunity. The national and international telecommunications infrastructure is being engineered and deployed at the same time as new structures are sought for education. Know-how about productive educational applications of computer-communications has been gained from previous and current projects. Productive projects in educational telecomputing will focus on the grand challenges of education, and at the same time help to build appropriate telecommunications infrastructure for education. While the NREN efforts focus on building national computer communications capacity, the grand challenges of education require that state and local communications infrastructure be built as well.

A reasonable goal is to have in place, by 1995, the intellectual, technological, educational, and organizational foundation necessary for productive and efficient use of computer-communications networks for education.

References

American Association for Advancement of Science (1989). *Science for All Americans: A Project 2061 report on literacy goals in science, mathematics, and technology.* Washington DC: AAAS.

Bank Street College of Education Center for Technology in Education and National Center on Education and the Economy (1990). *Restructuring for Learning with Technology.*

Congress of the United States Office of Technology Assessment (1989). *Linking for Learning: A New Course for Education.* Government Printing Office, Washington D. C. 20402-9325.

Executive Office of the President, Office of Science and Technology Policy (1989). *The Federal High Performance Computing Program.* September 8, 1989.

Executive Office of the President, Office of Science and Technology Policy (1990). *U. S. Technology Policy,* September 26, 1990.

Federal Coordinating Council for Science, Engineering, and Technology, Committee on Physical, Mathematical, and Engineering Sciences (1991). *Grand Challenges: High Performance Computing and Communications*. The FY 1992 U. S. Research and Development Program, February 1991.

Harasim, L. M. (1990). *Online Education: Perspectives on a New Environment*. New York: Praeger.

Riel, M. M., and Levin, J. A. (1990). Building electronic communities: success and failure in computer networking. *Instructional Science 19:* 145-169.

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NETWORKING FOR K-12 EDUCATION: BRINGING EVERYONE TOGETHER

by John Clement

Introduction

The argument pursued in this paper can be summarized as follows. There are many current developments and much debate about networking for K-12 education; many resources exist and many more are being developed or considered. However, there are a number of unresolved obstacles to widespread adoption of networking.

Stepping back from the current ferment, there are good reasons why, in principle, K-12 practitioners and resources should be linked with each other and with the nation's scholars, researchers, postsecondary educators, and information resources. A case can be made that this would be an effective (and cost-effective) way to support institutional restructuring and curriculum reform efforts now being attempted.

The case for networking needs to be convincingly articulated with evidence, argued out by the education community, and brought to national debate. Meanwhile, advocates can evolve a plan of action and begin implementing it.

The core of this paper is an annotated listing of existing network resources that serve K-12 education. Although this listing consists of everything known to the author, it should not be viewed as complete or definitive. The remaining parts of the paper sketch its lines of argument more schematically. This work should be viewed as work in progress; further entries to the list of resources, development of arguments or counterarguments, comments, or evidence (whether supportive or contrary) from readers are welcomed.

This list summarizes known networks, affinity groups, projects, services, and information resources serving K-12 education[1]. Wherever known or believed estimable, the numbers of participants or account holders are given; these numbers are not, however, to be relied upon without verification. When known, connectivity to the Internet is given.

[1] Current as of April 1991.

State-level, Regional, or Affiliative Networks

AZ EdLink: Provides electronic mail (800 dial-up), Internet, and FrEdMail access through a bulletin-board service to Arizona educators; run by Leids Communication/SINet.

Big Sky Telegraph: dial-in system linking 114 Montana rural schools with information resources, mentors (for example, university faculty collaborations with teachers), and community development projects. Free access (800 line); excellent menu-based interface. College courses offered by e-mail. Used in other states as an economic development resource.

ChemNet–Hawaii: A cooperative venture among Hawaiian schools, the University of Hawaii Laboratory School, and the Hawaii Science Teachers Association. Links chemistry teachers. Includes e-mail and bulletin boards.

Cleveland Free-Net–National Public Telecomputing Network (NPTN): Cleveland Free-Net is a multi-user community computer system serving northeast Ohio, based at Case Western Reserve University. Working via dial-in and with full Internet connectivity, the system offers e-mail, chat, Teleport (real-time connections to Internet computing and information resources nationwide), and a wide range of its own information resources (for example, full text of Supreme Court decisions). For schools with Internet access of their own, the creators of the Free-Net have devised a program called Academy One, in which schools may operate their own special interest groups, run bulletin boards, and link with other schools, all at no cost beyond that of the equipment needed for Internet access. One remarkable current effort of Academy One is a simulated Space Shuttle program, in which schools communicate with a full-scale shuttle mockup and control room during real-time simulations carried out in connection with actual shuttle launches; for example, in an April 1991 simulation run, a Finnish school provided weather reports for a secondary emergency landing site. Another program is their Virtual Worlds Simulation Project. The NPTN group is seeking to export the Free-Net model to other settings.

Delaware Statewide Telecommunications Network: Dial-up system available to school districts, universities, or state agencies. State subsidizes half of the costs. Used for administrative computing; also has bulletin board with conferencing facilities and e-mail.

Distance Learning North Dakota (proposed): Actually would be two networks. The first is a video network, connecting schools into eight regions across the state, and then hooking the regional nets into a T1 backbone. The second net would use the same backbone, but would be for students, faculty, and administrators, as well as for college extension and GED courses and for Native American groups.

Educational Native American Network (ENAN): Dial-in access; originally targeted to Native American schools; with approval, others may access this network for discussions and information, to converse with Native American students, and for courses from the University of New Mexico. Sponsored by the Bureau of Indian Affairs.

Educators' Electronic Exchange (EEE)–Iowa: A network for school superintendents, linking them to each other and to mentors.

Florida Information Resource Network (FIRN): FIRN connects all public education entities in the state: schools, libraries, 2- and 4-year colleges, and universities. Originally established for administrative purposes, it is now expanding into instruction. Local dial-in capabilities exist for the entire state; technical support is available through regional centers. Access to FIRN is free; access through FIRN to the Internet (via BITNET) is available for $5 per month plus mainframe CPU charges. About 1000 K-12 users estimated.

Free Educational Electronic Mail (FrEdMail): Built around "franchised" nodes run by volunteers, FrEdMail is an international network devoted to K-12 education. Its structure allows menus to combine local and selected national items. Many projects at all levels: "noon observing," global shopping survey, cultural exchanges. Gating software for Internet connection anticipated soon. About 125 nodes; some 5,000 users estimated in the United States, Canada, Australia, Europe, and South America.

Georgia College Educators' Network (GC EduNET): Provides e-mail, conferencing, file sharing, on-line databases to educators and educational administrators statewide. Dial-in access, free to all schools in the Georgia College service area and at low cost elsewhere in the state. Connection to the Internet promised. About 1800 users as of April 1991.

Indiana Department of Education Access Network (IDEAnet): Database, bulletin board, conferencing, and professional employment system. No charges except for telephone access. There is also a statewide fiber-optic network, INTELENET, meant to serve as a backbone to link state government and education resources.

INSTEPS–Indiana Electronic School District (ESD): This is a computer network experimenting with linking academic and administrative functions for a number of school districts. It includes electronic classrooms, local networking, and connections to the Indiana Department of Education and to state universities. Internet access is also available.

Iowa Communications Network (ICN): This is a statewide networking effort for all agencies of government. The original purpose of the K-12 part of ICN was to connect teachers at all levels throughout the state via computer conferencing to coordinate policy and administrative affairs related to student teaching. Users can also access the ERIC CD-ROM database.

K12-Net: A subgroup of the Fidonet system, K12-Net is an all-volunteer, free-access network that uses local nodes. Fifty or so nodes, perhaps 1000 users—very hard to tell because anyone on Fidonet can pick up any feed and become, in effect, a node. Fidonet itself has about 10,000 nodes in about 50 countries. K12-Net is fully accessible via the Internet, and K12-Net feeds are newsgroups on USENET.

ME-LINK–Maine: Part of the Maine Computer Consortium, ME-LINK is a dial-in bulletin board and e-mail system. Student access for short-term projects is also permitted.

MERIT/MICHNET–Michigan: MICHNET has been available to schools since the early 1980s, and has been particularly active in bringing together teacher groups for specific conferences and projects. Access is by dial-in to a local university host. MERIT is currently looking for ways to expand its services to K-12 education.

Maryland Educational Technology Network (METNET): Based on Learning Link, it offers access to all educators in the state to Learning Link services. Toll-free access statewide.

Massachusetts Corporation for Educational Telecommunications (MCET): Although principally a satellite-based broadcast network (the Mass LearnPike), its "Reach for the Stars" project (funded by the US Department of Education Star Schools Program for two years from October 1990) aims to integrate computer telecommunications, distance learning, and other educational technologies with investigative problem-solving and cooperative learning strategies.

Nebraska Statewide Network: Part of IRIS; teachers in Nebraska can use it to communicate with each other in the classroom, or as an adjunct for collaborative projects. Nebraska educators have their own conference area on IRIS. There are about 100 users, with limited participation from postsecondary faculty.

New Mexico Educators' Network for Educational Communication (NEDCOMM)–New Mexico: Includes e-mail, bulletin boards, and statewide databases. Access is free throughout the state.

New Jersey Education Technology Network: Dial-in access. Membership is open to anyone interested, and currently includes 3600 users: teachers, administrators, parents, board members, and postsecondary faculty. E-mail, discussion forums, and databases.

New York City Educational Network (NYCENet): Run by the Board of Education, provides bulletin boards, databases, curriculum guides, and computer conferencing, and also supports class projects in city schools. At least five projects on NYCENet involve contact with out-of-state or international groups through e-mail. About 6000 users. Internet connectivity should be available shortly.

New York State Educational and Research Network (NYSERNET)–New York: One of the "regional" parts of the national Internet. Has a number of special activities for K-12 educators, including a Special Interest Group (SIG) with about 250 members.

New York Teacher Resource Centers' Electronic Network: The Teacher Resource Centers (TRCs) are professional development centers organized and operated by teachers across the state. Focus is on the effective use of technology in the classroom. The Network operates a bulletin board, e-mail, information services, and databases.

North Dakota State University: Pilot project funded by the state Educational Telecommunication Council to train teachers and students in the use of telecomputing in curricular enhancement. Sixty secondary schools in 44 school districts; expect expansion to about 200 users.

Ohio Education Computer Network: Connecting over 80% of the state's school districts, this is a state-owned microwave communications network; it offers e-mail and various means for sharing data.

Pathways–South Carolina: Network operated by the Department of Education for the transfer of administrative information.

PENN*LINK–Pennsylvania: Provides e-mail service to school districts, intermediate units, and area vocational and technical schools. Also runs a bulletin board that includes administrative information.

SCHOLE–Boston University School of Education–Massachusetts: A computer network whose purpose is to teach children, assist teachers, aid researchers, and link students and scholars. Services include e-mail, conferencing, bulletin boards, and special interest databases.

Teacher LINK–Virginia: A local-access network around the University of Virginia. Connects teachers, student teachers, and interns access to each other and to mentors both locally and nationwide. Has Internet access.

Texas K-12 Networking: Current services available via Electric Pages, commercial service on GTE Telenet. After a number of attempts to set up a separate statewide network, current plans are to link the state's school districts through THENET, the Texas Higher Education Network. This would give users full Internet access. (See "TENET: Texas Education Network" by Connie Stout.)

Technology Network Ties (TNT)–New York: This is a comprehensive statewide network linking school districts and educational agencies with the state Department of Education. Mostly administrative uses, but also includes e-mail, conferencing using COsy, regional and topical conferences, and electronic clearinghouses of information. In some parts of the state, all school buildings are linked.

Technology Resources in Education (TRIE)–California Technology Project (CTP): TRIE is the electronic information service of CTP, an initiative of the California Department of Education. Running over CSUNet, the electronic network of the California State University system, TRIE access is free (through public access numbers) to practitioners and students statewide. Internet access is available. E-mail, access to information resources, and conferencing are available. There are a number of collaborative projects running.

University of Alaska Computer Network (UACN): Provides networked computer access to every school district in the state as well as access to the Alaska Teleconferencing Network, to commercial services (AlaskaNet/Tymnet, NorthWestNet), and to the Internet and BITNET.

VA.PEN–Virginia: Provides free access to e-mail and the USENET system of newsgroups (bulletin boards by a different name) to teachers and administrators in Virginia. Also provides Internet access. Local dial-in connections in about one third of the state, with 800 connections elsewhere. (See "Considerations Underlying the Architecture of a State Public School Telecomputing Network" by Glen Bull, Cameron Harris, and Harold Cothern.)

VT-HSNet–Virginia: Links 15 high schools to a Virginia Tech computer through local dial-in; provides students and teachers with access to e-mail, the VT library catalog, and the Internet.

UNIBASE–Saskatchewan, Canada: A dial-in system with truly extensive information resources and international extensions, including teacher resource materials, software and hardware abstracts, current years of ERIC CIJE, and an electronic library with both abstracts and full text. UNIBASE also supports other groups' networking services, including those of FrEdMail.

WCU MicroNet–North Carolina: Out of Western Carolina University, serving schools since 1982 through a toll-free number. Provides e-mail, conferencing, access to resources at other university campus and research centers, databases of class activities in science, mathematics, foreign languages, English, and history, as well as on-line quiz programs, access to university libraries, and other services.

West Virginia Administrative Network: Dial-in network that links the state Department of Education with local educational agencies. Services include e-mail, bulletin boards, and financial updates.

West Virginia Microcomputer Educational Network (WVMEN): An open instructional dial-in network for all state residents. Services include e-mail, bulletin boards, public domain software, and conferences.

Connection/Curriculum Projects

AT&T Learning Network: Project-based service, linking students from the United States, Canada, Australia, France, West Germany, the Netherlands, and Japan into learning circles with shared interests. As of Spring 1990 there were 32 learning circles.

The Beginning Teacher Computer Network–Massachusetts: Developed by the Harvard University Graduate School of Education, this dial-in system connects Harvard graduates in teaching positions with veteran teachers and Harvard faculty. There are about 40 users.

BreadNet: Links teachers and students in isolated rural areas (currently through dial-in) for a variety of educational projects.

Computer Pals Across the World: One of the largest pen pal programs; matches classes from different schools in an international writing program.

CSSS Network (PSI-NET): Nationwide network of the Council of State Science Supervisors, running on IBM's PSI-NET software. The equivalent for mathematics is MELNET.

EIES–New Jersey Institute of Technology: An early developer of a number of international networking and conferencing efforts. E-mail, conferencing, and custom-tailored communications systems.

Federalist Bulletin Board System: Dial-in bulletin board for educators and students interested in the U.S. Constitution and the Federalist Papers, run by the Political Science Department of Oklahoma State University.

First Year Teacher Project–Idaho: A bulletin board using Learning Link to connect first-year teachers with their peers and with former faculty.

Learning Link: A dial-in system that provides e-mail, in-service teacher training conferences, information resources, and gateways to other information resources. It is especially targeted to educators who use technology in instruction. Strongly connected with public broadcasting stations.

MELNET (PSI-NET, proposed): Nationwide network of the Association of State Supervisors of Mathematics (ASSM), funded by IBM and to run on IBM's PSI-NET software. See also the CSSS Network. Organized to implement the national standards for mathematics curriculum reform proposed by the National Council of Teachers of Mathematics (NCTM). Will also extend to a number of interstate networks.

MicroMUSE: Multi-User Simulation Environment is an Internet-based, text-based virtual reality running on a host computer at California State University, Fresno. Accessible through Inet, it allows guests to explore prototypes of informal science education through network access to virtual realities—things like the Science Center and the Cyerion City Museum.

NEA-NCIN School Renewal Network: A network for schools involved in the National Education Association's Mastery in Learning Consortium, an interesting experiment that pairs practitioners with researchers in efforts to put research quickly and effectively into practice and to prove the questions that researchers ask. Uses IBM's PSI-NET software; about 300 users.

National Geographic Kids Network: A National Geographic Society science curriculum series for grades 4-6. Students conduct research on selected topics, collecting data and sharing these data with their research teammates on the network. (See "A Developer's Perspective on Telecomputing" by Candace Julyan.)

SNET Links to Learning–Connecticut: Project to link 34 schools in 17 districts to each other and to database for news services and library system called CONNET. No Internet access; no university participation.

Telecommunications Enriches Language Experiences (TELEclass)–Hawaii: The Hawaii Global TELEclass project aims to enhance the learning of foreign languages. Uses EIES-developed networking and conferencing software. Students in Hawaii have been linked with students in Japan, Korea, Taiwan, Hong Kong, the People's Republic of China, Canada, Puerto Rico, Tahiti, Spain, France, and Germany.

Unified Network for Informatics in Teacher Education (UNITE)–Kansas: Links six school districts. With a grant from Apple, students and faculty at the University of Kansas do instructional development and provide a bulletin board.

Lists and Other Network Resources

Big Computer Pals: A list service accessible on the Internet that pairs students (especially differently-abled ones) with mentors. Big Pals are always urgently required.

EDTECH-L: A list service accessible over the Internet, with a focus on educational technology applications.

KIDSNET: A list service accessible on the Internet that covers any and all topics dealing with networking in K-12 education.

PHYS-L: A list service accessible on the Internet that covers the teaching of physics in secondary schools.

NASA Spacelink: A resource accessible on the Internet for a number of NASA databases.

National High School Supercomputer Programs–NERSC/LLNL/DOE: In a partnership between Cray Research Inc. and the Department of Energy, a Cray X-MP 18 supercomputer has been set aside for the exclusive use of K-12 teachers, students, and software developers. The computer resides at the Lawrence Livermore National

Laboratory's National Energy Research Supercomputer Center. It is fully accessible by the Internet, and can be reached via Tymnet in a more limited way.

OERI BBS: The U.S. Department of Education Office of Educational Research and Improvement maintains a toll-free bulletin board that allows e-mail and conferencing as well as file down-loading. Topic areas include: mathematics, reading, and international exchanges. DoEd maintains three other bulletin boards on Compu-Serve, GTE SpecialNet, and Alanet (American Library Association Network).

Student Awareness in Science (SAIS-L): A list service (in Atlantic Canada) accessible on the Internet for people with interesting laboratory experiments to contribute.

Sci-Link: A local dial-in bulletin board service in rural northwest Pennsylvania, aimed at connecting science classrooms.

Commercial Connectivity and Information Services

America On-line: Previously AppleLink Personal Edition, provides e-mail, bulletin boards, conferences, a reference library, encyclopedia, and "guest speakers" on topics of use to Apple users.

AppleLink: Apple's own network; includes a number of lists and conferences associated with Apple Global Education (AGE) and the Apple Classroom of Tomorrow (ACOT) efforts.

Classmate: A subset of the DIALOG line of information resources, Classmate offers over 80 full-text databases of journal, magazine, and newspaper articles in fields including general science, social studies, and the humanities. Can be used to teach on-line searching, and as general class research support.

Compu-Serve: Arguably the largest commercial networking service. Offers enormous numbers of conferences on every topic, including a number of specialized education groups. Also offers e-mail; a lot of Japanese educators link to the United States via Compu-Serve, for instance.

Education Network (EdNET): On the UNISON network service system. Access to a number of databases, computer conferencing, and e-mail; in addition, subscriber schools can build their own private information and conferencing networks.

GE Network for Information Exchange (GEnie): Run by General Electric Information Services, GEnie provides information retrieval, conferencing, and various education services. Notable is the Computer-Assisted Learning Center (CALC), which provides homework and tutoring help, continuing education, downloadable software, quizzes, student chatlines, and academic counseling.

GTE Education Network: This system claims to be used "by more than one third of the schools in America." Provides a number of databases on legislation, court cases, financing, and statistics. Also has a number of special-purpose conferences and groups, including SchoolLink, Electric Pages, and SpecialNet.

IRIS: A system aimed at practitioners and students, based on dial-in access. Includes collaborative projects for students, and curriculum and instructional support conferences for teachers.

Kidsnet: A dial-in service offering conferences and access to public broadcasting station schedules and supporting materials.

Maxwell On-line, Inc.: A general database and information service. Includes an Educator Line, geared to K-12 practitioners who want to do their own searches for research or classroom instruction materials.

Portal: Offers Internet connectivity.

Performance Systems International (PSI): A commercial firm offering Internet connectivity.

People Sharing Information—Network (PSI-NET): IBM software package for K-12 networking. A variety of specific applications are listed here. A future incarnation is planned to allow gating into the Internet.

Leids Communications/SINet: Offers network connections, bulletin boards, curriculum services to states (Arizona, Minnesota, Oregon, South Dakota). Linked to USENET and the Internet. About 700 K-12 users as of March 1991.

SchoolLink (GTE): A service of the GTE Education Network, SchoolLink is a school-year based project that provides science and social studies curriculum-based materials and discussions.

SpecialNet (GTE): One of the oldest networking services for education, SpecialNet includes information resources, conferences, and e-mail support for those involved with special education activities.

UUNET Technologies/ USENET: Provides access to the USENET set of newsgroups, about 1000 bulletin boards on every subject under the sun. Includes a number of K-12 boards and topics; VA.PEN, for instance, reproduces nearly 80. Also can provide connections to the Internet.

Research Centers

TERC: Space does not permit listing all of TERC's activities. Network-using activities include the Global Laboratory, Soviet participation in TERC's networked science activities in the United States, the LabNet teacher preparation project for physical science teachers in grades 9-12, and the NGS Kids Network.

Schools with Known Internet Connections

(There are many; these are a non-random sampling of schools with relatively advanced or intensive usage):

- Davis High School, Davis, California;
- Illinois Mathematics and Science Academy, Aurora, Illinois;
- North Carolina School of Science and Mathematics, Durham, North Carolina;
- McMillan Junior High School, Omaha, Nebraska;
- Montgomery Blair High School, Silver Spring, Maryland;
- Rocky Mountain High School, Fort Collins, Colorado;
- Thomas Jefferson High School for Science and Technology, Alexandria, Virginia. These folks also have a dedicated supercomputer (an Eta10, won in the first SuperQuest competition) that could serve all of K-12 education--except that it is not directly connected to the Internet.

Issues and Obstacles

The first and most basic issue in extending networking to K-12 is that of poor access to computers and telephones. Beyond that, as the above list should convincingly establish, there are many resources and services, but they are largely lacking in interconnection to one another and to a user base. In addition, interfaces and support services are quite often poor, although some of the resources listed above are outstanding in their commitment to user support and training. There are, without overstatement, no directories or catalogs listing network participants and available resources and services. There is no general means of information exchange between users, both because there are no directories and because there is no shared system. Finally and most fundamentally, there is no basic consensus among K-12 leaders about networking's potential to contribute to improvements in education.

There are good reasons for achieving a "critical" mass of linked K-12 practitioners and institutions. The most fundamental reason is infrastructural: to connect the practitioner communities (teachers, administrators) among themselves and to one another. Not only will such a step reduce practitioner isolation, but it will drive other efforts. By also linking practitioners with other subject specialists and educational researchers, networking will help to carry out curriculum reform and restructuring projects; it will help schools of education be better informed about what is going on in the schools, and will reduce the turnaround time between research and practice. It will enable schools and teachers to carry out student projects and other experiments in collaborative learning.

Important reasons for networking extend even further. Connections with colleagues, mentors, supporters, and advisors in subject matter disciplines, in corporations, and in educational research will lead to new forms of collaboration. Other groups (publishers, for instance) provide new reasons for connectivity. Last but not least, network access will allow educators to obtain access to information resources.

An evolving plan

- Integration of disparate physical networks and resources into a common network system, the national Internet.
- Provision of an integrated set of services over the national network, directed toward addressing K-12 needs.
- Improved links between users, resources, and services; and creation of new resources and services.
- Increased linkages between K-12 districts and schools and postsecondary education.
- Development of user-friendly interfaces to network resources.
- Increased participation by the K-12 educational community.
- Planned evolution toward a complete national K-20 network system: networked schools and districts, connected with regional, state-level, and national networks serving education, scholarship, and research.

Guiding Principles for Achieving Widespread Connectivity by the K-12 Community

- Use elements in the existing structure as technical support foci.
- Provide access to the entire K-12 community.
- Treat the community as an equal networking partner (no special distinctions or restrictions).
- Every user should have an individual electronic identifier and address.

- To the maximum degree possible, end users should be able to connect with no more than a local telephone call.
- To the maximum degree possible, the user interface should be standard, consistent, and intuitive.
- To the maximum degree possible, open systems standards should be used.
- Computer technology vendors should be encouraged to provide hardware and software that conforms to standards and to provide technical support to their K-12 customers.
- During a start-up period, charges to the K-12 community should be no greater than incremental costs.
- To the maximum degree possible, charges should be fixed rather than usage-dependent.
- Funding sources should include Federal and state governments, industry, foundations, and state, regional, and local educational authorities.
- Technical support and cost-sharing should be provided by higher education and industry.

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A Developer's Perspective on Telecomputing

by Candace L. Julyan

Our work at TERC focuses on educational research and/or development efforts related to mathematics and science. A central question that concerns us is how to infuse the excitement of science or math as experienced by scientists or mathematicians into the classroom. A secondary question concerns how to use technology effectively in this enterprise. In 1986, TERC entered into a unique collaboration with the National Geographic Society (NGS) through a project funded by the National Science Foundation (NSF). Developed by TERC and published by NGS, the National Geographic Kids Network was conceived as a new curriculum series designed to improve elementary science education by combining hands-on science with computer networks. The objective was to design a series of socially relevant, environmentally-oriented science experiments, to make use of telecommunications, and to create a collaborative network of student-scientists. At the time TERC began this work, few models existed regarding the use of telecommunications in an elementary curriculum. Those early years of development raised many questions concerning the balance between technology and curriculum, between science and pedagogy, and between innovation and school reality. While we have not necessarily resolved all these questions to our satisfaction, our decisions regarding the final product design can inform others interested in developing this type of curriculum.

Issues of Curriculum Design

We realized from the start that the curriculum we envisioned included two major challenges for elementary teachers: Few classrooms are equipped with phone lines and modems, and few elementary-level teachers are familiar with collecting real data and helping students explore the numerous questions that these data raise. Like the teachers, we as developers also faced a number of challenges in creating a curriculum that would encourage teachers and students to make sense of real, and frequently messy, data; creating software that could provide simple, yet powerful tools for data collection and analysis, and developing a unit of classroom activities that would encourage students to raise questions and find answers regarding their data. The development of the software and curriculum for the NGS Kids Network raised issues regarding software design, topic choice, and curriculum structure. This effort served as the foundation for a variety of TERC-developed curricula now called "Network Science." (See "The Network Science Experience: Learning from Three Major Projects" by Cecilia Lenk.) The purpose of this paper is to discuss the issues explored and the decisions made regarding the development of one such curriculum, the NGS Kids Network.

Software Design

The software developed for the NGS Kids Network project needed to provide teachers with tools for telecommunications and data analysis and to provide network managers with a systematic way to collate and return students' data. Above all, the software should provide simple tools that would help teachers and students complete the work of the unit.

To simplify the telecommunications process, all the transactions involving sending and receiving data are automatic. Data and letters are compiled off-line and sent to the network in a bundle; data and letters from other classes are picked up from the network and then read off-line. Although the off-line creating and reading of data and letters eliminates any opportunity for real-time bulletin board discussions, the simplification of the telecommunications activity makes the experience more accessible to a larger number of teachers.

To provide support for data analysis, the software offers two important features: graphs and maps. Any data table created by students or picked up on the network can be displayed as a variety of graphs: pie charts, bar graphs, and line graphs. Selected data are compiled into map files and can be viewed on a computer map, permitting students to view the data displayed on a whole world or single-state magnification.

These features are particularly important in supporting the focus in this curriculum on collecting, sharing, and examining data. Our decision regarding a simplified, and limited, telecommunications feature was based on concern that the curriculum be accessible to a wide range of teachers. The popularity of the software with both novice and experienced computer users is encouraging, suggesting that easy-to-use software can meet a variety of teacher interests and needs.

Topic Choice

Early on in the project, TERC developed several criteria to help determine the suitability of proposed investigations for inclusion in the curriculum. Topics needed to provide: appropriate topics of investigation of interest to upper elementary students; geographically significant data; socially significant data; and reliable data. Each of these criteria offered us a variety of challenges.

Appropriate Topics of Investigation

First and foremost, we believe that classroom investigations need to hold the interest of upper elementary students. This often meant that topics of great interest to TERC or NGS staff were discarded if they did not engage students. In the early development of *Hello!*, the introductory unit in the series, students collected data about their birthplaces. This data set allowed us to make great use of the computer map by allowing students to overlay the data from a single class onto the computer map. The results were powerful. Students could easily identify those classes in which most of the students were born locally and those in which students were born all over the country and the world. Although adults took great delight in these comparisons, checking their assumptions about location and mobility, many of the younger students, with many fewer assumptions about location and mobility, were uninterested in the data. With great regret we moved on to a data set—pets—that was more compelling for these students.

Geographically Significant Data

In the NGS Kids Network curriculum we are concerned with the geographic relevance of data for three reasons: 1) Location is an interesting and intriguing aspect of data analysis; 2) our software has a powerful mapping feature that allows students to examine their data geographically; and 3) our publisher, the National Geographic Society, has a clear interest in increasing student awareness about geography-related information. In some cases, data is included that are significant internationally rather than nationally. In the *What's In Our Water?* unit, students examine the nitrate concentration in their drinking water. While these levels are generally low in the United States, nitrate contamination in other countries has been reported to be quite high, offering students an opportunity to consider the political and environmental differences of location.

Socially Significant Data

A primary focus of this project is to encourage students to see that science has important, real-life applications in their world. In addition to data analysis activities, the curriculum challenges students to consider the social aspects of the data. For example, in the *Acid Rain* unit, the concluding activity is to consider whether the acid rain problem requires immediate action or more research. Students' debate on this issue is fueled by two position papers: one from "Chris," a child in the Midwest whose father might be laid off if the local factory is forced to change its emissions standard; and the other from "Lee," a child from New England who has seen the decline of the fish population in a local lake.

Reliable Data

The original intent of the data collected on the NGS Kids Network was that the student-collected data be available as a large, free database of information to interested professionals in the scientific community. Clearly, if this is the intended audience for the students' data, scientists need to feel that the data have some validity. While this was often the hardest criterion to meet, we remained sensitive to finding simple, reliable measures—from litmus paper to accurate descriptors—that would increase the validity of the students' data. To our surprise, we discovered that scientists could see the potential of these data and were often quite interested in assisting our searches for accurate measures. Perhaps more than the other criteria, the concern for reliable data offered an ongoing tension between pedagogy and science as we struggled to find the balance between student exploration and setting the parameters required for data reliability.

While all the final topics did not address each criterion equally well, we found that using the criteria as a measure of suitability was extremely useful. For example, if a topic was neither reliable nor socially significant, it was clearly not appropriate for further consideration. However, if a topic offered rich possibilities for student investigation but was not of particular interest to the scientific community, we continued to explore ways in which the topic could be incorporated into the series. The *Weather in Action* unit is a good example of this type of decision. Students enjoyed and learned from collecting simple weather measurements, from temperature readings to wind directions; however, the data that students collected were not of particular interest to the scientific community. For this unit we chose to minimize the importance of one criterion because of the strength of the importance of another.

Curriculum Structure

The structure of any curriculum is determined by the goals of the developer. With the NGS Kids Network curriculum, our goals were to have a large number of teachers with varied backgrounds in science and computers take part in a collective data collection enterprise. The National Geographic Society envisioned a network of as many as 10,000 participating schools. These goals required that conversations be kept manageable and that students and teachers build a knowledge and interest in the unit's content that would permit them to undertake a meaningful examination of their data.

To keep the conversations manageable, we developed the idea of research teams. Each classroom is assigned to a small research team of 10 to 15 classes. All of the letters and data are exchanged throughout the six-week unit with this group of geographically dispersed classes. In addition to these detailed exchanges, each class receives a collated data set representing the findings of the entire network. These data are compiled by the managers of the network (TERC staff for the field tests, NGS staff for the published units) and sent to all classes in the final weeks of the unit in the form of a network data table, a series of maps, and a unit scientist letter.

To build a knowledge base for the students and teachers, we provide curricular features of software tools, communications with a unit scientist (an expert in the unit's topic), and a fairly structured series of steps to encourage communication and attention to the data. These steps include: exchanging information with research teammates and building a foundation of information about the topic at the beginning of the unit; collecting data in the middle of the unit; and analyzing data and exchanging more letters at the end of the unit.

The clearest way to understand how this structure works is to examine it in relation to unit topics. In all NGS Kids Network units, the first week focuses on examining the community in relation to the data to be collected. In *Too Much Trash?*, students explore how trash is handled in their community. Students then share their findings with research teammates in the form of community letters. In this first week, students also receive a letter from the unit scientist who introduces the scientific concerns regarding the topic of study.

After completing this survey of their community, students consider issues related to data collection. At this stage in the curriculum, the tension between student exploration, data reliability, and classroom time are most obvious. In an ideal situation, students would have ample time to explore fully their ideas about how to collect the data. In real classrooms, teachers' concerns about covering a particular subject within specific periods of time come into conflict with the messy, meandering, and often lengthy activities that encourage student explorations. In the NGS Kids Network we attempt to resolve some of this tension by providing some parameters for student exploration. In *Too Much Trash?*, students consider how they will collect and sort their trash, but are provided with the categories of trash that they will need to share with their teammates. In *Solar Energy*, students complete a variety of activities that explore the heat retention properties of various materials before beginning to design a solar home.

As students collect data, they also consider in greater depth the scientific information by conducting experiments related to the topic. In the *What's In Our Water?* unit, students spend the middle weeks of the unit conducting experiments on the nitrate levels in runoff water from several plants with varying amounts of fertilizer. In the *Acid Rain* unit, students study the effects of acidic solutions on various types of materials.

In the final two weeks of the unit, students examine their own data and compare their findings with the data from their research team. This comparison is designed to encourage them to use their new knowledge about the data set to predict patterns in the network data. In the *Too Much Trash?* unit, students compare their own data with those of their teammates to develop an understanding of the range of the amount of trash thrown out in schools. This knowledge can then be used to consider various questions about the data, and the national data set gives students an opportunity to check out their predictions.

In addition to the data sets of teammates, the curriculum offers teachers and students two other features for data analysis: software tools and the unit scientist letter. The graphing and mapping tools are used to consider the data in different ways; the unit scientist suggests several patterns of interest in the network data set and offers various questions raised by the data.

One of the largest constraints for both teachers and developers in the curricular design of the NGS Kids Network involves the telecommunications deadline. Again, this was a purposeful constraint based on classroom realities. We wanted all classes to take part in the study, to have a timely exchange of information, and to feel like collaborators with other students on the network. In some instances, like *Acid Rain*, the data had to be collected during the same time period in order to be meaningful. While the deadlines create problems for some teachers by inhibiting the time available for student inquiry, other teachers and some principals report that the deadlines are useful in keeping the unit moving along. In our current development of the Middle Grades version of the Kids Network, we will continue to explore this issue.

The Curriculum Today

Today, a rich array of curricula using computer networks is available. We hope that our project, the National Geographic Kids Network, has helped others to see the possibilities of this medium, and that our efforts can provide a model for others to follow or discard as they consider how to combine classroom activities and computer networks.

Our work with the NGS Kids Network project has provided us with many opportunities to explore issues related to telecommunications curricula, as well as generating considerable interest in incorporating computer networks into classrooms. Now that we have completed the final units for the NGS Kids Network series, we feel satisfied that these challenges are being met to some degree. In terms of the popularity of the curriculum and the effectiveness of the software, we exceeded our expectations. We created an active network of student-scientists. In 1991, more than 250,000 students used the NGS Kids Network materials to collaborate on a wide variety of experiments, ranging from acid rain, nutrition, weather variation, solar energy availability, nitrates in drinking water, school trash, and pet choices. To date, participants include schools in 22 countries, with another 15 countries expressing interest in including the curriculum in their schools in the coming year. These numbers are striking evidence of the interest that both teachers and students have in the NGS Kids Network project.

In addition, the project has generated considerable media interest, resulting in more than 1000 stories in television, radio, and newspapers. Coverage has included articles in the *New York Times, Chicago Tribune, Los Angeles Times, Boston Globe, Washington Post, Philadelphia Inquirer, Christian Science Monitor, London Times, Newsweek, Business Week, Education Week, Network World, The Computing Teacher, Technology & Learning,* and *Electronic Learning*. Television coverage has included the BBC, "Good Morning America," "Chronicle," and a number of local news stations. This response clearly speaks to public interest in educational telecommunications. At the start of the project, few elementary school teachers knew of, let alone used, computer networks in their classroom activities. Today, tens of thousands of teachers and students have actually used our software to link telecommunications to their class investigations. Our work with the NGS Kids Network has convinced us that Network Science promotes an excitement about and interest in science that is all too rare in today's classrooms. Our hope is that the lessons learned from this project will be used by others as they consider appropriate uses for computer networks in local and regional, as well as national and international, projects. While the territory of telecommunications-based curricula continues to be a challenge, it is no longer uncharted waters.

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A Publisher's Perspective on Telecomputing

by Monica Bradsher

Telecommunicating through school computers fits beautifully with the original mission of the National Geographic Society (NGS). Chartered in 1888 as a nonprofit scientific and educational institution "for the increase and diffusion of geographic knowledge," the Society is best known today for its yellow-bordered magazine and its television programs, hardly at all—yet—for its ventures into "telecomputing." The staff responsible for those ventures, in the Educational Media Division, feel a special fondness for one of the Society's founders, Alexander Graham Bell. In his search for a way to ease communication for his wife, who was hearing impaired, he invented the telephone.

Although the potential of Bell's invention struck him immediately, it would be decades before improvements in telephones and "connectivity" allowed the telephone industry to take off commercially. We fancy that if he could see our efforts in telecomputing today, he would counsel patience and perseverance. After all, it has been only five years since NGS began using computers and telephone lines to increase and diffuse geographic knowledge. In that time we have offered three different kinds of services to schools:

- NGS Bulletin Board, 1986–1988;
- The Weather Machine, 1987– ;
- National Geographic Kids Network, 1989– .

Each of these services has taught us different lessons and brought unique rewards to us and to subscribers, but each has also encountered obstacles. We have made progress against some obstacles. Other obstacles are, quite frankly, too big for us, and NGS welcomes a concerted effort by educators, legislators, government agencies, and businesses to address them. The following history of successes and frustrations may help others better understand the barriers that still prevent typical K-12 schools from tapping into the power of telecomputing. Keeping such experiences in mind is especially important when considering options for developing a national policy on the edu ational uses of computer networks.

The National Geographic BBS

The National Geographic Society launched its bulletin board service (BBS) in 1985 with excitement and dreams that will sound familiar to anyone who can still remember first learning that computers can send files to each other through phone lines. What could be more efficient as a way of sharing some of the geography resources of NGS with schools? Any school with virtually any kind of microcomputer and some compatible communications software could reach our board and down-load items posted there. Teachers could print out the materials they wanted and bypass the rest. They could incorporate NGS files into their own computer filing system. They could go on-line with other teachers to discuss ways to use these materials. And wouldn't this be a dandy (cheap) way to share lesson plans related to our TV programs and magazines and to let people know about all the materials we have available?!

The initial investment was laughably modest. NGS bought a BBS software package for only $8.00 and dedicated an IBM XT computer and one modem and phone line to the experiment. Users could read a brief history of the Society and consult the schedule for exhibits in Explorer's Hall, the Society's museum. We set up asynchronous conferences for different age groups on various aspects of geography. Staffers from several Society Divisions volunteered as hosts for the conferences, such as the one for elementary schoolchildren, moderated by the father of a little girl who wanted to see more happening on the board for her age group. One of the most popular topics discussed on the elementary level conference was pets, foreshadowing the success of the *Hello!* unit later developed with TERC for the NGS Kids Network curriculum.

Since the BBS software was experimental, NGS did not charge any access fees. Many users responded to that generosity by donating simple computer games they had created, many of them about geography. The bulk of our system operator's time went into screening these games to be sure they were wholesome, reasonably bug-free, and, as best we could discover, not published elsewhere. At its peak, the BBS offered about 1000 programs for various computers. Most of the users were teenagers at home, but many schools acquired a modest software library from us at a time when schools were investing in computers but usually neglecting software needs. Although we had only one phone line, which was busy almost continuously, the BBS received more than 35,000 calls in a four-month period. Most were local callers, but plenty called from distant parts of the country. And all had heard about the NGS board by word of mouth or by reading other boards. NGS never promoted the service in any way.

Our BBS died in 1988, shut down as part of a cost-cutting plan. In a sense, we were the victims of our own generosity. A service offered free to the public is always especially vulnerable to downturns in economic fortunes. Moreover, it does not bring in revenue that could finance improvements or expansion. We couldn't get approval to install a second phone line, much less an X.25 pad or a stack of modems. Even if we had been allowed to expand, the BBS would probably have succumbed to one of several growing threats. Providence (or the shade of Alexander Graham Bell?) saved us from viruses, but it is doubtful that we would have escaped that plague much longer. Expansion from our simple system would have led us into more and more capital investment for equipment that, in those days, would have taken a lot of valuable office space. And, as one can see in retrospect, that equipment would have become rapidly obsolete. But the BBS served its purpose in teaching us a few things about telecomputing.

Lessons From the BBS Experience

- People will use a telecomputing service if it offers something they want (such as computer games) at a bargain price (such as free except for connect charges).
- Kids (younger children and teenagers) seem particularly drawn to the telecomputing medium.
- When a service is free, people seem willing to accept some inconvenience and fumbles without complaint. (Lots complain anyway, but what can they do about it? Cancel a free subscription?)
- The low cost of entry would make a BBS a practical way for a school district to promote sharing of information within a local calling area.
- For an institution like the NGS, a large national subscribership carries with it the potential for high costs in capital investment. Buying and babysitting a lot of hardware is not the same as increasing and diffusing geographic knowledge!

The Weather Machine

By the time the BBS died, we were launching a new telecomputing service, this time charging a fee to cover expenses. The Weather Machine Telecommunications Service provides packets of weather data in a form designed for use in Apple IIe software that we developed and still sell to schools for weather study. The subscriber's software transforms binary files into fascinating color maps. This service is quite different from a BBS in that it is essentially one-way. Subscribers down-load data but do not send any to us or to each other. The Weather Machine offers several advantages as a method of sharing weather data with schools:

- It is colorful, not just text, and so has extra motivational value;
- It is up-to-date, compiled on-the-fly from National Weather Service data received by satellite;
- Data in computer format can be manipulated and more easily and readily used in analysis;

- Transmission is fairly cheap because the files are small. The color graphics are created by the user's computer.

In launching this service we had to face the fact that long-distance telephone charges are anathema to school administrators. Many school telephone systems are designed to block all but local outgoing calls. And with good reason. More than one lenient principal has been shocked by the arrival of a huge telephone bill run up by an enterprising teacher. We designed The Weather Machine to require a minimum of time on-line (in contrast to most other services, which count on recouping development costs by encouraging users to stay on-line as long as possible and charging for services by the minute).

Providing a service that can be purchased in advance with a school purchase order has been our greatest challenge. In the case of The Weather Machine, we solved it by using AT&T Mail, a store-and-forward service accessible only through an 800 number. Our subscribers can receive current data for at least 30 different maps for less than $1.00 per day, if they choose to call every day. Each down-load costs us a little more than $1.00, but we limit users to no more than one down-load per day to protect ourselves from enormous bills. (We have no way to cut off service until we see the monthly AT&T statement, by which time a weather enthusiast with unlimited access on an 800 number could have spent more than the yearly fee!)

It quickly became clear that many school subscribers to The Weather Machine would prefer to use the service intensively, down-loading up-to-the-minute data several times a day, for two to four weeks instead of once a day for a year. Although we have adjusted the subscriptions to offer service for shorter periods, we have not yet found the ideal solution to the dilemma of how to offer information on demand to people who cannot pay per-use charges. An obvious solution would be to decentralize: Sell the service to state or district education offices that can make it available through local bulletin boards at little or no cost to schools. However, negotiating site licenses for districts of various sizes carries a labor cost of its own, and we have found few districts equipped to carry out such a plan.

Lessons From The Weather Machine

- Using the power of the subscriber's desktop computer is a good way to deliver color graphics at reasonable cost.
- A user-friendly built-in communications program greatly increases educators' willingness to try telecomputing.
- It is much more difficult to serve schools than to meet the needs of businesses or homes because schools require an all-inclusive fee payable with a purchase order.

- People who have to pay for a service are far more demanding than those who feel they are getting something for nothing. Schools tend to expect more technical support than they are willing or able to pay for.

National Geographic Kids Network

The collaboration between TERC and NGS to develop and implement a telecommunications-based science and geography curriculum owes much to its early financial support from the National Science Foundation, under a program designed to encourage publishers to take risks in producing hands-on science curriculum materials. When our project began in 1986, it was widely considered the riskiest of the new NSF-funded science curricula because it relied so heavily on technology, particularly on telecomputing. Surveys indicated that fewer than 15% of elementary schools owned modems, and most of those were used for administrative purposes or inter-library resource sharing.

By the time NGS began operating the service early in 1989, TERC's evaluation data provided comforting evidence that both the software and the curricular structure were a hit among the 200 schools chosen as field test sites in 1988. TERC chose schools on the basis of geographic location (at least two in every state) and other variables to provide a mix of ethnic groups, rural and urban schools, affluent districts and economically depressed areas.

This success owed much to TERC's clever software design and to an almost magical blend of curricular ingredients that had long been favored by educational researchers but that had failed to win acceptance in typical classrooms:

- Reliance on hands-on experiments and discussion rather than on textbooks;
- Interdisciplinary connections and extensions;
- Students working in small collaborative groups;
- Depth of thinking rather than breadth of facts;
- Emphasis on science process skills, particularly building and testing hypotheses and analyzing data.

Telecommunications permitted the sharing of data collected by students and dissemination of the comments of a professional scientist who could help teachers and students analyze the data. This approach varied significantly from National Geographic's traditional formulas for success, which rely on visual excitement and editorial research to bring large numbers of facts into focus in a style that holds attention more by evoking wonder and awe than by stimulating inquiry. Although the NGS Kids Network approach captured the imagination of many at NGS, our marketing mavens correctly predicted that such an innovative program would be very expensive to sell. Instead of letting people know through catalogs and other direct mail that we had what they were looking for, we would have to go out and convince them that they needed something they had never seen or used before.

Choosing topics for unit development has often proved a vexing problem. Our market research surveys did not predict winners very accurately because the educators surveyed tended to play safe by choosing topics already included in their curriculum. In practice, they have tended to buy units about topics that held personal appeal or for which few materials were already available rather than those with obvious ties to traditional curricula.

NGS staff and TERC agreed that the units must have intrinsic appeal to children but fit somewhere in a typical scope and sequence of science concepts that teachers are expected to present to the target age group, grades four through six. We agreed that topics must be ones in which the data that children collect will vary geographically; otherwise there is no compelling reason to be linked to distant partners. Although we did not set out to create an ecology curriculum, the topics that best suited these criteria have tended to focus on the environment.

And we agreed, for slightly different reasons, that the units should focus on issues of scientific and social significance. For NGS staff, with their journalistic bent, issues like acid rain and water quality had a timely urgency. For TERC staff, with their strong science background, such issues held out the hope that children could make a valuable contribution to the work of professional scientists. For NGS staffers the idea that the NGS Kids Network would truly increase, rather than merely diffuse, geographic/scientific knowledge held great appeal but was less important than making sure that the topic itself would fascinate typical elementary teachers and so inspire them to impart enthusiasm for science to their students.

Certain aspects of the software and telecomputing environment have also been key to the success of the NGS Kids Network. The mapping and graphing utilities in the software package add visual appeal that e-mail letters alone would lack. These tools for data analysis promote informal learning because kids and teachers alike enjoy playing/experimenting with them. Like The Weather Machine software, the NGS Kids Network program creates color graphics from relatively small files that do not require much transmission time.

TERC designed the software to shield users as much as possible from the complexity of sending and receiving different kinds of files. Addressing and batching of files and the use of an error-correcting protocol (X-modem) are performed automatically with minimal input from the user. The NGS Kids Network software includes an automated dialogue with the host, SprintMail, so users are shielded from the arcane style of the messages exchanged during log-on and transmissions.

In choosing SprintMail (called Telemail in those days), TERC shared our desire to use a host with the capacity to handle large numbers of subscribers who, in meeting the prescribed deadlines in the curriculum, tended to transmit most of their files on the same days. We did not have the capital to invest in the modems, phone lines, and computing power and memory needed in a host that could accommodate everyone if the NGS Kids Network were to attract many subscribers. (Even on SprintMail, which has more than one building full of mainframe equipment, on deadline days the NGS Kids Network users now nearly swamp the system, often delaying each other in logging-on!)

Initially the choice of SprintMail caused some problems that we had not encountered on The Weather Machine with the AT&T Mail system, whose rate structure is modeled after the U.S. Post Office system of flat rates for letters within certain ranges of size (length rather than weight for e-mail). SprintMail's rate structure, more typical of the industry, was so complex that even the company's representatives found it next to impossible to forecast the costs we would be absorbing under a pre-paid subscription system for schools. Furthermore, while AT&T Mail used 800 numbers for all subscribers, SprintMail charged a hefty premium (more than double) for any subscriber using an 800 number. The SprintNet packet-switched network had nodes in areas where business activity promised a high level of use, also typical of the telecomputing industry. Many schools are not close to centers of business activity.

The NGS Kids Network field test sites chosen by TERC all used SprintNet nodes, not an 800 number. For the small number of schools that were not within local calling range of a node (about 50), NGS could and did reimburse long-distance charges. But the overhead involved in paying all those little bills created nightmarish visions of a future in which success in building subscribership would ruin us financially.

Faced with these issues, NGS made several decisions that have contributed to the success of the program—and to the headaches of the staffers who run the system.

1. Equal Access

To ensure that students would have an interesting mix of data to analyze, we were determined to encourage the participation of both rural and urban schools. That has meant providing 800-number access to schools located outside the local calling area of SprintNet. The added cost is spread across all users, because all users benefit from this diversity. Consistently, for every curriculum unit and in every semester, approximately one third of our subscribers have been rural schools.

SprintMail has proved to be a cooperative partner. Early on, they agreed to a special flat rate per mailbox for NGS Kids Network schools, whether they use the 800-number or a local node. As our service has grown, SprintMail has continued to make allowances for our special needs. Because we serve thousands of schools, we are able to negotiate a better deal for nationwide and international communication on behalf of our members than they would have on their own.

However, the need to provide 800-number access to large numbers of schools continues to cost a lot in labor. During TERC's field test, when teachers were required to find a network access number on their own using a SprintNet directory, many teachers chose a long-distance number by mistake, even when a local access number existed. So each NGS Kids Network subscriber now receives a personalized letter giving the number to be used for network access. Although to a large degree we have automated these personalized letters, this system still requires much expensive special handling.

2. Acceptance of Purchase Orders

NGS has been shipping materials to schools on the basis of purchase orders for many years. Although school purchasers insist upon this method, few realize that our obligations (and therefore our prices) would be dramatically reduced if we insisted on payment by check or credit card. On the positive side, NGS has found that schools are good credit risks. They almost never fail to pay, eventually, for the materials we send in response to purchase orders.

Accepting purchase orders for NGS Kids Network kits, which are designed to be shared by many classes within a building and used for many years, presents no new challenges beyond what NGS has always done in selling books, filmstrips, videos, and so forth. But the purchase order system is not well suited to paying for a telecommunications service. Most schools make a large proportion of their purchasing decisions in late spring. They often have limited time in which to use dedicated funds or lose the money. In deciding to participate in an NGS Kids Network unit, they must choose an eight-week period from our calendar of offerings and promise to pay a Tuition and Telecommunications fee, currently $97.50. That fee covers not only all long-distance charges but also all aspects of the service, including the creation of geographically diverse research teams of about 15 schools each, the personalized mailings, letters from the unit scientist, and preparation and sending of the compiled sets of data for mapping and graphing.

Too often, when the personalized letter and other information arrives shortly before the beginning of the selected unit, teachers realize that they are not, in fact, ready to begin: The promised modem still hasn't reached the school; the teacher who was going to teach the unit has been transferred; no one has taken time to read any of the materials in the kit; or some unforeseen event has interfered. (Before running this time-sensitive service, we had no idea how many schools are affected deeply by hurricanes, floods, fires, and accidents.) SprintMail has allowed us a grace period after each unit begins in which to cancel mailboxes, but the labor involved in setting up those accounts and generating and mailing materials is lost. Postponing participation to a later date costs us quite a bit of money, but we have absorbed these costs because the schools that need to postpone are usually newcomers. We don't want them to give up on telecomputing forever.

3. Pre-set Charges

Purchase orders cannot be open-ended. Yet schools and teachers will vary in the amount of on-line time they will need or use in an eight-week period. The NGS Kids Network software contains a system for metering just how much time is used; it cuts off network access when a maximum of 120 minutes has been reached. Unfortunately, many teachers fail to use all of their allotted time. When a unit ends, we usually receive calls from teachers asking if their unused time can be applied toward their next unit. We have had to tell them that this is impossible since we have already purchased the time for them in advance. In many ways, schools would be better served by a pay-as you-go service, but they will not agree to open-ended purchase orders in the foreseeable future.

4. Toll-free Technical Support

Toll-free numbers for placing orders are now commonly offered in catalogs, and they pay for themselves in increased sales. But toll-free hot lines for technical support are rare, and with good reason. We do a lot of basic computer training through our hot line service. We have had countless calls from teachers who have never used a computer before and clearly have not even opened the software manual that we labored so hard to make easy to read and use.

TERC made the NGS Kids Network software easy to use, but getting a teacher on-line the very first time in almost every case still requires some handholding. For the time being, until many more teachers become familiar with the technology or schools find the money to provide training, we are investing in what we hope will be lasting loyalty on the part of subscribers who first tasted success with a modem thanks to our hot line. We are also trusting that teachers eventually will turn to each other for help instead of calling long distance.

Lessons from the NGS Kids Network

- A rich curriculum that reliably motivates teachers and kids meets current needs so well that many schools will want to participate in such a program delivered through a telecomputing system.

- Few schools will actually be able to participate in such a program if required to sign up on-line with a credit card or an open purchase order. Running a service that caters to these special needs of schools costs more than running the services that businesses currently use, yet schools usually have less money to spend than businesses do!

- Rural schools sign up for telecomputing services in large numbers if they are not forced to pay far more for access than their urban counterparts do.

- Ease of use in software is essential but does not eliminate the need for training or technical support.

- Developing different versions of software to suit the various computer platforms is very expensive and multiplies the complexity of technical support but is necessary to expand the number of participants.

- Software that takes advantage of the power of the user's computer and minimizes the time spent on-line is a must for schools communicating beyond their local calling area.

- The rigid structure of the NGS Kids Network (eight-week units, deadlines for sending data) has advantages as well as drawbacks; our participation rate, completion rate, and renewal rate all have been higher than those of more open-ended services.

Looking Back

Veterans of the struggle to bring telecomputing to K-12 may be surprised by the small amount of emphasis given here to "the last mile" and other wiring and connectivity issues. It is true that most schools have few telephone lines and that those lines are often old and "noisy," but the NGS Kids Network does pretty well even in those schools. Many of our subscribers have tried the NGS Kids Network in some makeshift fashion before committing to installation of an additional phone line or one dedicated to telecomputing. Investment in computers, modems, and phone line installation follows fairly quickly in most school systems if one can demonstrate real instructional power and gains in learning. That the NGS Kids Network succeeds in those areas is due mainly to the vast amount of field testing and revision that went into the materials, including the software. Our experiences and our resource limitations have led us to concentrate on content more than on delivery system.

When NGS started its BBS back in 1986, we had visions of growing into a comprehensive service with all kinds of features operated on our own host computer. Instead, we began to use other companies' e-mail facilities: AT&T Mail for The Weather Machine and SprintMail for the NGS Kids Network. That meant giving up parts of our vision. But it also relieved us of some nightmares. Just how many phone lines must one install to cope with incoming calls during a deadline week in one of our units? What kind of redundancy would we have to build in, and at what cost, to guard against a power failure or some other interruption to our service? We decided that we were not a telephone company or a telecomputing carrier and had no desire to become one.

Senator Al Gore and others have likened communication networks to highways and other transportation networks. (See "Networking the Future" by Al Gore.) National Geographic, and other publishers, have never been important in building highways, but without these highways we would have a hard time delivering our magazines and other publications. Neither have we been in the business of building delivery trucks—or giving driving lessons. We produce popular, educational television programs, but we do not run TV stations. Similarly, in the new medium of telecomputing, we are more interested in the content of the information packets than in the delivery system. Yet, at the moment, we seem to be forced to pay an inordinate amount of attention to the highways and delivery trucks of telecomputing because they are so unfinished, so plagued by potholes and flat tires.

In the touching belief that we have all the answers, educators who have used the NGS Kids Network often turn to NGS to meet their other telecomputing needs. They would like to be able to communicate with other schools within their district or their state as easily as they communicate with schools in other states or countries on the NGS Kids Network—but of course at lower cost because the distance is not so great. They are blissfully unaware of LATA boundaries and other obstacles to low-cost intra-state communication. The economies of scale that we can offer at the national level do not translate into greater savings at the regional level. It hardly makes sense for a school near Cedar Rapids, Iowa, to send messages to one near Iowa City via our SprintMail host in Virginia, yet the NGS Kids Network may actually be cheaper and easier to use than other ways that two rural Iowa schools could find to send messages to each other.

National Geographic will continue to make improvements to the NGS Kids Network service and The Weather Machine services. At the same time, we have found in the Prodigy videotext service another way to diffuse geographic information to a large audience of homes as well as schools. We are discussing with other telecommunications services a variety of types of information and formats that we can provide for informal education at home. But schools remain both our primary concern and the most difficult group to serve.

NGS and TERC have contributed greatly to demonstrating the potential of telecomputing by producing curricula of high quality. We hope that other information providers and service providers will follow our lead in emphasizing *equity, ubiquity,* and *ease of use* in educational telecomputing, but it seems unlikely that many will do so until the regulatory and political climate begins to make K-12 education a higher priority.

Ever since the current telecommunications policy was adopted by Congress—in 1934, the Stone Age of this technology!—schools have had to pay the same rates as businesses for telephone service. Today, schools increasingly are paying higher rates than businesses. (The biggest and most profitable businesses often pay the least, because they have the resources to set up private networks.) Surely our country should be investing more in the infrastructure of the information age. That infrastructure is not just the "highways" of communication but, more importantly, the generation of "knowledge workers" who will determine the nation's economic success in the coming century. A long overdue new national telecommunications policy should emphasize investment in our children's education.

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THE NETWORK SCIENCE EXPERIENCE: LEARNING FROM THREE MAJOR PROJECTS

by Cecilia Lenk

The Network Science Approach to Science and Mathematics Education

The overarching goal of Network Science is to give students and teachers the opportunity to *do* science and mathematics—to experience for themselves the excitement of inquiry and discovery. Too many of our students view science and mathematics as irrelevant and unconnected to their lives. All too frequently their experience with these subjects consists only of rote memorization of formulas and long lists of vocabulary words. Too often, they have little or no opportunity to participate in science and mathematics activities that are real and important in today's world.

Network Science takes a dramatically different approach to learning and teaching science and mathematics. Using the capacity of microcomputers and telecommunications networks, Network Science provides students and teachers with the tools they need to undertake scientific and mathematical inquiry. Although substantial differences exist among current Network Science projects, common elements of the Network Science approach include:

- Hands-on, project-oriented activities that emphasize cooperation, problem-solving, data collection, and data analysis;
- Investigations into meaningful and important problems in science and mathematics, such as acid rain, radon, chaos theory, and astronomy;
- The sharing of data, ideas, and results with other schools using a telecommunications network;
- Collaboration both within and outside the classroom among students and teachers; and
- The involvement of professional scientists and researchers in student investigations through the network.

Over the past six years, the author has been involved in three major projects that use the Network Science approach to improve science and mathematics education: the National Geographic Kids Network; the TERC Star Schools Project; and most recently, Reach for the Stars at the Massachusetts Corporation for Educational Telecommunications

(MCET). This paper gives an overview of important aspects of each of these projects, summarizes the major outcomes of these three projects, and suggests how the experiences of these projects can provide guidance in expanding the Network Science concept.

The National Geographic Kids Network Project

Described more fully elsewhere in this volume (see Candace Julyan's "A Developer's Perspective on Telecomputing"), the NGS Kids Network is a collaborative project among TERC, the National Geographic Society, and the National Science Foundation. The NGS Kids Network was one of the earliest efforts to use computer-based telecommunications to connect students nationally and laid much of the groundwork for developing the concept of Network Science.

Briefly, the NGS Kids Network is a series of curriculum units in which elementary school students (grades 4-6) undertake cooperative experiments in areas of current scientific interest, such as acid rain, water quality, and garbage. Using a network, students in the United States, Canada, and abroad send the results of their local experiments to a central computer, which pools the data and sends back the combined results. Classes then analyze trends and patterns in the national data, examining how their findings contribute to the overall picture. Through the network, students and teachers share their questions and observations with other classes on the network and with professional scientists.

The NGS Kids Network Software

One key element in the success of the NGS Kids Network and the concept of Network Science was the development of easy-to-use computer software that integrates three key components of the curriculum: telecommunications, data collection, and data analysis. From the inception of the NGS Kids Network project, we recognized that one of the major hurdles to teachers and students using these curriculum modules effectively would be the telecommunications technology. We wanted the focus of the project to be on doing science, not on using the technology. If elementary school students and their teachers were to collect, send, and receive data and information successfully, then the software must be unlike the majority of communications software packages. The software needed to be simple, intuitive, engaging, and powerful.

Originally developed for the Apple IIGS computer, the NGS Kids Network software successfully integrated easy-to-use communications software with data analysis tools. The software is organized around a picture of a desk. Each icon (or picture) on the desk represents a different function:

- Clicking on the notebook brings you to a series of tables for entering data;
- Clicking on the envelope brings you into the word-processor for writing and reading mail messages;

- Clicking on the graph lets you create line graphs, bar graphs, or pie charts;
- Clicking on the globe lets you view data as a map;
- Clicking on the telephone lets you access the network for sending and receiving messages and data.

The software completely automates sending and receiving data and electronic mail. Students and teachers work entirely off-line to write e-mail messages and enter data. The ability to work off-line is critical to using telecommunications effectively in classrooms. Not only does it keep down network costs, but students can write a message or type in data at their own pace without the pressure of being on-line.

Equally important, classrooms do not absolutely need a telephone line (although a phone line in the classroom is certainly desirable). The NGS Kids Network software bundles together all mail messages and data files for sending to the network. To access the network, students (or the teacher) simply click on the picture of the telephone. The bundled data and messages are then sent to the network and data and messages from other classes are picked up from the network at the same time.

In addition, the integrated software also lets students analyze their own data and data from the network as tables, graphs, and maps. Each of these utilities allows students to see data in different ways and to work with the data. For example, when a student views data as a map, he/she can change the map scale, add rivers and boundaries, or view different areas of the world.

The NGS Kids Network software has been used successfully in a large number of classrooms. In the vast majority of cases, the teachers have had little or no workshop training. The underlying concepts of the software, ease-of-use, and the integration of telecommunications and data analysis tools eliminate many of the technological hurdles and help students and teachers concentrate on the curriculum activities.

The TERC Star Schools Project

The TERC Star Schools Project expanded TERC's commitment to Network Science and to using telecommunications to improve science and mathematics education. In 1988, TERC received a two-year $4.5 million grant from the U.S. Department of Education Star Schools Program to create a telecommunications-based science and mathematics curriculum for middle and high school students (grades 7-12). The central educational strategy of this ambitious project was to provide students with the opportunity to be researchers. Our goal was to involve students in cooperative hands-on projects which were very open-ended and required students to plan and carry-out their own investigations. Telecommunications was a critical component of this approach. Through the computer-based network, students could plan their research, take part in joint investigations with other classes, obtain expertise, and share results and data with other students and professional scientists.

In spring 1989 we tested the first 5 units in 200 classrooms throughout the United States, including the U.S. Virgin Islands. By the end of the project in fall 1990, nearly 700 teachers and their classes in 41 states, as well as classes in Japan and the Soviet Union, were participating in the project.

The curriculum units—*Intronet, Radon, Weather, Polls and Surveys, Solar House, Descent of a Ball, Connectany, Koetke's Challenge, Triangle Chaos, Iterating Functions*, and *Trees*—included both mathematics and science units. In addition, small groups of teachers worked together on the network to develop classroom activities using Lego/LOGO.

Following a set of core activities in each curriculum unit, students were able to develop their own projects with their classmates or with others on the network. For example, in the Radon unit, all classes measured the radon in their school basement. These data were shared among the participating classes in different parts of the country. Each class then undertook to develop their own radon investigation. For example, a class in Salem, Massachusetts, measured the radon in the historic buildings of the town. Other classes undertook radon surveys of homes in their communities. Information about these research projects was shared on the network. Students involved in the radon unit could also contact professional radon researchers through the network.

A major undertaking of the TERC Stars Schools Project was to develop a prototype of a new type of integrated telecommunications and data analysis software, which, when completed, will substantially improve students' ability to work with data. (See "Alice: Telecommunications for Education" by Patricia Parker).

The TERC Star Schools Project: Staff Development and Support

A major effort of the TERC Star Schools Project was teacher professional development to enable teachers to incorporate effectively telecommunications technology and project-based mathematics and science into their classes. Twelve Resource Centers nationwide provided extensive teacher preparation and support: Arizona State University; Biological Sciences Curriculum Study (BSCS); Boston Museum of Science; The City College of CUNY; MECC; Northwest Regional Laboratories; Pepperdine University; State University of New York (SUNY) at Stony Brook; Tufts University; University of Georgia; University of Michigan; and University of Virginia.

Each of the Resource Centers was responsible for recruitment, teacher preparation, and ongoing teacher support during implementation. Not only did their personnel give the project a national reach, but they provided invaluable expertise in the needs of teachers, schools, and districts in their region. The Resource Centers played a critical role in providing support and assistance to teachers. Each Center conducted hands-on workshops for participating teachers and provided ongoing support. Importantly, each Resource Center had its own approach to staff development, based on its knowledge of schools and districts in its region.

The Center model, in conjunction with the telecommunications network, was designed to provide support precisely as teachers were implementing the curriculum. In some cases, Centers were located near schools, and Center staff visited teachers. The network, however, offered another important way for Center staff to stay in touch on a regular basis with teachers.

Evaluation of the TERC Star Schools Project

Under the direction of Dr. Sylvia Weir, the TERC Star Schools Project conducted a major evaluation of the project specifically focusing on the role of technology as an integral part of this innovative curriculum effort. Evaluation data were collected through teacher surveys, teacher interviews, student interviews, and an analysis of the messages and data sent on the network. Some of the major findings of Dr. Weir and her collaborators were:

1. Many teachers found their participation in the project to be a rewarding experience. The approach encouraged them to use more open-ended and collaborative teaching and evaluation approaches with their students. By the third semester of the project (April–June, 1990), 78% of the participating teachers reported that the open-ended project activities had led them to modify their teaching methods and that their students participated in more small group work. In addition, teachers reported that the project promoted team-teaching across disciplines. The network also provided a mechanism for teachers to establish peer collaboration and learning.

2. The TERC Star Schools Project was particularly successful in addressing the needs of disadvantaged students. Teachers reported that students who were traditionally less successful in science and mathematics, including learning-disabled and minority students, were better served by the TERC Star Schools curriculum than by their regular science and mathematics curriculum.

3. The combination of the Resource Centers and the telecommunications network provided an effective and efficient means of providing support to teachers and enhancing communications among project participants—TERC project staff, Resource Center staff, and teachers. The network was especially important in managing a complex project. E-mail greatly facilitated communication among TERC and the 12 Resource Centers.

4. Each of the units was successful in developing important student skills and understanding in one or more areas:

   - Some units, such as *Descent of a Ball* and *Solar House*, were more effective in promoting student inventiveness than others. *Descent of a Ball* and *Solar House* are units in which students design and build structures within a given set of criteria;

   - The *Radon* unit helped students see science as a collective enterprise;

- The mathematics units (*Connectany, Koetke's Challenge, Triangle Chaos,* and *Iterating Functions*) in which students undertook computer-based mathematics projects were effective in increasing students' observation skills.

5. Our predictions as to which activities would promote network use were not always accurate. It was difficult to promote conversations on the network beyond the initial send and receive stage. The role of the network in the curriculum units and methods to promote network exchanges needs to be addressed more systematically.

6. The project promoted a high level of student interest and, importantly, an awareness among students of their role as learners.

7. Communication between scientists and students was often difficult to achieve. Although many scientists volunteered to participate in the project and were eager to converse with students, there were few exchanges between scientists and students. We need to develop ways to strengthen the links between the scientific community and students and teachers.

8. For many teachers, lack of time was a real problem in implementing the curriculum. Teachers also reported problems in getting access to computers, modems, and phone lines.

Reach for the Stars

Reach for the Stars is designed to improve science education in middle grades (grades 5-8) by integrating multiple educational technologies (including distance-learning by satellite, computer-based telecommunications, interactive videodiscs, videotapes, and computer software) with instructional strategies that emphasize investigative problem-solving and cooperative learning. Funded by the U.S. Department of Education Star Schools Program in October 1990, Reach for the Stars is working with teachers and their classes at all levels of interest and achievement. Currently 59 schools and districts in New England and New York are participating as demonstration sites in the two-year project. A critical component of Reach for the Stars is the involvement of school and district administrators, school committee members, and families in this effort to improve middle grades science education.

Reach for the Stars is a collaboration among MCET and 21 leading educational organizations. Over the next 2 years, this partnership will focus on 5 key areas:

1. Develop, adapt, and disseminate innovative programming and products that use multiple technologies, including interactive satellite broadcasts, computer telecommunications, and interactive videodiscs. These programs and products are being developed for students, teachers, administrators, school committee members, and parents.

With a focus on space and environmental science, the interdisciplinary programs to be developed for classroom use include: interactive videodiscs produced by WGBH and by Chedd Angier Productions; *Environmental Adaptation*, a distance-learning course which combines videodisc and computer activities, taught by Alan Hein, MIT; telecommunications-based curriculum units from TERC; and *Science by Mail*, from the Boston Museum of Science, which puts students in direct contact with scientists as mentors.

Distance-learning courses for teachers include: *The Process of Science*, on teaching strategies from the Education Development Center; and *Developing Critical Thinking Skills in Science*, an interactive satellite and computer course taught by David Perkins, Harvard University, and Robert Swartz, University of Massachusetts.

Recognizing that change affects the entire school community, the project will produce several teleconference series for school committee members and superintendents on policy issues around changing science teaching; for principals on problems and solutions in teaching science in the middle grades; and for parents on supporting their children's science education.

2. Implement the Reach for the Stars interdisciplinary and multi-technology approach to science education in 59 demonstration schools and districts in New England and New York.

   Each demonstration district and school will develop its own plan for participation in the project, choosing from among the Reach for the Stars programming and products and meshing these with its own ongoing programs. At each demonstration school, a team of two teachers, one focusing on science, one on another discipline, will work together on the project, developing an interdisciplinary approach to science teaching. Teachers involved in the project include science, mathematics, English, language arts, social studies, computer, reading, and special education teachers.

   A critical component of the project is the development of a science school improvement team at each site. Although different participants make up the science school improvement teams in each community, teams include the participating teachers, technology and discipline-specific coordinators, school-building and district administrators, and school board members. Based on their needs and their experience with Reach for the Stars, each team will produce a school Science Action Plan to implement after the grant period.

3. Provide assistance and support to teachers, schools, and districts at the research sites in improving science instruction.

   Reach for the Stars is providing staff development and ongoing support to participating teachers on the use of technology and assistance in selecting and implementing the programs they wish to use. One-day workshops, a one-week

Summer Institute, and school visits are being conducted by the project's teacher support staff. In addition a computer network keeps teachers, administrators, and project staff in daily contact.

Importantly, through its teleconference series and site visits, Reach for the Stars will involve school principals, superintendents, school committee members, and parents in understanding the need for, and being part of, improved science education.

4. Document and evaluate the innovation process at the demonstration sites.

   Reach for the Stars is developing substantial formative and summative evaluation programs that will contribute to knowledge about how to improve middle grades science education and the role of multiple technologies in assisting this effort. In collaboration with Dr. Barbara Flagg, the project is undertaking extensive formative evaluation of Reach for the Stars programs and products now under development. The Regional Laboratory for the Northeast and Islands is conducting a summative evaluation of the project. The summative evaluation process involves documentation of the change process at all demonstration sites and the development of intensive case studies in ten districts.

5. Disseminate the products of Reach for the Stars regionally and nationally.

   Reach for the Stars will disseminate two types of products: curriculum products and programming for students, teachers, administrators, school committees, and parents; and case studies of the innovation process. All distance-learning programs developed by Reach for the Stars will be available through MCET's satellite network. The videodisc and other hands-on student materials will be available through commercial publishers during the second year of the project. The ten case studies will be disseminated as a book or through a series of journal articles.

Building on the Experience of these Three Network Science Projects

In each of these Network Science projects, in addition to formative evaluation of the software and curriculum materials, we are looking at the broader issue: Does Network Science make a difference to science and mathematics learning and teaching, and if so, in what ways? In addition, in each of these projects, we are concerned with the problems of the Network Science approach. What issues do we need to solve in order to incorporate Network Science more widely into classrooms?

The NGS Kids Network and TERC Star Schools Project offer some answers. The formative and summative evaluation of Reach for the Stars will add to our base of knowledge about the problems and successes in integrating telecommunications technologies and hands-on science. In addition, Reach for the Stars may offer some important models for how schools and districts can more widely adopt this approach.

Network Science has already shown itself to be a successful approach to science learning and teaching. The author has been particularly impressed with the high level of enthusiasm and interest this approach has generated among teachers and students. Despite frustration with aspects of the technology, including poor telephone lines and problems with prototype software, teachers report that Network Science motivates their students. Students especially feel empowered by their involvement in current and meaningful scientific issues and the ability to communicate using telecommunications with other students in the next town, across the country, or around the world. Importantly, in the NGS Kids Network and the TERC Star Schools projects, teachers have reported that the hands-on activities and telecommunications network engage many students not normally interested in science and mathematics, including girls, minority students, and learning-disabled students. Reach for the Stars, although still in its initial stages of development, indicates that districts and schools are anxious to improve their science education and become involved in education programs that involve telecommunications. Nearly 90 districts in Massachusetts applied to be demonstration sites for Reach for the Stars (30 of these districts were accepted into the program).

There are also indications that Network Science can effectively change how teachers teach science. In the TERC Star Schools Project many teachers reported that they made changes in their teaching styles to allow for more student initiative and exploration. Teachers and students worked collaboratively within the classroom. However, network collaborations, beyond simple data exchange, are more difficult to establish and more work needs to be done in this area.

There is a widespread need to help teachers and students undertake data analysis. Despite the emphasis of Network Science on data analysis, students frequently do not go on to do any meaningful exploration of their findings. Teachers frequently do not know the questions to ask or how to guide their students in analyzing data. This finding should not come as a surprise. Knowing how to look at data is difficult. TERC'S software (Alice) and similar integrated software, that lets students work with information easily, may help alleviate some of this problem.

Teachers also need ongoing support in this area. Successfully involving scientists in Network Science projects could encourage more attention to data analysis and interpretation. Although many scientists are eager to get involved in these projects, developing communications among students, teachers, and scientists is difficult using a computer network. Reach for the Stars adds an additional component here which may assist in connecting students and teachers to scientists. Through the one-way video, two-way-audio teleconferences, students and teachers are able to see and talk directly to scientists. This ability first to see and talk to scientists may increase students' and teachers' willingness to communicate with them subsequently on the computer network.

Lack of time is a major hurdle that teachers face in implementing Network Science activities in their classes. TERC is addressing one aspect of the time problem by making telecommunications software and the network flexible and easy to use. But finding the time to do telecommunications is not the only problem. Teachers and students also have rigid schedules that allow little flexibility. Reach for the Stars will assist schools and districts in taking a systematic look at how they need to change in order to accommodate these effective curriculum innovations.

Based on the author's experience working on these three projects, several critical areas need to be addressed in order to expand Network Science:

1. Providing K-12 students, teachers, and administrators with low-cost, global telecommunications that link classrooms, colleges and universities, and research institutions;

2. Developing effective ways to promote communication and collaboration among students, teachers, and professional researchers through telecommunications;

3. Eliminating technological hurdles, including lack of phone lines in classrooms and clumsy communications software;

4. Increasing the flexibility of schools in order to accommodate more open-ended inquiry and collaborative activities; and

5. Increasing our understanding of the impact of Network Science on teaching and learning.

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BUILDING ELECTRONIC COMMUNITIES: SUCCESS AND FAILURE IN COMPUTER NETWORKING[1]

by Margaret M. Riel and James A. Levin

The technology to create electronic, global communities exists today. There are currently global networks through which people can exchange electronic messages at a reasonable cost. Creating the social organization of these communities, however, requires careful planning. Too many networking communities have fallen silent, as electronic ghost towns. This paper will explore the successes and failures experienced in our efforts to develop electronic communities, in the belief that there is much to learn by contrasting network successes with failures.

Today, the most common form of interaction on electronic networks is the exchange of electronic messages. These messages are typed on a microcomputer and beamed instantly through telephone lines, satellites, and computers to end up at their destination—the computer screen, printer, or disk of the receiver. The messages can go around the world to many different locations in a matter of seconds.

Here is an example of an electronic message:

> From: TCN268 24-Lines
> On: 11 OCT 1984 At: 10:43
> To: TCN268
> Subject: FROM MOSHE IN ISRAEL TO JIM
>
> HI Jim
>
> You can imagine how exciting it is to be
> here writing to you from home. Shlomi is
> standing by and laughing. Esther and Einat
> just joined us.
> Please let everybody know that I am
> on-line already.
>
> Shalom Moshe.

The sender of this message, like the senders of many such initial messages, expresses his high level of excitement and a sense of accomplishment, joining the ranks of information-age pioneers. Such first messages are the opening moves in the construction of a new social organization. But will these messages be followed by others in a system of communication that creates and sustains a new community? Or will these first words

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1 This paper first appeared in *Instructional Science, 19*, 145-169 (1990), and is reprinted by permission of Kluwer Academic Publishers.

be nothing more than a quick introduction at an electronic cocktail party which fails to lead to any further exchange? These messages themselves do not contain the clues that help us to predict the success of the development of a networking community. They simply index a potential, a level of expertise in forms of technology that is but one of the essential building blocks of electronic communities.

Electronic Community Development

Electronic message systems allow for many different kinds of interactions, including one-on-one dialogues, one-to-many broadcasts, and many-to-many group interactions. Information is sent instantaneously but without the demand for immediate attention by the receiver. It is as easy to specify all users of a network as it is to specify a single receiver. While the form of exchange is often informal, there is a written record of the communication. Information can be electronically stored and retrieved as new members join an information exchange.

Initially, electronic networks are viewed by their users as just a more efficient way to conduct the same kinds of interactions. However, they soon find that computer telecommunications can facilitate group interactions in ways that are qualitatively different than that provided by other media. It is this potential to create and maintain group interaction among people separated in time and space that we are beginning to explore. The promise of a new social organization is not easily realized. To understand this new form of community building, we believe it is necessary to take an analytic perspective on early efforts, both successes and failures.

To do this, we employed a research strategy that has proved successful for comparing interaction in different educational settings. Philips (1972, 1982) analyzed patterns of behavior in educational settings in terms of their "participant structures." Participant structures of group interaction have helped explain why students from certain cultures systematically function poorly in the conventional western classroom setting (Au, 1980; Erickson & Mohatt, 1982; Florio, 1978; Mehan, 1979; Moll & Diaz, 1987; Philips, 1982). The strategy has also been used to compare classroom interaction with and without the presence of a computer (Mehan, Moll, & Riel, 1985). The list of participant structures used in these classroom studies are:

- Organization of the work group;
- Task organization;
- Response opportunities;
- Response obligations;
- Evaluation.

We have adapted these participant structures to provide a schematic frame for describing computer network communities. They help isolate features that correlate with successful patterns of network interaction. Participant structures were modified for examining network interaction in the following ways:

Organization of the Network Group

Participants on a network can range in number, amount of past experience, degree of common interest, and relationships within the group. Networks range in size from very small groups to groups of indeterminate, changing size. Network participants can range from those who have never interacted in any way other than by electronic mail to those who know each other well. In some networks, participants have shared a common experience, such as a class, conference, or project. In others, the network interaction is the only shared experience among the participants. Their relationships to one another can be organized horizontally or vertically.

Task Organization

Networks serve as a communication medium for a group of people with some common interests or background. Beyond that, networks vary greatly in terms of the specificity of the activity that is supported. For some groups the activity is only specified in the broadest terms, such as to facilitate cooperative tasks, exchange information, or share ideas. In other cases, the form of the interaction is highly specified with a particular goal to achieve, such as the publication of a paper or the development of a product.

Response Opportunities

Response opportunities on a network index the ease of access to the network, the presence of electronic equipment, and the expertise necessary to use it, as well as the presence of social resources that form the necessary link to the electronic network. How technical knowledge to send and receive messages through all computer gateways is distributed among the participants would be captured by this participation structure. This participation structure also indexes the communication context. The electronic medium is one of a number of communication media that are generally available for the exchange of information. The comparative ease and costs of these other systems will influence the participation on an electronic network.

Response Obligations

In any form of exchange tacit assumptions develop of how long a wait is appropriate before a response is expected. In face-to-face interaction, a pause of more than a few seconds is often marked as uncomfortable by participants; however, one year may be seen as an appropriate time period in which to receive a response to questions asked in a Christmas card.

When we send postal mail to a person, we operate on the shared convention that mail collecting is a daily activity. While electronic mail may be delivered more quickly, shared assumptions about how often electronic mailboxes will be checked do not immediately exist. Therefore, the participants often need to create their own conventions on a network as to what is an appropriate time delay to wait for a response. In a networked community this participation structure examines the response conventions as well as obligations.

Coordination and Evaluation

Evaluation is a critical dimension of classroom interaction. Examining how teachers evaluate their students is an indirect way of examining the power and authority structure of the classroom. Teacher assessment leads to organization of the group and task.

In a network community, evaluation can also play a central role, but who is doing the evaluation and how it affects the organization of the group and task is not always as clear. The evaluation may be done by all the participants with no clear responsibility located in an individual or by a number of people who take on the role of evaluating different aspects of the interaction. For example, there may be a task leader and a technical expert.

Just as there are numerous ways to lead a face-to-face group, so too are there many ways to coordinate an electronic discussion, each of which is suitable for different kinds of groups engaged in different kinds of activities. The following chart summarizes the participant structures modified for use in examining group interaction on computer networks:

Network Participant Structures

1) **Organization of the network group:** its size, common knowledge and interests, past experiences, and the physical location of the participants

2) **Network task organization:** the types of activities that participants engage in over the network

3) **Response opportunities:** ease of access to the interaction, including social and technical resources for sending and receiving messages

4) **Response obligations:** the tacit or formal requirements for a response to a message

5) **Evaluation and coordination:** any forms for assessing the quantity or quality of the exchanges on the network

Next we describe several successful and unsuccessful efforts to develop electronic networks for three groups: (1) university faculty, (2) elementary and secondary teachers, and (3) elementary and secondary students. The evidence that we use for success is a high level of use coupled with user reports of its efficacy. Unsuccessful networks were networks that either exhibited "failure to thrive" tendencies from the beginning or networks that gradually fell silent as the needs of participants were not met.

University Researchers Networks

Many electronic networks are used to coordinate university departments and research units. Electronic "message groups" are formed to facilitate communication among groups that share common interests. In this first pair of case studies, we contrast two message groups at the same university. The differences point to some of the features that we believe are important in determining the success of electronic networks.

The goal for establishing these networks was to create a channel of communication that takes advantage of "non-real" time for sharing information (Black, Levin, Mehan, & Quinn, 1983; Quinn, Levin, Mehan, & Black, 1983). The sender does not have to locate the receiver in time or space to send a message. The message can be sent to any one person, a number of individuals, or to the whole message group. Each group was involved in regular collaborative work that took place in different types of settings. A variety of uses of the message system grew out of this activity. This section compares two different research laboratories that had access to a university-wide electronic mail system.

The first research lab used electronic communication to organize a wide variety of forms of interaction. Researchers, faculty, and graduate students used electronic messages to coordinate tasks, schedule meetings, work collaboratively, and post information. Message traffic varied across the participants interviewed, but over half the participants sent at least one message daily. An average user received about 10 messages daily with about 8 of these from people within the message group and the balance coming from other users in the university.

The second example of a university message group is from a laboratory of about 20 researchers, faculty, and students. This smaller group all had accounts on the university message system, but while some participants accessed their mail daily, other participants checked mail only once every few weeks. This communication medium became increasingly less reliable and was eventually abandoned by the group in favor of other forms of information exchange. Despite efforts to encourage its use, the message system failed to provide an efficient form of communication.

By exploring the reasons that contributed to the success and failure of these two groups' networking experiences, we can begin to establish the critical factors for developing networking communities. The participation structures for the two groups are summarized in Table 1. The features shown in italics are comparisons that participants identified as important for the activity level of the network.

Table 1: Networks for University Research

Participant Structures	Successful Network Research Lab 1	Unsuccessful Network Research Lab 2
Group Organization		
Average size	50	20
Prior knowledge	extensive	extensive
Common interests	Yes	Yes
Location	*2 (multi-level) buildings*	*1 (one-level) building*
Professional status	diverse	diverse
Network interaction	1-1; 1-many; group	1-1;1-many; group
Other forms of interaction	many	many
Task Organization		
Group goal	many/changing	many/changing
Timeline	for some tasks	for some tasks
Ending date	none	none
End product	none	none
Response Opportunity		
Work access	*in office*	*common location*
Home access	*for most*	for some
Response Obligations		
Response time expectation	same day	same week
Evaluation/Coordination		
Technical support	Yes	Yes
Coordinator	Yes	Yes

Comparison of Participant Structures on University Networks

Group Structure

Members of each group knew one another well and interacted with each other in meetings, classes, colloquium series, and other informal settings. The first group occupied offices throughout two different buildings with many small areas where people could congregate, drink coffee, and talk. Members of the second group had offices adjoining one another on the same floor of a building. There was a single central office where mail was delivered and coffee and supplies were available. Most people saw each other in this informal setting several times a day.

Task Structure

In both groups there was no single task on the network that was shared by all the users. The network served as another general-purpose communications tool like the telephone or interoffice memos. Participants interviewed indicated that they found the system effective for both professional and personal communications in their lab. The system was used to distribute news, extend discussions after colloquium or other face-to-face meetings, write cooperative papers, and schedule meeting times. It was also used for more personal exchanges in the workplace, such as announcing the birth of a child, inviting groups to parties, and advertising or searching for items for sale or rent.

Response Opportunities

There was a critical difference between the two groups in terms of the access to electronic mail. Almost all participants in the first research laboratory did their daily work on computer terminals in their offices, connected to a common computer, so it was easy for members to check their mail several times a day. Also, their terminals beeped to indicate the arrival of new mail. Many of the participants had terminals at their homes as well.

The members of the second lab used personal computers rather than terminals. Not all of these personal computers were equipped with communications hardware. Checking mail often required a visit to an adjoining office or the computer center. Only a few participants had access to the message system from their homes.

Response Obligations

Response obligations are tied to response opportunities. When checking mail is a routine part of one's work, the expectation of a quick reply is higher. In fact, members of the first research group checked their messages several times a day, often more frequently than they monitored their physical mail boxes. There was a tacit notion that it was rude not to respond to a message within 12 hours (Bannon, 1986).

Since easy access to the message system in the second group varied, important messages were usually printed and distributed in physical mail boxes to ensure distribution to all the participants. This method of distribution decreased personal obligation to read electronic mail regularly. Given the patterns of social interaction, people were likely to see each other in person sooner than they could connect electronically.

Evaluation/Coordination

The heads of each of the two research labs were technically sophisticated and set up mechanisms to assure that all members had access to the technical skills required. However, there was a different response in the two labs to unanswered mail. In the first lab, phone and print messages would alert a nonrespondent that a message was waiting. Failure to read the mail was marked in the same way as failure to turn up at group meetings or unwillingness to participate in cooperative endeavors.

In the second lab, the most common use of the message system by the head of the lab was for reporting lab activities and projects to interested people in other research units. This use did not place any pressure on the participants within the lab to increase their access to the message system.

Summary

The contrast between these two groups points to some of the dimensions that are likely to contribute to successful networking at the university level. Networks are more likely to succeed if:

- The participants work closely together but have physically separate work places;
- There is easy and equal access to the technology by most participants;
- There is reasonable pressure to access mail regularly.

Smaller groups working in confined areas have more efficient methods of coordinating activity than electronic mail. Large groups that regularly work together on a variety of tasks and that have easy access to the technology find electronic mail an efficient way of coordinating their work.

Teacher Networks

Teachers spend most of their time in classrooms isolated from one another. They are one of the few categories of professionals who have very limited access to telephones or other means of interaction with those outside the classroom. Computer telecommunication offers the possibilities of professional contact from their classrooms in a way that does not disrupt teaching. The following three examples are of networks designed to provide professional growth for teachers.

Just placing the technology in the hands of teachers is not the best strategy for establishing a network. The first two case studies show the shortcomings of attempts to develop networks of teachers by focusing on the technology and technical expertise.

The first group was a small number of teachers and researchers who were working together to study the impact of computers in classrooms. The team worked closely together and the director of the group thought that an electronic network would organize the work better. The second group had shared a common learning experience in the form of a summer institute sponsored at a university. Summer institutes are an effective method of in-service training and a way to bring together teachers with common professional interests. A decision was made to extend this learning experience by establishing a computer network for their use.

In both cases teachers developed the technical skills necessary for participation, but neither of the groups matured into a networking community. The third case study provides a contrast.

The third group was composed of teachers enrolled in an electronic university extension course. Teachers wanted to learn more about telecommunications but scheduling a time and place when instructor and teachers could meet was difficult. A decision was made to offer a university course over a bulletin board system that supported electronic mail.

Teachers could take the course for university credit or for professional growth. The teachers' interaction was regular and the group formed a close working partnership, a networking community. This electronic community continued to develop after the course was completed.

Table 2 compares the participant structures for these three teacher networks.

Comparison of Participant Structures on Teacher Networks

Group Structure

The groups varied in the amount of prior and continuing contact they had with one another. The research team included a small number of teachers, researchers, and graduate students who were working closely on a research project. The research was ongoing when the network was formed to facilitate their interactions. The teachers from the summer institute in mathematics had participated in an intensive education program daily for a period of several weeks prior to the construction of the network. Most of the Tele-Class participants did not have any prior knowledge of one another. There were 20 teachers, a university instructor, and a computer technician.

Table 2: Networks for Teachers' Professional Development

/ Participant Structures	Successful Tele-Course	Unsuccessful Research team	Unsuccessful Summer Institute
Group Organization			
Size	20	11	5
Knowledge of each other	minimal	extensive	moderate
Common interests	yes	yes	yes
Location	20 locations	5 locations.	20 locations
Professional status	similar	diverse	similar
Network interaction	group	group	group
Other forms of interaction	none	*many*	none
Task Organization			
Goal	specific	specific	*general*
Timeline	yes	yes	*no*
Ending date	yes	yes	*no*
End product	yes	no	*no*
Response Opportunity (for majority of users)			
Work access	classroom	classroom	classroom
Home access	yes	no	no
Response Obligations			
Response time expectation	2 days	weekly	not specified
Evaluation/Coordination			
Coordinator	yes	yes	*no*
Evaluation	yes	*no*	*no*

Organization of the Task

The research team network was set up to facilitate communications among the different members of the research team. Specifically, the network was expected to contribute to the coordination of meetings, allow for the discussion of ideas, and enable teachers to request any help they might need from the university. The network for the summer institute teachers was designed to extend the mathematics teachers' access to a broad set of social and university resources, provide new ways to improve mathematics education through teacher collaboration, and allow the easy coordination of visits to these teachers' classrooms by university pre-service teachers. The goal of the Tele-Class was to learn how to integrate computer networking with classroom instruction. Telecommunications was both the medium of instruction and the topic of study for the semester.

Response Opportunity

The members of the research team network all had easy access to the network. Phone lines were installed in the teachers' classrooms, university researchers had access to the network from the university, and some also had access from their homes. All participants had training to use the network with ready support on any technical issues.

Similarly, equipment and telephone lines were placed in the classrooms of the teachers from the summer institute. Each of the teachers was extensively trained in the use of the hardware and software. They received on-site visits from a telecommunications expert who set up and tested their communication systems. When teachers did not respond to messages on the system, visits were made to the classrooms to solve any technical problems that had developed.

The Tele-Course was offered to teachers who already had access to equipment and the technical skill necessary to call into FrEdMail (Free Education Mail System), an electronic bulletin board established by Al Rogers (1988). There was an on-line technical assistant who was available to provide any needed support with hardware or software problems. Most teachers had computers with modems in their homes as well as in their school settings. The class met face-to-face once at the beginning of the course and again at the end of the course. The rest of the interactions between this group took place through computer conferencing.

Response Obligation

In the research group, the project director would send summaries of the weekly research meetings and suggest topics or ideas for discussion. Messages sent by the project director sometimes required a response, but the response did not have to be on the network. The interactions between different team members were frequent enough that messages and materials were exchanged in face-to-face encounters rather than on the network.

The teachers from the summer institute were under no obligation to use the system in any specific way. The excitement of the teachers to continue their professional contacts with this new technology was expected to translate into regular use.

There was a very well-defined response obligation for the Tele-Course. Roll call was taken electronically. Teachers were expected to spend at least three hours on the system reading or sending mail, and their "attendance" was monitored electronically. Teachers who did not participate regularly were dropped from the class. There was no minimum number of messages that a class member was required to send, but all class participants were expected to be involved actively.

Evaluation/Coordination

For the research team, there were regular messages from the project director summarizing meetings and posing new issues. There were no negative consequences if a participant did not read or send messages. There were many channels other than the electronic network for exchanging information.

The network for the summer institute teachers did not have a person on-line who acted as a coordinator or project director. University researchers who established the network offered technical assistance but assumed that the teachers would direct their own use of the technology.

The instructor in the Tele-Course served in the role of coordinator and evaluator of the network interaction. She sent 16% of the total messages exchanged by the group. Many of these group messages raised topics for discussion. The instructor also sent messages to individual students. Students who enrolled for credit were evaluated on the basis of their network participation as well as on their term projects.

Summary

Networking can provide a means for teacher learning and teacher development, but placing the technology in the hands of teachers is not likely to be enough. In the first two cases, even with prior knowledge and work patterns, there was no development of a networking community.

In the case of the research group network, there was no real need for telecommunications since the patterns of "real-time" communication were sufficiently rich to make asynchronous communication unnecessary. Weekly meetings with the whole group were efficient for sharing ideas with the group. The coordination with classroom observers was best accomplished by regularly scheduled telephone conversations. Sending information to the university was easily accomplished by sending verbal or written messages with classroom observers. The only exception to this pattern in the research group occurred when a researcher in a distant city visited the project. For the next few weeks, there were a number of messages between this person now located in a distant city and the teachers on the research team network. Other than this exception, minimal need to communicate using the electronic network led to infrequent access, which then made it an unreliable way to communicate. In short, the network was inefficient given the level of coordination required and the alternative means of communication available.

The summer institute teachers shared interests and may have had a need for asynchronous communication, but they had no shared task about which to communicate. A substantial amount of equipment and training was invested to set up the network for the summer institute teachers. Messages were sent out from the university. A few initial messages (like the one shown at the beginning of this paper) suggested the network's potential. A well-known mathematics curriculum expert was asked to serve as a regular consultant on the network and was ready to respond to the needs of the teachers. But, with no common task, there were no needs.

There was no specified goal for these teachers and no one took the lead in establishing a cooperative goal or project. Setting up the technology of the network was like setting up a physical classroom, and the curriculum expert was analogous to good resource material. However, the group lacked educational objectives or goals and did not have a coordinator to help it function cohesively to achieve goals. This example points to the importance of shared goals or activities as a basis of group organization on electronic networks.

The participants in the third case study, like those in the first group, had a shared, specified task and a time frame for its completion. Unlike the first group, the third group had a need for asynchronous communication. The third case also differed from the first two in terms of direction. There was a person who was in charge of facilitating the interaction and there was a response obligation that was dictated by the course structure. While a course structure may not be the only way to create successful networking experiences, the role of a leader or facilitator may be a critical factor in success.

Also unlike the first two examples, activity in the Tele-Course remained high during the period of the course and continued after the course was over. During the 10-week period, 121 messages were sent to the group conference by the 20 people who participated. This does not include the electronic messages that were sent to individuals, for example, between the instructor and a student or between two students. Fifteen participants enrolled in the class, 2 were dropped because they failed to read mail regularly, and 6 joined the group some time during the semester, sending at least one message. The instructor and the 5 most active participants averaged one and a half messages a week.

This network addressed a need expressed by the teachers. The class was less than half over when the teachers began to discuss ways to continue the class beyond the ending date. The teachers and their instructor continued their interaction through electronic mail on a bulletin board network, developing new ideas for telecommunication and strategies for implementing them. The role of a coordinator and a focus on a topic seemed to be the critical features that contributed to the success of this network.

These comparisons point to the crucial role played by the teacher or group leader and the role of the specific networking task in development of a learning environment. No one suggests that inviting teachers to spend the afternoon in the same building will result in their professional development. To expect that teachers will simply share their knowledge with one another in an open discussion format on a network ignores the need for organizational structure that is taken for granted in other forms of social interaction.

These comparisons suggest the following guidelines for the construction of electronic communities:

- Asynchronous network communication needs to be more efficient than other forms of group interaction;
- A goal or task needs to be shared by the group;
- Someone needs to take the responsibility of facilitating the interaction.

Student Networks

Students, like teachers are also isolated in schools. They acquire much of their knowledge in silent interaction with printed material. The skills they will need as adults, however, include the ability to express themselves, to share ideas, to create and explore new information, and to learn from others. Networking provides a way to extend the audience and experiences of students across geographic and cultural boundaries. Students serve as teachers and learners in partnership with other students. Two examples, one failure and one success, mark the beginning of our explorations of how to structure educational activities across distances.

Like many other educators and researchers, our first thoughts on how to use computer networking to improve students' writing abilities was to get them to write letters to one another. We realized that students in different cultural and geographic regions could provide one another with valuable contrasts to their taken-for-granted assumptions about the world. With the help of Ron Scollon in Alaska, we sought "computer-pals" for students in California. Teachers collected computer-pal messages from their students and these letters were sent by computer to classrooms in distant places.

Students in Alaska and California were very excited about sending letters to their computer-pals, but matching large numbers of students in one-on-one relationships was problematic. The schools in Alaska had many fewer students, so that letters from a single California classroom were distributed to four or five different Alaskan schools. This resulted in time differences for responses, with some students never receiving responses. Letters that came addressed with the general greeting "Dear Computer Pal" were not eagerly received by students who were awaiting personal responses. After six months of frustrations with the organization of the group and teacher dissatisfaction with the limited nature of the task, we abandoned the idea of computer-pals.

Our experience with computer-pals suggested the need for a group context for networking rather than one-on-one interaction. We set up a children's newswire network (Levin, Riel, Rowe, & Boruta, 1985; Riel, 1985) to encourage students to write and edit stories for publication in school newspapers. Students were excited to think of their stories being read by students "across the country and around the world." They were especially excited when a story they wrote appeared in a newspaper from another school.

The newswire continued to exist for several years as a relatively successful example of computer networking in schools. Stories were transmitted in several languages. Teachers reported that student reporters and editors took their task seriously and that it had positive effects on students' writing abilities. These improvements have been found in several research studies of classrooms participating in the electronic newswire network (Cohen and Riel, 1989; Levin et al., 1985; Mehan et al., 1985).

Table 3 shows the participant structure comparison for these two groups.

Table 3: Networks for Student Learning

Participant Structures	Successful News Network	Unsuccessful Computer Pals
Group Organization		
Size	12 classrooms (average)	7 classrooms
Knowledge of each other	none	none
Common interests	no	no
Location	8 sites/2 states	7 sites/2 states
Age range	Elementary	Elementary
Network interaction	*group*	*1-1*
Other forms of interaction	none	none
Task Organization		
Curriculum task	writing articles	writing letters
Timeline	yes	no
Ending date	no	no
End product	*yes*	no
Response Opportunity (for majority of users)		
Work access	classroom	classroom
Home access	no	no
Response Obligations		
Response Time Expectation	2 weeks	2 weeks
Evaluation/Coordination		
Coordinator	*yes*	no
Evaluation	yes	yes

Comparison of Participant Structures of Student Networks

Organization of the Group

In terms of group organization, there was only one clear difference between these two networks. The computer-pals network tried to match students in a one-on-one pairing. In order for the network to succeed, the teachers needed to match each student with another student and ensure that all students exchanged mail at about the same time. Establishing this group structure of writing pairs was complicated by the difference in school and class size in Californian and Alaskan schools.

The children's news network was developed as a solution to the problems that teachers found trying to match students one-on-one. The one-to-many or many-to-many group structure was easier to manage on a network and resulted in more communication and learning opportunities for the students.

Organization of the Task

The educational goal in both cases was to encourage students' writing skills, but the tasks were very different. In the computer-pals network, the task was to write friendly messages to peers. This exchange was seen as a way to motivate reluctant writers. It was hoped that the writing fluency that developed would translate into increased writing skills.

The task on the students' news network was to create a classroom newspaper that contained news and information from peer reporters from distant classrooms. This student-run newswire encouraged well-written and edited contributions. Students sent their finished work on the newswire to share with students in other locations. They also read, selected, and edited the writing of distant reporters for use in their newspaper.

Response Opportunity

In both networks, response opportunities were controlled by the teachers. They scheduled the time for students to work on the tasks in the classrooms. When they wanted to send information on the network, they gave their disk to a computer coordinator who facilitated the sending and receiving of computer messages. Therefore, response opportunities varied from school to school depending on teacher interest, computer resources, and time commitments. In the computer-pals networks teachers and coordinators felt more of a responsibility to try and organize responses for students at the same time, but the difference in timing and the lack of direct contacts between the classrooms made it difficult to provide students with ready access to their peers.

In the children's newswire network, all the students' articles were sent to all the schools on the network. The coordinators did not have to find a match for each writer, and the work was read and enjoyed by all the participants. The sending of messages did not depend on having received a response. Any number of student essays could be sent at any time.

Response Obligations

A personal letter carries with it the obligation to respond. When students had completed their first "Dear Computer Pal" letter, they were not interested in letters that were not a direct response to their original letters. They were waiting to see their personal name in the salutation. A letter that opened with "Dear Computer Pal" was not accepted by students as the second part of the dialog. None of the classrooms had any formal obligation to respond to all the letters. In many cases, "Dear Computer Pal" letters crossed at the same time, with each group of students wanting personal replies before sending a second letter. Those students who did receive personal responses did not really know what to write about after their first exchange of information. There was little or no motivation to revise or edit informal messages. The writing experience was limited to learning to write friendly letters. The messages were written quickly with little attention to form, style, or grammar, and generally contained a series of questions.

The schools in the children's newswire network also had no formal obligation to respond to the messages they received. However, the expected response of a transmitted news article was very different from that of a personal letter. The returning newspaper articles did not have to be paired to be seen as a response. All work was shared with all students, so any student's writing served as a response to previously sent articles. Direct responses to articles were received with enthusiasm and led to increased motivation, but all messages were read with interest.

Coordination/Evaluation

The teachers who participated in the computer-pals network were trying to organize the project to ensure that all students sent and received replies. Teachers and researchers evaluated the educational value of the project. In the newspaper writing network, a coordinator facilitated the activity as part of a research project on technology and writing. The network coordinator organized the sending and receiving of the students' work. She also sent press cards and blackline masters for the layout and production of the local versions of the student's newspapers. The support and organization provided by the network coordinator seemed to be an important factor in keeping the network functioning.

Summary

Student participants on networks rarely begin their interaction with any direct, personal knowledge of each other. Sharing personal information one-on-one with strangers on an electronic network was time-consuming, costly, and found to be of limited educational value. There seemed to be no way to ensure that teachers and students in other locations responded in a time frame that maintained student interest. In fact, there was no way to ensure that all students would receive responses. The group communication structure in the student newswire network made it easy for the classroom teachers to manage. It was not necessary for participants to work in close coordination with each other, and the number of participants was flexible. Classes could join or leave the network at different times.

The sharing of information at the group level on networks can be a very effective way to motivate language arts, as well as writing in given subject areas. When students are writing in print form to a general audience, to share information about themselves, their class, school, or community there is an increase in the need for explicit, well-written products. The demand for this type of writing has been shown to be extremely effective in increasing the writing skills of elementary (Miller-Souviney, 1985; Riel, 1989) and secondary (Cohen & Riel, 1989) students.

When students work together to create written products, they create fewer essays, but of increased quality (Mehan, Moll, & Riel, 1985). When classrooms participate on a network to send messages as a group (as in the electronic newswire example), it becomes possible to interact with many different classrooms rather than with different individuals in a single classroom. Instead of trying to learn about each other personally, the sharing is about each other as members of a group. The organization of the task takes on increased importance as each group must know how to respond as a group. This type of group interaction with a rich diversity of groups may prove to be a critical factor in educational networking.

Our experience with these networks suggests the importance of a network coordinator. Sharing group knowledge requires some structure and planning among the sites. Interactions between teachers and a network coordinator increased the amount of student activity on the newswire. After several years, the network was left by the coordinator to continue on its own. Without support, the mail traffic became lighter and lighter until the newswire no longer existed.

The comparison of these two case studies points to another set of critical features that distinguish them. The more successful student networking project had the following features:

- A group rather than one-on-one structure;
- A well specified task which accomplished set educational goals with a timeline and end product;
- A coordinator to facilitate group planning.

Participant Analysis of Networks

An analysis of the different networks in which we participated or created leads us to make some predictions about what factors will lead to continued success in the development of social organizations that extend over space and time. An overview of the major points from each of the sets of comparisons suggests that network designers ask themselves the following questions before setting up an electronic network:

- Does the group already exist?
- Does this group have a need for telecommunications?
- Is there a shared goal or task with a specified outcome?
- Will access to the technology be easy and efficient?
- Will all participants have regular patterns of mail access?
- Is there a person who will facilitate group planning and work?

If the answer to all these questions is yes, it is likely to be very easy to establish an electronic community (see Table 4). It is also possible to create a thriving network community if one or two of these factors is less than optimal; however, it places a stronger weight on the other factors. Let us now look at all the networks in light of these factors.

Table 4. Comparison of Network Characteristics

Optimal Network Conditions	**Successful Networks**			**Unsuccessful Networks**			
	Univ.	**Teacher**	**Student**	**Univ.**	**Teach 1**[2]	**Teach 2**[3]	**Student**
Existing group	X			X	X	X	
Communication need	X	X	X			X	X
Specified task/end product		X	X		X		
Easy access	X	X	X		X	X	X
Expected pattern of responses	X	X	X				
Coordinator	X	X	X	X	X		X

Each of the three successful case studies described here differed from the above characteristics in *only one* feature. The research network did not have a particularly well-specified task, and the teachers in the Tele-Class and students in the electronic newswire project lacked any past experience of working together, yet each of these networks was viewed as successful by the participants.

On the other hand, if we look at the case studies of the networks that failed, we find they lack between two and four of these features. The second university group had many other effective ways to communicate, no well-specified task, had access problems, and no common response obligation. The teachers in the research project met at the same time and place often enough to make the network unnecessary and there was no specific task that was to be done on the network. The math teachers lacked a specific task, a response obligation to the group, and group leadership. The students in the

2 The teachers on the research team

3 The teachers from the Math Summer Institute

computer-pals network did not know each other and they did not share a specified group task or a predictable pattern of response.

In reviewing all the successful and unsuccessful experiences together, we can offer some prescriptive advice for those who take on the task of designing electronic networks:

- Network communities can be organized *either* by well-established relationships among people who seek new ways to coordinate their collective work *or* a shared commitment among relative strangers to a specific task. These case studies suggest that a network of strangers seeking to find their common interests is likely to fail;

- The response opportunity or access to the network should be very easy and reliable;

- There should be some form of leadership for the group. The group needs one or more people who take on the responsibility of monitoring and facilitating the group interactions.

Theory into practice: International Networking

The InterCultural Learning Network

In an attempt to put these generalizations into practice, we created an international electronic network called The InterCultural Learning Network (ICLN), jointly organized by Moshe Cohen in Jerusalem, Israel; Naomi Miyake in Tokyo, Japan; Margaret Riel in San Diego, California; and Jim Levin in Illinois. This network was formed to examine explicitly the way such networks might be used as an educational setting for learning a range of academic skills.

Organization of the Group

The ICLN participants included university researchers, faculty and students, and pre-college teachers and students. It was organized by four university researchers and their graduate students, in the United States, Japan, and Israel. ICLN organizers and participants have visited each other's countries through international conferences, exchange programs, and personal travel.

Projects on the ICLN were organized to include the participation of secondary teachers and students in a number of different locations (Alaska, California, Illinois, Connecticut, Hawaii, Japan, Israel, Argentina, Puerto Rico, and Mexico). Usually three to six classrooms formed a group to participate in intercultural activities.

Organization of the Task

The general task was to create functional learning environments in which students cooperated with peers and adults in other places to share ideas, explore issues, and solve problems. The university researchers and students were interested in mapping out the properties of electronic message systems and their usefulness for instructional interaction. The pre-service and in-service teachers were interested in principles and design of cooperative learning on the network. The students were involved with the content of projects in science, social science, and language arts.

Examples of student projects include: a comparison of educational systems; a study of career choices and how they have changed across generations; comparisons of news coverage of world events; a study of how the water cycle operates in different places and of techniques for dealing with water shortages; a comparison of food prices and import/export policies; and comparisons of television-watching patterns.

Response Opportunity

The ease of access varied across different locations. In sites with university support, the university covered costs and supplied technical support. Where teachers worked without this support, the cost in money and time was sometimes too great to ensure regular interaction. The indeterminate cost of telecommunications services did not fit easily the limited budgets of schools.

Response Obligation

Schools working closely with site and activity coordinators agreed to spend some part of the school week on networking activities. Despite strong personal commitment to this project by most of the teachers, state- and district-mandated curriculum and differences in school holiday schedules and testing periods sometimes resulted in response delays.

Coordination/Evaluation

To coordinate this network, a person in each location was designated as a "site coordinator." This person was responsible for locating and working with the teachers and students at each site. In addition to this site coordination, each activity had an "activity coordinator," who took the initiative in developing and running an activity on the network. These activity coordinators provided the group leadership that is so important to keeping a task functioning.

ICLN assumed a very strong activity-based approach to networking. Over the past several years, we have had the opportunity to explore activities in the sciences (Levin & Cohen, 1985; Waugh & Levin, 1988), social sciences (Riel, 1987; Waugh, Miyake, Levin, & Cohen, 1988) and language arts (Cohen & Riel, 1989; Mehan, Riel, & Miller-Souviney, 1984). We find that the same factors listed above continue to be critical.

Students enjoyed writing and reading the work of other students even when they knew little about them personally. With increasing knowledge about their partners came increased interest in interacting. Exchange of other media, photos, audio tapes, and videotapes provided a common meeting ground for students who worked together across distances. This exchange enabled students to create their own tasks on the network. If the participants do not know each other, then they need to be given a well-specified task.

Activities that lacked a coordinator were not likely to be successful, as success depends on sustained interaction. There were many messages with good ideas for projects, but only those that had at least one person strongly committed to the project were likely to continue. Good ideas without the commitment of a coordinator rarely generated much network activity. A strong coordinator seemed to be a necessary but not sufficient condition for success. It is the purpose or function of the activity from the perspective of the participants that seems to determine its likelihood of success (Levin, Rogers, Waugh, & Smith, 1989).

The Long Distance Learning Network

Can this model of networking be applied to a large international user base? Is the benefit of participating in the network project a good investment? Is it likely to offset the cost in time and energy invested by the teachers and students? Currently, AT&T is conducting a trial, the Long Distance Learning Memory, based on the ideas developed in the InterCultural Learning Network that should provide some of the answers to these questions (Riel, 1990a).

The Long Distance Learning Network (LDLN) has connected hundreds of teachers from the United States, Canada, Holland, France, Germany, and Australia into networking units of 6 to 10 classrooms. Each group is a Learning Circle with specific educational goals and a curriculum-based task to complete. LDLN provides curriculum support as well as technical support. Each Learning Circle has a leader to help facilitate the interaction. There is a beginning and ending date for each Learning Circle and also a well-specified sequence of tasks. The continuing success and growth of this pilot project supports the conclusions of our analysis here.

Organization of the Group

The participants on LDLN are grouped into Learning Circles of about 6 to 10 classrooms each. While the size of the entire network is very large, each class works only with the small number of other classes in their own Learning Circle. Each Learning Circle has a Coordinator, and each group of similar Learning Circles has a Mentor Coordinator.

Organization of the Task

Each Learning Circle has a curricular theme. At the beginning of each semester, each teacher selects a specific Learning Circle to join. Each Learning Circle shares a fixed time line and has as its goal a jointly produced publication containing reports of all projects in that Learning Circle. Each classroom proposes and sponsors a particular task within the general curricular theme and also is expected to participate in the tasks proposed by all the other participants in its Learning Circle.

Response Opportunity

The LDLN communication software allows messages to be generated "off-telephone-line" and automatically sent later. Students and teachers can compose their messages on computers without modems, store them on a floppy disk, and then send them later with an automatic procedure. Waiting messages are also automatically picked up to be read later off-telephone-line. There is a fixed one-time charge for joining a Learning Circle, with no additional charge for the use of the network.

Response Obligation

Members of a Learning Circle are expected to send at least one message every two weeks and are encouraged to send about two to three messages a week. Each participant is expected to contribute at least minimally to all projects proposed by the other participants of its Learning Circle.

Coordination/Evaluation

Each Learning Circle has a Coordinator who facilitates the work of the Learning Circle toward the completion of projects and generation of the Learning Circle publication. Each group of Learning Circles has a Mentor Coordinator who is a resource for curricular ideas and who monitors the progress of the Learning Circles.

In this way, the same structure that evolved for the InterCultural Learning Network can be extended to a much larger scale network, while maintaining the rich set of interactions among a relatively small set of people.

Network Form and Function

The design and development of both the InterCultural Learning Network and the Long Distance Learning Network drew upon the framework of the Network Participant Structure Analysis described in this paper. This framework gives us a way to see the dimensions of variant possibilities in this new institutional medium. The most important factor leading to successful networks is the presence of an important function that the network serves for the participants. The nature of this function determines the particular form the network should take. In these early days of the medium, in which we are primarily concerned with building networks that work, a good design principle is to have the form of the networks follow the functions that the networks serve.

As communication technology advances, "user friendly" interfaces will become the norm and the technical barriers to networks will disappear. At that point, the social design of networks will become the dominant issue: What should be the nature of the interactions, how should leadership be provided, and how should activity be organized in this new communication medium? New interactional patterns are already emerging, as are new conventions for effective communication, and new possibilities for effective cooperation among diverse people around the world (Levin, Riel, Miyake, & Cohen, 1987; Riel 1990b). We plan to continue our study of these networks, to chart out effective and ineffective designs, so that we can more systematically build the global communities that are required to deal with the global challenges that we now face.

References

Au, K. H. (1980). On participation structures in reading lessons. *Anthropology and Education Quarterly, 11(2)*, 91-115.

Bannon, L. (1986). Computer mediated communication. In D. Norman and S. Draper (Eds.) *User-centered system design: New perspectives on human-computer interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Black, S.D., Levin, J.A., Mehan, H., & Quinn, C.N. (1983). Real and non-real time interaction: Unraveling multiple threads of discourse. *Discourse Processes, 6*, 59-75.

Cohen, M., & Riel, M. (1989). The effect of distant audiences on students' writing. *American Educational Research Journal, 26*, 143-159.

Erickson, F. & Mohatt, G. (1982). Cultural organization of participation structures in two classrooms of Indian students. In G. Spindler (Ed.) *Doing the ethnography of schooling.* New York, NY: Holt-Rinehart and Winston.

Florio, S. (1978). *Learning how to go to school.* Unpublished doctoral dissertation, Harvard University, Cambridge, MA.

Levin, J.A., & Cohen, M. (1985). The world as an international science laboratory: Electronic networks for science instruction and problem solving. *Journal of Computers in Mathematics and Science Teaching, 4*, 33-35.

Levin, J.A., Riel, M.M., Boruta, M., & Rowe, R. (1985). Muktuk meets jacuzzi: Computer networks and elementary school writers. In S.W. Freedman (Ed.), *The acquisition of written language: Revision and response.* Hillsdale, NJ: Ablex.

Levin, J.A., Riel, M., Miyake, N., & Cohen, M. (1987). Education on the electronic frontier: Teleapprentices in globally distributed educational contexts. *Contemporary Educational Psychology, 12*, 254-260.

Levin, J.A., Rogers, A., Waugh, M., & Smith, K. (1989). Observations on educational electronic networks: The importance of appropriate activities for learning. *The Computing Teacher, 16*, 17-21.

Mehan, H. (1979). *Learning lessons.* Cambridge, MA: Harvard University Press.

Mehan, H., Moll, L., & Riel, M. (1985). *Computers in classrooms: A quasi-experiment in guided change.* (Final Report to the National Institute of Education.) La Jolla, CA: Interactive Technology Laboratory.

Mehan, H., Riel, M.M., & Miller-Souviney, B. (1984). Knowledge of text editing and control of literacy skills. *Language Arts, 5,* 510-515.

Miller-Souviney, B. (1985). *Computer supported tools for expository writing: One computer—twenty-eight kids.* Unpublished master's thesis. University of California at San Diego, La Jolla, CA.

Moll L. & Diaz, E. (1987). Change as the goal of educational research. *Anthropology and Education Quarterly, 18(4),* 300-311.

Philips, S. (1972). Participant structures and communicative competence. In C. Cazden et al. (Eds.) *Functions of language in the classroom.* New York: Teachers College Press.

Philips, S. (1982). *The Invisible culture.* New York: Longmans.

Quinn, C.N., Mehan, H., Levin, J.A., & Black, S.D. (1983). Real education in non-real time: The uses of electronic message systems for instruction. *Instructional Science, 11,* 313-327.

Riel, M.M. (1985). The Computer Chronicles Newswire: A functional learning environment for acquiring literacy skills. *Journal of Educational Computing Research, 1,* 317-337.

Riel, M.M. (1987). The InterCultural Learning Network. *The Computing Teacher, 14,* 27-30.

Riel, M.M. (1989). The impact of computers in classrooms. *Journal of Research on Computers in Education, 22,* 180-190.

Riel, M.M. (1990a). Four models of educational telecommunications: Connections to the future. *Education & Computing, 5,* 261-274.

Riel, M. M. (1990b). Cooperative learning across classrooms. *Instructional Science.*

Rogers, A. (1988). *Networks, functional learning environments, and the acquisition of language skills.* (A report to the California State Educational Technology Committee, FrEdMail Project AB803, Curriculum Development.) San Diego, CA: County Office of Education.

Waugh, M.L., & Levin, J.A. (1988). Telescience activities: Educational uses of electronic networks. *The Journal of Computers in Mathematics and Science Teaching, 8,* 29-33.

Waugh, M., Miyake, N., Levin, J.A., & Cohen M. (1988). *Problem solving interactions on electronic networks.* Paper presented at the meeting of the American Educational Research Association, New Orleans, LA.

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Electronic Communities of Learners: Fact or Fiction

by Sylvia Weir

Introduction

One way or another, we are all affected by computer networks, whether it be how we bank our money, do our shopping, or book a trip to Hawaii. Educators and researchers at the college level have communicated electronically for more than a decade with colleagues around the world over networks such as Bitnet and Internet. Pre-college educators are becoming increasingly aware of the potential of telecommunications networks to enhance learning, and over the past decade there have been numerous experiments in the use of networks at the primary and secondary levels (Office of Technology Assessment, 1989). The first comprehensive primer on ways of integrating telecommunications into classroom activities has arrived (Roberts, Blakeslee, Brown, & Lenk, 1990).

The benefits of linking microcomputers at one site through Local Area Networks (LANs) are obvious: money is saved on peripherals and software that is networkable, obviating the need for floppies. By 1987-88, a Quality Education Data survey indicated that 64% of 173 of the largest school districts in the United States were networking in this way (Reinhold, 1989). A more substantial and successful use of a LAN is the Bank Street Earth Lab project, which supports a geography-based science curriculum (see Note 1).

The focus of this paper is on networks that link schools across the country and across the globe. Just how extensive these developments are is surprising (see "Networking for K-12 Education: Bringing Everyone Together" by John Clement). Many states have set up or are developing plans for networks that link schools across the state (see, for example, "TENET: Texas Education Network" by Connie Stout). One of the early projects linking geographically separated schools was the Alaska QUILL Network, set up primarily to connect teachers (see Note 2). Another network focusing on teachers is the Science Teachers' Network at the Educational Technology Center, Harvard Graduate School of Education (see Note 3). TERC's LabNet project links high school physics teachers and students (Gal, 1991; see also Note 4).

Some networks link students, for example, the InterCultural Learning Network (see Note 5): "The goal of the project is for students from different cultures to use each other as resources for learning more about themselves and the social, cultural, and physical world" (Riel, 1987, p. 27). From this grew the AT&T Learning Network (Riel, 1990). Some networks link both teachers and students: TERC and the National Geographic

Society (NGS) have brought science telecommunications to elementary teachers and students (see Note 6); TERC's Star Schools project did the same for secondary level teachers and students (see Note 7); and TERC's Global Laboratory project links secondary teachers, students, and scientists (see Note 8).

The motivation behind these developments varies. Some networks are developed as an information source for teachers. Some have an administrative purpose. Others have been set up to bring academic opportunities to isolated rural students. For many network researchers, the attraction is telecomputing's potential to mediate educational change.

TERC has been at the forefront of work in this area, and a central concern is the role of telecommunications in triggering and supporting educational change. What does it take for meaningful educational change to happen? What are the features of a telecommunications network that would support such change? What are the patterns of network participation by teachers and students? The question is not: What was the effect of having the network?, but rather: In what contexts does the innovation work; what adaptations work with which sets of circumstances? As Bruce and Rubin (in press) write: "The use of an innovation is both a product of the innovation itself and of the social context in which it is placed."

This paper summarizes the experience of several pre-college telecommunications projects, with a special emphasis on those administered by TERC, including an in-depth account of the evaluation findings in the largest project,TERC Star Schools.

Networks and Educational Change

An electronic network can provide a framework for encouraging change within a complex social, interactional setting. Indeed, network projects can serve as an instructive model of how to use technology to provide continuing teacher support while achieving widespread dissemination of innovative ways of encouraging classroom learning. Technology can invite change but does not, alone, ensure it. Educational change involves three components: possible use of new or revised materials; possible use of new teaching approaches; and possible alteration of beliefs (Fullan, 1982).

Several issues provide a framework for discussion.

Changing teaching approaches and beliefs takes time. Introducing innovative curricular approaches can present major hurdles for teacher trainers, and many past failures can be ascribed to the lack of ongoing teacher support. "Change is a process, not an event" (Hall & Hord, 1987, p. 8). Help is most necessary during the activity, and network communication can be designed precisely to provide this ongoing support, providing both an opportunity for information exchange as well an opportunity for genuine discussion about classroom issues. What are the conditions under which this will occur?

Teacher concerns. At its best, the process of introducing innovation should entail mutual adaptation between innovator and consumer. Advocates of the Concerns-Based Adoption Model (Hall & Hord, 1987) stress that many innovations fail not because they are at fault, but rather because the process of implementing them is inadequate. In particular, the views and perceptions of the teachers are not addressed. Teachers are learners, and learning requires the mutual appropriation of goals. The network can provide a forum for teachers to voice their concerns during the course of the activity. They can participate in determining the nature of the innovation rather than having it thrust upon them. Do teachers take advantage of this opportunity?

The role of collaboration. Building on Vygotsky (1978), the role of collaboration in facilitating learning must be stressed. Learners can achieve much more with help than they can on their own, and a crucial feature of doing things together is talking about them (Weir, 1989). One obvious way in which a network can play a role is its potential to extend opportunities for collaboration and communication, both among teachers and among students. Does this in fact lead to more learning in the classroom? What is the role of curriculum units that specifically require collaboration?

Changing patterns of interaction in classrooms. Teachers who become involved in telecomputing encounter much that is new. They are communicating regularly over distances and over time about their daily activities with people they have never met and who may or may not share their concerns; they are using unfamiliar technology; and, most importantly, they are adapting to changing patterns of interaction in their classrooms. Increased collaboration and communication, both within and across classrooms, create a new kind of learning environment. The existence of a collaborating network with a specific set of objectives could make an enormous difference in how comfortable and successful teachers are with the new ways of working. Working with objectives takes some of the insecurity out of discovery situations (Ennever & Harlen, 1969). How do teachers adapt to changing patterns of control that allow for group activity and peer teaching and learning? And how does the network help them to do this?

Readiness to change. The prospect of educational change does not appeal to all teachers. Teacher-centered instruction is a survival mechanism (Cuban, 1989) and not necessarily something that all teachers find easy to relinquish. Many find the idea too daunting, too difficult to implement. Our focus should be on those teachers who would not change instruction on their own, but could do so if given the right help (Weir, 1989). Consider this learning context in terms of Vygotsky's concept of the zone of proximal development, defined as the "distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). Does the telecommunications network and the activities it promotes act as the zone of proximal development for teachers ready to accept this help?

Effect on students. The effect on students should come in part from how their classroom experiences are changed, but also more directly from their own interactions on the network. What aspects of student behavior are affected and which groups of students are affected? Of special interest is ascertaining the students' point of view: How do students view their participation on the network?

The role of institutions. Crucial to the whole enterprise is the need for institutional support for the educational changes envisioned. Central to school support is the role of the school principal: "Throughout our years of research and experience, we have never seen a situation in which the principal was not a significant factor in the efforts of schools to improve" (Hall & Hord, 1987, p. 1). How does the attitude of the school administration affect the successful adoption of telecommunications-based activities in a school?

Of all these themes, the role of collaboration and communication is paramount.

Collaboration, Communication, and Learning

Collaboration and communication in a learning situation are theoretically desirable. Since learning involves the internalization of social knowledge, learners need constantly to interact with other people, to do things with others, and to talk to each other about what they are doing (Vygotsky, 1978). Research shows that learning is indeed enhanced during collaborative problem-solving activity. Three examples illustrate.

In bilingual classrooms where children were talking about and working together on tasks using math and science concepts that demanded thinking skills, the more they talked and worked together, the more they learned how to do word problems (Cohen & Intili, 1981). In classroom research on a curriculum using learning centers, children who talked and worked together more showed higher gains on their test scores than children who talked and worked together less (Cohen, 1986). Finally, low-achieving students in fifth- and sixth-grade classrooms showed dramatically increased rates of time on task for those students doing group work as compared to seat work (Cohen, 1986).

Too often, a student's first attempt to communicate on a subject is during a test in answer to an examination question. A student participant in the TERC Star Schools project talks about working in a group of students: "It was better because, you know, people could understand and explain their ideas to us . . . so you would know more about it."

Note that the advantages of group work in a classroom can best be achieved if teachers receive guidance in instituting this kind of change. Obvious problems arise. The ideal is to have a mixed group whose individual members have different strengths to maximize the amount of interpersonal learning that can occur; but how to stop bullies from dominating, retiring children from shrinking even more, socially dominant kids from being listened to more? Cohen (1986) describes specific steps that teachers can take to avoid these problems.

Both students and teachers can increase their collaboration efforts by using an electronic network.

Students Communicate and Collaborate on a Network

Specific benefits for students can be achieved from *distributed science activities,* where the same activity is carried out at sites separated widely geographically, so the results will differ in detail because of different conditions. This allows for cooperative problem solving on a network.

One such activity on the InterCultural Learning Network concerned water shortages and conservation methods used in a number of different countries. An analysis of all the messages sent over the network during the water problem-solving project indicated that a large number of ideas were contributed to the discussion. At the end of the activity, 20 students from an eighth-grade class in San Diego collaborated to write and send a summary message. That message contained 71% of all the ideas mentioned during the entire joint activity. Moreover, among the ideas mentioned by the San Diego students, 66% had been contributed by sites other than San Diego (Waugh, Miyake, Levin, & Cohen, 1988).

Providing a network audience for writing can provide an unexpected effect. Two seventh-grade classes, 22 students in each class, wrote two compositions: one for a regular mid-term examination, and one addressed to peers in other countries on the InterCultural Learning Network. The compositions were graded by the classroom teacher on a 0-100 point scale. The classroom teachers were confident that the examination grades would be higher because students would take more care. They were surprised to find that they had judged the papers that were written to peers on the network significantly higher than those produced for the examination. Two independent raters evaluated the papers with respect to content, organization, vocabulary, language use, and mechanics. The scores on each of these criteria confirmed the superiority of the network compositions; the differences were statistically significant (Cohen & Riel, 1989).

Clearly, specific benefits accrue to students working and communicating collaboratively on a distributed science network; what of teachers?

Teachers Collaborate on a Network

Network exchanges present a prime opportunity for collaboration among teachers. In principle, teachers join a community of learners, where the network becomes the framework for cooperative learning and the scaffolding for teacher learning. The network serves as a forum to share expertise, to try out new ideas, to reflect on practices, and to develop new curricula. Making a classroom experience public on the network enables participating teachers and students to share a teaching and learning experience. In this way, good teachers can serve as models for others by describing the way they handle particular aspects of the activity.

The record of network exchanges in the TERC Star Schools project (see Note 7) provides examples of effective peer collaboration and learning among teachers. Reflecting on their experiences, some teachers pointed to particular network exchanges that led them to adapt their teaching practices. One teacher wrote to another participant in the TERC Star Schools project, commenting on the value of her exchanges with a more experienced teacher and expressing her thanks:

> It has been a rewarding experience working with you. You are the kind of teacher I admire. Not only do you teach the students the subject matter in a manner which they understand and retain, but also in an enjoyable atmosphere. You have been a wonderful friend and most patient teacher to me. I thank you.

Many teachers (56%) worked with other teachers in their schools, co-teaching the units and sharing teaching ideas. At times, the project also promoted team teaching across disciplines. Some teachers reported that this was a new experience for them.

> All three of us . . . teachers have decided to work together — this is a first for us! Because the topic has several aspects, we decided to put the two classes together. Now, children who never would have talked to each other are working together, and I think it will last.

For some teachers, collaboration was related to the network, which was used by teachers to seek partners for joint projects. For others, the network activity was simply the context in which this collaboration was stimulated, although it could have arisen without the network. In addition, more than half the teachers (58%) involved other members of the school or local community (such as school administrators and parents) in the project.

Patterns of Teacher Participation

Here two networks are contrasted. In the Science Teachers' Network, administered by the Harvard Graduate School of Education, teacher support and development were not specifically linked with any curriculum. The study did not follow the teachers into their classroom. In contrast, the TERC Star Schools project offered an integrated program that linked technology, curriculum, and teacher support and documented evidence of changing classroom practices.

The Science Teachers' Network

The Educational Technology Center at the Harvard Graduate School of Education established a telecommunications network in December 1985 that focused on teachers, in an effort to reduce teacher isolation and provide a vehicle for staff development (Katz, McSwiney, & Stroud, 1987; Katz, Inghilleri, McSwiney, Sayers & Stroud, 1989). Secondary science teachers from eastern Massachusetts were recruited, including a group of recent graduates who knew each other well. Messages could be sent privately or placed on public forums, organized by function (e.g., the Notice Board forum) or by topic (e.g., the Chemistry forum).

The findings in this study were analyzed in terms of technical and logistical difficulties experienced by participating teachers; social issues of managing and facilitating group process on the system; and substantive content issues concerning contributions to the designated topics of the conference. A summary of findings is illuminating.

Seventy five teachers signed on; 45 stayed with the project (60%). About one-quarter logged in once or more a week. Most teachers read ten or more times as many messages as they wrote, that is, they used the network as a resource. About one-quarter wrote one or more messages a week—an average of one every two weeks. The average number of messages read was five per week. Having a computer at home affected significantly rates of logging on. The researchers expected message writing to increase logarithmically with net membership—in fact, it ran parallel.

The pattern of communication varied depending on the extent to which participants knew one another. In a typical sample week, 32 messages were sent on the network. Of these, 63% were sent as private mail to individuals, 29% were posted to the public forum, and 8% were sent to both. Three-quarters of participants attended a training meeting, and this correlated positively with the amount of public writing. Teachers who had taught longer knew more members and wrote more. A group of recent graduates, wanting to stay in touch, wrote messages with a large social content. Teachers who were unacquainted with each other wrote messages about very specific topics rather than about general science: the exchanges centered around making inquiries, answering inquiries, and offering unsolicited information on rather discrete topics related to science teaching in the classroom.

In two conferences whose participants were mainly unacquainted with each other, almost half the messages were responses to previous messages, indicating that the network was indeed encouraging exchange. The network appealed especially to teachers who were more isolated professionally. Teachers with fewer informal contacts with colleagues outside school logged in and read more, and their perception that the lack of colleagues was a difficulty correlated positively with the extent of their public writing.

The TERC Star Schools Project

The TERC Star Schools project linked a large number of teachers (932) across the country (see Note 7). The project aimed to promote a total educational experience, of which the network was only one part. In addition to the network, there were 12 innovative curriculum units, purpose-built software, and a training program carried out by 12 Resource Centers across the country.

Introducing innovative curricular approaches demands ongoing teacher support, and heavy use of the TERC Star Schools telecommunications network to administer the project is one example of the importance of this support. The layered, distributed support structure that TERC adopted incorporated a mixture of local support from Centers around the country and on-line support in a variety of modes. Messages were exchanged between TERC, the Centers, and teachers. Such exchanges, which focused on organizational and technical concerns, provided an organized, efficient way to relay information to participants. Trainers, cluster chairs, and scientists served as resources for participating classes, providing on-line support and facilitating project goals. Overall, of all the messages sent, 59% were related directly to the curriculum, 33% focused on network coordination and administration, and 8% on personal issues.

On average, teachers reported that they used the network frequently. Forty percent used the network three or more times each week, and 48% used it once or twice each week. The remaining teachers (12%) used the network less than once each week. Teachers reported that they used the network for varied purposes, primarily for exchanging ideas about unit activities, for requesting and giving technical support, and for analyzing data. Interestingly, teachers and students sent approximately the same number of messages, demonstrating that teachers shared the responsibility of sending network communications with their students.

Promoting Teacher Change

TERC's evaluation instruments paid particular attention to the issue of teacher change. TERC did not expect all teachers suddenly to change what they were doing, but there are clear indications that participating in the Star Schools project was a very rewarding experience for many teachers, prompting them to both use and value more open-ended, collaborative teaching approaches and new evaluation methods.

A substantial number of teachers reported that they implemented the Star Schools curriculum units in a different way from their usual approach to teaching science (57% in Period One [October, 1989 - January, 1990], increasing to 78% in Period Three [April - June, 1990]). In specifying the differences, teachers reported that the open-ended nature of the activities encouraged them to adapt or modify their teaching methods; that their students carried out more group work than usual; and that collaborative work in their classes resulted in a positive experience for them and their students. Almost all teachers (95%) reported that their students worked in small groups to carry out in-class activities. Forty-three percent of the teachers noted this was a change from the way they typically had organized their classes. Teachers commented:

> Students who would normally never associate [with one another] collaborated on their designs. Students solved a problem without the teacher giving them any solutions and [found] that a number of solutions were successful.

> With more [class] discussion, group problem solving, and student-centered learning, issues arise that would not ordinarily. Examples would be who would manage the group . . . and differences between inner-city, rural, and suburban responses to identical polls.

Many teachers reported that the unit activities extended beyond their regular curriculum. In carrying out the unit, most teachers (80%) raised concepts and issues that they normally did not discuss with their classes. An important role of the network is to connect teachers and students to scientists actively engaged in research. One of the most extended exchanges over the network took place between a class studying radon and a participating scientist. The class was concerned about high radon readings, and the scientist's responses gave the students a taste of the process of investigating possible reasons for these readings.

Star Schools teachers appreciated the role of the innovative curriculum in the success of the project; however, there was varying effectiveness among units. Some units, such as *Descent of a Ball* and *The Solar House,* were particularly successful in encouraging student inventiveness, but others, such as Radon, were less so. On the other hand, *Radon* was especially successful in helping students to see science as a collective enterprise. The math units (*Connectany, Iterating Functions, Koetke's Challenge,* and *Triangle Chaos*) were successful in increasing student observation skills. The *Weather* unit was effective in helping students to increase their observation skills, but did not particularly encourage students to reflect on the significance of their results.

Some units lend themselves more easily to network communications, providing specific suggestions for how to integrate the network into project activities. Some teachers felt that the units did not take sufficient advantage of the network: network activities, in their view, should be an integral part of the activities, not an add-on feature.

Evaluators saw a change in classroom dynamics. For example, there was a greater initiation of conversation by students on the network than is usual in traditional classes, where the standard, so-called IRE pattern is initiation by teacher, response by student, evaluation by teacher. This difference has been found in other studies (Goldman & Newman, 1988).

Although the Star Schools curriculum specified no particular means of evaluation, 81% of the teachers reported that they had evaluated their students' work, and (50%) of these teachers reported that they used a new approach in evaluating their students. Teachers used primarily non-traditional means of assessment, such as student participation in discussions (60%), hands-on activities (55%), and group skills (54%). Traditional evaluation approaches—such as quizzes (15%) and tests (9%)—were used less frequently.

Focusing on Student Outcomes

This paper provides examples of several studies dealing with the effect on students of their participation in telecommunications activities. In this section, more details are added, drawn mainly from two TERC projects: Star Schools and the National Geographic Kids Network. Direct quotes from students and from teachers about their students help to flesh out the quantitative information.

Which Students Benefited and How?

One important result of the TERC Star Schools project was progress in addressing the needs of disadvantaged students. Teachers reported that students who were typically less successful academically were better served by the Star School activities —which included hands-on and technology-based activities—than by the regular curriculum. Teachers were enthusiastic about the better performance of learning disabled and minority students in the Star Schools setting (see Table 1). Teachers gave specific examples of the benefits of a hands-on, technology-based approach to teaching science to students with learning difficulties, both with regard to improving self-esteem and in increasing understanding of the material.

> Some of my less academically-inclined students became "master supervisors" in their groups. One male in particular has taken on a complete change in personality and performance after his [solar] house was one of the most successful. He just displays a confidence I didn't see (nor his peers) before this unit. Learning styles were so evident to me while observing my students complete the unit. It gives me new insight into better teaching methods.
>
> As a matter of fact, I asked three students from the LD [learning disabled] classes to participate and one practically took over the project—certainly his group. He was one of five; four were regular students.
>
> One student who shows no interest (or relatively little interest) in completing assignments became the best worker when it came time to use the network, all aspects from editor to gathering data to learning the graphics program.
>
> Some of the poorer students were very successful with this unit. They would get to class early so they could work on the computer.

Hands-on activities that rely on visual and manual skills can elicit students' strengths. This is true for all students, but most especially for students who are failing academically. Technology-based activities employ a variety of modes of representation, for example, the graphics screen provides interactive feedback and supports spatial problem solving. Such features allow the preferred modes of individual students to emerge, enabling them to succeed in an academic setting. Working to students' strengths in this way has far-reaching implications for science and mathematics education, and it is important to highlight these advantages so that the teaching community at large can come to appreciate their significance.

One example of the network approach with high achievers is the RING project, established by Indiana University for gifted students in rural areas (Southern & Spicker, 1989). In this project, activities were supported by an electronic network, together with a videotape exchange and two face-to-face meetings. Faculty members acted as consultants and mentors for the students as they carried out an environmental unit and a heritage unit. The network involved 200 students in grades 4-8 and 30 teachers. A pilot study revealed numerous problems, including poor quality telephone service in some rural areas, the high cost of long distance calls, and the timing of activities (for example, the winter field trip camera froze). Over the next two years, student participation climbed and student information requests and social contacts increased sharply. The number of faculty assistance requests also rose, to an average of three to four weekly. Important features contributing to success were that students had met and established contacts across sites at an early stage in the project; and that students

Table 1

Serving Diverse Student Populations: The Regular Curriculum vs. the Star Schools Activities

(Percentage of teachers (n=184) reporting "very" or "extremely well"—the two highest ratings on a five-point scale.)

	Regular Curriculum	Star Schools Activities
Promoting students' interest in science		
Male students	51%	73%
Female students	47	66
Minority students	43	59
Students with poor academic performance	16	49
Encouraging students to take leadership roles		
Male students	31%	61%
Female students	28	55
Minority students	20	44
Students with poor academic performance	12	38
Improving students' understanding of academic content		
Male students	54%	66%
Female students	52	64
Minority students	43	58
Students with poor academic performance	24	38

needed information from each other. Teacher participation was, however, less successful. Several teachers were openly technophobic and tended to communicate by more standard means. Some were uncomfortable in directing independent inquiry and swung between totally unstructured, unspecified demands and rigid, highly structured assignments.

A Student Point of View

During the second year of the TERC Star Schools project, TERC collaborated with its Resource Centers in an investigation designed to obtain the reactions of participating students across the country (Weir, Krensky, & Gal, 1990, 1991). TERC was interested in probing student perceptions of the nature of science and the scientific process, student understanding of what scientists do, and attitudes to scientific challenges and to a possible science-related career. Students were interviewed before and after their Star Schools experience. The sample consisted of 80 students (40 males and 40 females) from 22 classes (grades 7-12) in 8 states (55% suburban location, 22.5% rural, and 22.5% urban).

Overall, three-quarters of the students were enthusiastic about Star Schools activities, and the same percentage perceived a difference in these activities compared with their regular science class. Signs of positive change among students included a high level of student interest and a new awareness of the importance of being active learners. Students commented that the shift from lecture and instructional teaching to student-controlled team work was very apparent and welcome. This change took place in the context of a network-based project, in which teachers received support for changing the way they organized their classes.

In the pre-Star Schools interview, students expressed general dissatisfaction with the way classes were carried out, while in the post-Star Schools interview, they were more explicit about what they wanted. In explaining why they liked Star Schools, students introduced an issue that had not arisen in the pre-activity interview, namely, a strong preference for learning both on their own and from other students. It was as though participation in Star Schools introduced them to the possibility of being in control of their learning, of being probed about their knowledge as opposed to being told what to know, and of having input to the experimental design rather than being confined to a ready-made experiment. One student commented:

> We're given, like, basically how passive solar heating works and stuff, but we kind of had to find out for ourselves, you know? Discover it, because sometimes when you're told something you just don't understand it, but this way you understood in your own way. It wasn't like somebody trying something and you just memorizing it.

Students preferred the way collaborative arrangements were implemented in Star Schools compared to their previous experience of group work. Students described their previous experiences working in groups where the teacher controlled the communication process. TERC's curriculum materials demand a degree of autonomy and self-direction, with recognition of students' own ideas. Studen talked about "working and thinking in teams." In reporting their classroom activities via the network, students were extremely enthusiastic about their group efforts. For example, one student remarked:

> Overall I think this [project] was something I would never forget. It was a great experiance [*sic*]. I learned about other schools and what questions they have been wanting to ask us. This gave us a chance to learn about other schools all around us. This also gave us a chance to get to know people in our class better. We got better acquainted with other people.

Over half the students remarked that the curricular topics in the Star Schools curriculum were different from those in their regular science class. For many students, studying topics relevant to the outside world and to their own reality was important.

> I didn't know anything about radon and [before this unit] I didn't care. I never really cared about our environment . . . [The unit] started to make me think about things and everything about recycling and stuff like using aerosol cans. I really started, I feel bad now when I use hair spray, you know? And I'm starting to really understand that people aren't just telling me to, aren't just teaching me things for nothing. I really have to use what people teach me, you know?

> Building the house. Gee, that was . . . it was something that I wouldn't expect that we would do, something like solar houses and stuff, it's just, people hear about it all the time. It's something that's kind of interesting to most people. I think of school as a little bit behind and I was kind of impressed. I was like, hey this is what's going on outside.

Students appreciated the excitement and importance of investigating questions for which the answers were not known beforehand. Several students mentioned how their participation in Star Schools had involved them in thinking more deeply about their work. Associated with this was a significant shift toward a willingness to work with the more open-ended inquiries that are part of the Star Schools approach.

> Oh . . . we didn't have to write as much, or, you had to think more. It wasn't like writing data charts, because data charts are really easy, you just copy things from the board or you do math, but this you have to sit down and think. You had to use your brain a little more than usual, so that's how it was different . . . I think if we didn't do this radon activity I wouldn't have to use my brain at all the whole year. This is the only time that I really had to think and I really, like, I had to struggle a little, you know, and I'm not really used to doing that in science.

Scientific investigation requires an ability to respond to the challenge of the unknown and to tolerate ambiguous situations. Indeed, science is the process of making sense of such situations, of finding appropriate explanations for the ambiguities and unknowns. TERC was interested in exploring student attitudes to the challenge of new and uncertain situations, and included in the interview a set of six questions designed to probe these attitudes. A small but consistent change can be noticed when comparing responses before and after the Star Schools experience (see Table 2). The percentage of students with a preference for simple, familiar questions with one straightforward answer lessened, with a corresponding increase in those who preferred unfamiliar questions quite difficult to solve, with no straightforward answer or one right approach.

Based on their responses to the six questions, students were rated on their overall style in terms of whether they preferred to *Tackle the Known* or to *Tackle the Unknown*. In both interviews (pre- and post-Star Schools activity) the majority of students preferred the *Known*, but the number who felt that way decreased from 80% before to 64% after the activity ($p<.005$).

The project served to expand students' views of science. Students appeared to develop a more intimate knowledge of science and scientists and a decreased sense of alienation from the scientific enterprise. From the fall to the spring, the percentage of students who had a more complete picture of scientists increased from 31 to 55%, with a corresponding drop in the number of those who had a stereotypical picture.

Evaluation of the NGS Kids Network

During September 1989 and January 1990, TERC carried out an evaluation of NGS Kids Network activities. Again, as in the Star Schools project, telecomputing in this project was part of a larger endeavor to support innovative curriculum activities.

Three fourth- and fifth-grade classes who carried out the *Hello!* and *Acid Rain* units participated in pre- and post-written tests, oral interviews, and classroom observations. Findings in experimental classes were compared with those in a control class. The

Table 2

Students Report on Their Preference for Tackling the Known vs. Tackling the Unknown
(Students' Interview, n=80)

Types of Questions Preferred	Fall	Spring
Questions similar to ones you've considered before	75%	25%
Questions that don't have one right approach	61	70
Questions that are quite difficult to solve	47	50
Questions that you are confident you know the answer to	80	68
Questions that don't have a straightforward answer	33	48
Questions that are really different from anything you've considered before	64	72
Overall style		
Prefers to tackle known questions	79	64[1]
Prefers to tackle unknown questions	16	27[1]

following selection of evaluation findings was taken from the NGS Kids Network Evaluation Report (Mokros, Goldsmith, Ghitman, & Ogonowski, 1990).

1. Students demonstrated significant gains in their ability to organize and represent data. Students in the NGS Kids Network group demonstrated significant pre- to post-test increases in the use of conventional graphs for organizing a small set of observations, while the control group did not.

2. Students' skill at data interpretation also improved significantly. More students were able to make observations about the data set on the post-test. For example, while 34% of the NGS Kids Network students were unable to make even a single comment about a data set on the pre-test, this proportion dropped to 7% on the post-test. In addition, students were better able to use available data to draw a conclusion on the post-test than they were on the pre-test.

3. Students demonstrated gains in specific content areas: significant gains in place knowledge (19% increase, from 71% pre-test to 90% post-test), and significant increases in the ability to use latitude and longitude to identify map location (25% increase, from 25% pre-test to 50% post-test). Students' understanding of the factors contributing to acid rain and their ability to reason about the impact of these factors improved significantly from pre- to post-test: For example, causal explanations of the relationship between factc y emissions and wind patterns increased by 26% (6% pre-test to 32% post-test).

4. When the performance of learning disabled (LD) students in the sample was compared with the responses of non-LD students, their gains paralleled the improvements observed in the whole sample, with respect to graph use, comments about data, mapwork, and level of explanation they offered for the cause of acid rain.

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1 $p < .005$. Degree of significance was calculated by Chi-Square Test.

Although no comparisons were made between LD students' learning using NGS Kids Network materials and learning using other science curricula, "This 'first look' at the success of the NGS Kids Network units with respect to special populations is nonetheless encouraging" (Mokros et al., 1990, p. 49).

5. Interviews demonstrated that the students' understanding was in fact richer than had emerged from their written answers. Measures requiring short written responses are, by necessity, constrained in terms of the richness of problems to be solved and the means of assessing children's thinking about how to solve them.

Predicting Network Success

Since different networks have different goals, the criteria for success vary. Factors that affect the degree to which teachers begin and persist in their involvement include ease of access to the network, the level of motivation or obligation to use the system regularly, the extent to which the activities fit into the teacher's available time, and the degree of support from the school administration.

A striking feature of the Harvard Science Teachers' Network study was that having a computer at home significantly affected rates of logging on, reading, and writing, both private and public. This is a specific instance of a more general finding: Ease of access is crucial to success. This applies even at the university level. In a comparative study, Riel and Levin (1990) assessed several groups of similar networks. For example, they compared two university networks, one successful and one unsuccessful. In both cases, participants knew each other and shared common interests. The most important difference was in ease of access: in the successful case, participants accessed the network in their offices, whereas in the unsuccessful case, they had to walk down the corridor to a public machine.

Agresto (1989) described a fascinating telecommunications project at Boston University designed to train and mentor history teachers to use the Federalist papers. A lesson plan was provided and the idea was interesting, but the implementation not good. There was a mismatch between the access required to complete the unit and teacher access to the network: some teachers had to travel to a site to get on-line.

In the TERC Star Schools project, many teachers reported struggles with the school administration around this issue of access to the means of communication. For example, telephones are generally not located in classrooms, and for a teacher to get an outside telephone line is an unheard of luxury for many schools, particularly those in inner cities. In addition, many teachers reported that their network use was restricted because school computers were available only in certain locations at certain times. Approximately one-half of the teachers had access to only one computer (and the average class size was 24 students). In addition, although two-thirds of the teachers had a computer in their classroom, less than one-half also had a modem within easy reach in the classroom. One cannot benefit from a telecommunications support system if one cannot get on it. A teacher explained:

> No computer in room; computer locked in A-V room, and then used in department head's office. This arrangement was too inconvenient for a course that has a computer as one of its primary resources.

For many teachers a major problem arose with regard to the time demands associated with the Star Schools activities. Some teachers lost their initial enthusiasm when they found out what was involved and did not participate as actively as they had first intended. Other teachers decided not to participate at all. To learn more about why teachers did not follow through on their original plans, TERC asked teachers who signed up to participate but then changed their minds to explain why. Sixty-nine respondents attributed their change of plans to four major reasons. Approximately half (49%) reported that lack of time was the primary reason. Some teachers had problems obtaining the necessary equipment to carry out project activities (37%), had an unexpected illness or illness in the family (8%), or encountered a logistical problem—such as signing up too late or not being "aware of the options available" (6%).

Clearly, the criteria for success will vary with the purposes of the network. Katz et al. (1987) distinguished two different approaches. If interest is in maximizing group solidarity, then peripheral members (e.g., those who only read) should not be admitted. If information sharing is the goal, then a large membership may be required with accommodation for variable log-on frequency. Riel (1990) made a similar distinction between two kinds of interaction. One is the conference format, which supports a variety of tasks with distributed control, in which participants come and go, and pick and choose what they are interested in. In contrast, another type of organization resembles a task force, in which participants come together to achieve a specific task that is centrally controlled.

Conclusions

As this paper illustrates, introducing telecommunications into an educational setting is a multi-textured affair. When given the opportunity, some teachers participate actively; others do not. Recall the concern to collect evidence for the claim that telecomputing has the potential to catalyze educational change: An electronic network cannot play a role in generating change for teachers who do not use it.

This survey of projects revealed several factors that play a role in determining successful participation. In all studies, ease of access was found to be a crucial predictor of success. Providing an efficient system is the first requirement. Put simply, teachers do not have the time to mess around with baroque configurations that break down, take time, and demand attention that detracts from their educational usefulness. Second, support from the school administration is necessary to ensure the physical implementation of the network system. Minimally, a teacher needs ready access to a computer, a modem, and an available telephone line at times convenient to her/his schedule.

When teachers do participate, the pattern of communication tends to vary with the extent to which participants have met face to face (Katz et al., 1987; Gal, 1991). The network appealed especially to teachers who were more isolated professionally. An interesting common finding is that teachers tend to read more messages than they write. Being a silent onlooker could be thought of as the first stage in network participation.

When teachers do participate, there is good evidence that benefits accrue. The reports presented confirm the usefulness of telecommunications networks in encouraging collaboration at several levels in the educational system. For example, in the TERC Star Schools project, teachers reported increased collaboration among their students. They themselves worked more with other teachers in their schools. Students valued collaborating with students in other parts of the country. Teachers related to other teachers across the country in a variety of ways, and the network was used to effect administrative coordination among participants.

With respect to teacher change, a substantial number of teachers in the Star Schools project reported that they implemented the units differently from their usual approach to teaching science, that the unit activities extended beyond their regular curriculum, raising concepts and issues that the teachers normally would not have discussed with their classes. Star Schools teachers appreciated the role of the innovative curriculum in the success of the project, and many teachers reported that they used a new approach in evaluating their students.

It should be noted that the Star Schools network was successful in providing a forum for voicing teacher concerns. Teachers were able to let TERC know in detail about the difficulties they were having at the time the difficulties occurred. It seems clear that this aspect of network use could serve an important function in facilitating the implementation of educational innovations. Education provides a community of learners, each of whom needs a customized telecomputing tool. As Beverly Hunter (1990) observed: "The most effective networks are likely to be those that are designed to support a shared vision of the collaborative social and organizational reality desired by and for teachers and educational communities" (p. 6).

The effect on students was dramatic. Teachers reported that students who are typically less successful were better served by the Star School activities than by the regular curriculum. The student interview was particularly revealing: participation in Star Schools introduced students to the possibility of being in control of their learning. Students found it refreshing to have emphasis placed on their own knowledge and their own input to the experimental design rather than being confined to a ready-made experiment. Studying topics relevant to the outside world and to their own reality was important and involved students in thinking more deeply about their work. An encouraging result was the high number of students prepared to tackle new and unknown topics.

The changes reported by Star School teachers revolved largely around the use of new kinds of materials and new classroom practices. Whether this was accompanied by a change in teachers' beliefs about teaching is not clear from the reports. Changing beliefs about teaching takes time (Fullan, 1982), and to find out the extent to which this happens during participation in a telecommunications project will require more in-depth and long-term research than has yet been undertaken. Our recommendation is that such a study must include explicit network discussions about pedagogy designed to promote the growth of a self-reflective practitioner.

Predicting which teachers might be ready to change their beliefs and practices has been the focus of many studies reported by Fullan (1982). In one study, teacher professionalism (aggregate level of education as indicated by a master's degree) in a high school district was positively correlated with initiation of change by teachers and adoption of innovations for college-bound students, but negatively correlated with adoption of innovations for high school terminating students (Fullan, 1982). This study also found that a higher ratio of district support staff—so-called linking agents—facilitated the adoption process. How this works in the context of a network would need to be part of further research.

The importance of a supportive school administration in innovation adoption (Fullan, 1982) was manifest in the Star Schools project. In implementing the changes incorporated in the Star Schools materials, a recurring theme is teachers' struggles with the school administration. Innovative curricula require changes in classroom scheduling and evaluation methods that are difficult for teachers to implement without the support of school authorities. Existing organizational settings wield awesome power in shaping behavior in schools, and educational change comes slowly. Given how schools are currently structured (the graded school, self-contained classroom, a segmented curriculum, etc.), teachers pay a high price in trying to put into practice different views of learning, teaching, and the roles that adults play in school (Cuban, 1989). In evaluating the TERC Star Schools telecommunications project, TERC's recommendation was that the Star Schools approach be implemented on a system-wide basis to optimize support from school administrators and policy makers who decide what teachers in their area do and how they do it (Weir et al., 1990).

A concern for equity in access to the benefits of technology led Michael Cole and his colleagues in San Diego to make an interesting sociological point (Laboratory of Comparative Human Cognition, 1989). They regret that technology has up to now tended to widen the gap between the advantaged and the disadvantaged, because more computers are available to middle- and upper-class children than to poor children. Further, computers for poor children tend to be used for rote learning rather than for the cognitive enrichment they provide for middle- and upper-class students. Cole and his colleagues speculated that access to cheap computers linked in telecommunications networks with appropriate support could help to reverse this trend. In the extreme, if a school or a class has only one computer, using that computer to telecommunicate could be about the best, most cost-effective use one could find, since so much of the activity ıld be off the computer, which would be used only for downloading and uploading ssages.

ǝ survey findings show that when telecomputing is embedded in an integrated ›gram of teacher support and curriculum development, with an involved school ninistration, it can be a powerful agent of educational change. This approach is .ovative, and we are learning all the time about how to run a network more ǝctively and about what kind of curriculum best supports its use. Many questions nain, and additional research is needed in critical areas such as depth of change ong teachers participating in an electronic network.

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The Bank Street Earth Lab project, started in 1986, created a local area network implemented in two inner city sixth-grade classes. It introduced a geography-based science curriculum that relied heavily on students working collaboratively in groups. Interestingly, that change in classroom organization persisted into the regular, non-project classes (Goldman & Newman, 1988; Newman, Goldman, Brienne, Jackson, & Magzamen, 1989). To evaluate the project, the researchers analyzed network messages, video records and classroom observations, and interview protocols.

One of the most fully described educational networks is the Alaska QUILL Network (Bruce & Rubin, in press). Five Alaskan school districts and the University of Alaska-Fairbanks, Department of Education, formed a consortium and provided funds for a part-time coo.dinator for 25 participating teachers and administrators. The predominant use of the network was for teacher communication. The central classroom activity about which teachers communicated was writing as a form of problem solving, with an emphasis on revision as a necessary part of that process. Bruce and Rubin describe situated evaluation as a way of analyzing the process of use of an innovation in a variety of contexts.

The Educational Technology Center at the Harvard Graduate School of Education has been conducting an experiment in computer-based conferencing since 1986 to facilitate collegial exchange among science teachers. The researchers (Katz, McSwiney, & Stroud, 1987) undertook an ethnographic study of the use of the network, using a sample of saved network messages and machine log files, data from telephone interviews of teachers, and teacher questionnaires.

LabNet is a telecommunications teacher enhancement program that links physics teachers in grades 9-12 on a network in order to support the development of projects incorporating microcomputer-based laboratory tools. Teachers meet face-to-face at summer training workshops. Preliminary evaluation shows the importance of this personal interaction in fostering productive use of the network (Gal, 1991).

5. The InterCultural Learning Network started as a collaboration between children in Alaska and suburban San Diego to produce a newspaper called *The Computer Chronicles* (Reil, 1985), and it culminated in an expanded Network (Levin, Riel, Miyake, & Cohen, 1987; Riel, 1987; Levin, Kim, & Riel, 1988). In this network, elementary, middle, and secondary teachers and students, as well as undergraduates, graduate students, and faculty in California, Illinois, Connecticut, Alaska, Hawaii, Puerto Rico, Mexico, Japan, and Israel engaged in joint newspaper-writing activities on such topics as cultural celebrations, water conservation, and local social problems of concern to the students. The InterCultural Learning Network formed a tight-knit community, several of the site coordinators having worked together previously in face-to-face settings. Typically, a small group of classrooms (3-8), geographically separated, worked together on specific topics. The AT&T Learning Network is a commercial service that evolved out of this research project.

6. NGS Kids Network is a collaborative project of TERC, the National Geographic Society, and the National Science Foundation that brings a telecommunications-based science curriculum to grades 4-6 classrooms around the globe. Students participate in large-scale, cooperative experiments and share their results on the network. Unit topics, developed by TERC, include acid rain, water quality, weather, trash, health, and energy.

7. The TERC Star Schools project was an ambitious, two-year network science program involving many participants around the United States in an integrated program of teacher support and curriculum development. The project can serve as a model of how to use technology to provide continuing teacher training while achieving widespread dissemination of innovative ways of doing science and mathematics in the classroom. After a pilot program in the Spring of 1989, a total of 932 teachers signed on during the 1989-90 school year. Classes carrying out the same unit were grouped together in clusters. Each cluster included approximately 15 classes, grouped by grade level. Most clusters had a cluster chair to facilitate network exchanges. Curriculum units included topics in science (Radon, Weather, Polls and Surveys, Solar House, Descent of a Ball, and Trees) as well as four innovative math topics (Connectany, Koetke's Challenge, Triangle Chaos, and Iterating Functions). An extensive evaluation was undertaken using a database of stored network messages, teacher questionnaires, some classroom observation, and student interviews pre- and post-activity (Weir, Krensky, & Gal, 1990). Evaluators followed intensively the activities of selected participants (116 teachers and cluster chairs in eight clusters) who used specifically-designed software that automatically saved a copy of all messages into a network database. Center Directors, trainers, and TERC staff also used this software.

8. The TERC Global Laboratory project links teachers, students, and scientists in an international program of ecology research. Over 80 schools worldwide are involved in physical and biological monitoring, modeling, data analysis, and experimentation activities. TERC developed low-cost instrumentation and curriculum materials to support these monitoring activities.

References

Agresto, J. (1989). *Teaching Federalist #10: A lesson plan for high school teachers.* Boston, MA: Boston University, School of Education.

Bruce, C. & Rubin, A. (in press). *Electronic quills: A situated evaluation of using computers for writing in classrooms.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, E., G. (1986). *Designing groupwork.* New York: Teachers College Press.

Cohen, E. G. & Intili, J. K. (1981). *Interdependence and management in bilingual classes, Final report I* (NIE Contract #NIE-G-80-0217). Stanford, CA: Center for Educational Research at Stanford.

Cohen, M. & Riel, M. (1989). The effect of distant audiences on students' writing. *American Educational Research Journal, 26*(2), 143-159.

Cuban, L. (1989). Neoprogressive visions and organizational realities. *Harvard Educational Review, 59*(2), 206-225.

Ennever, L. & Harlen, W. (1969). *With objectives in mind: Science 5/13.* London, England: Macdonald Educational.

Fullan, M. (1982). *The meaning of educational change.* New York: Teachers College Press..

Gal, S. (1991). *Collaborative tele-learning of physics: Expanding the teaching experiences of physics teachers.* Paper presented at the Joint Conference of the Educational Computing Organization of Ontario and the International Conference on Technology and Education, Toronto, Canada.

Goldman, S. & Newman, D. (1988). *Electronic interactions: How students and teachers organize schooling over the wires.* Paper presented at the meeting of the American Educational Research Association, New Orleans, LA.

Hall, G. E. & Hord, S. M. (1987). *Change in schools: Facilitating the process.* New York: State University of New York Press.

Hunter, B. (1990). *Computer-based network support for teacher collaborations: Researching new contexts for both learning and teaching.* Paper presented at the meeting of the American Educational Research Association, Boston, MA.

Katz, M. M., McSwiney, E. & Stroud, K. (1987). *Facilitating collegial exchange among science teachers: An experiment in computer-based conferencing.* Cambridge, MA: Harvard Graduate School of Education, Educational Technology Center.

Katz, M. M., Inghilleri, M., McSwiney, E., Sayers, D., & Stroud, K. (1989). *Talking about teaching, by writing: The use of computer-based conferencing for collegial exchange among teachers.* Cambridge, MA: Harvard Graduate School of Education, Educational Technology Center.

Laboratory of Comparative Human Cognition (1989). Kids and computers: A positive vision of the future. *Harvard Educational Review, 59*(1), 73-86.

Levin, J. A., Kim, H., & Riel, M. M. (1988). *Instructional interactions on electronic message networks.* Paper presented at the meeting of the American Educational Research Association, New Orleans, LA.

Levin, J. A., Riel, M. M., Miyake, N., & Cohen, M. (1987). Education on the electronic frontier: Teleapprentices in globally distributed educational contexts. *Contemporary Educational Psychology, 12*, 254-260.

Mokros, J. R., Goldsmith, L. T., Ghitman, M., & Ogonowski, M. S. (1990). *Evaluation of NGS Kids Network: Hello! and Acid Rain units.* Cambridge, MA: TERC.

Newman, D., Goldman, S., Brienne, D., Jackson, I., & Magzamen, S. (1989). Computer mediation of collaborative science investigations. *Journal of Educational Computing Research, 5*(2), 151-166.

Office of Technology Assessment, U. S. Congress (1989). *Linking for learning: A new course for education.* Washington, D.C.: U. S. Government Printing Office.

Reinhold, F. (1989). *Use of local area networks in schools.* Syracuse, NY: ERIC Clearinghouse on Information Resources.

Riel, M. (1985). The computer chronicles newswire: A functional learning environment for acquiring literacy skills. *Journal of Educational Computing Research, 1*(3), 317-337.

Riel, M. (1987). The InterCultural Learning Network. *Computing Teacher, 14*(7), 27-30.

Riel, M. (1990). Four models of educational telecommunications: Connections to the future. *Education and Computing: The International Journal, 5*(4), 261-274.

Riel, M. & Levin, J. (1990). Building electronic communities: Success and failure in computer networking. *Instructional Science, 19*, 145-169.

Roberts, N., Blakeslee, G., Brown, M. & Lenk, C. (1990). *Integrating telecommunications into education.* Englewood Cliffs, NJ: Prentice Hall.

Southern, W. T. & Spicker, H. H. (1989). The rural gifted on line: Bulletin boards and electronic curriculum. *Roeper Review, 11*(4), 199-202.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Waugh, M., Miyake, N., Levin, J. & Cohen, M. (1988). *Problem solving on electronic networks.* Paper presented at the meeting of the American Educational Research Association, New Orleans, LA.

Weir, S. (1989). The computer in schools: Machine as humanizer. *Harvard Educational Review, 59*(10), 61-73.

Weir, S., Krensky, L., & Gal, S. (1990). *Final Report of the TERC Star Schools Project* (NSF Grant #MDR-8954749). Cambridge, MA: TERC.

Weir, S., Krensky, L., & Gal, S. (1991). Experiencing science: Students' accounts of learning science. *Proceedings of the Joint Conference of the Educational Computing Organization of Ontario and the International Conference on Technology and Education,* Toronto, Canada.

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ALICE: TELECOMMUNICATIONS FOR EDUCATION

by Patricia Parker

Introduction

Over the next few years, the United States will invest an estimated $2 billion into the creation of the National Research and Education Network (NREN), a telecomputing infrastructure widely thought to be as important for the long-term economic development of the United States as the interstate highway system. However, the impact of NREN will be slight unless its cost to the educational user is reduced greatly and its value enhanced greatly. Thus, software that can simplify access, reduce costs, and promote the development of new educational materials and services is a necessary part of the infrastructure required to make the educational promise of NREN a reality.

The number of networks and network software packages currently available to educators is phenomenal. It is possible to count over one hundred networks or bulletin boards serving educators in the United States alone. (See "Networking for K-12 Education: Bringing Everyone Together" by John Clement.) Many of these use unique software, and most are not interconnected. A handful of telecomputing-based curriculum materials and activities are available on many of these networks. This fragmentation results in little incentive to develop more curricula and diminishes the value of each network. The creation of a software system that would support interconnection through the Internet and be widely adopted because of its utility and low cost would greatly enhance the value of educational telecomputing.

TERC proposes to develop a software environment based on interconnectivity, and by so doing, hopes to create an environment that fosters new material development which will, in turn, foster wider educational use of telecomputing.

We have developed a preliminary version of the proposed system, which we have named Alice. It is software not just for one network or project; it is a system design that provides a common, powerful platform for many educational networks. The technology will transform telecomputing into a far more flexible medium to support the development and easy dissemination of new educational materials and new styles of education. The design itself is modular and based on established standards, permitting the approach to grow and allowing others to add functionality. "Reach for the Stars," a project of the Massachusetts Corporation for Educational Telecommunications, and TERC's Kids Network/Middle Grades project are using a preliminary version of the Alice user software. This version provides teachers with word processing, data analysis, and telecommunications tools to facilitate three network-based science units. Teachers and students use the software and SprintMail, a store and forward electronic mail system, to communicate with their peers.

User Software

The Alice user software has two major goals. The first is to provide easy and dependable access to the Alice-Internet network servers. The second goal is to support teachers, students, and other educators in their collaborations on the network by providing an easy-to-use, inexpensive integrated environment. The Alice user interface is based on our experiences in developing the award-winning NGS Kids Network software and the more recent TERC Star Schools software. The software incorporates a point-and-click interface universally adopted in all modern microcomputer applications. Macintosh and Windows versions of the software are graphics-based, and a character-based version for low-end IBMs is planned.

Educational telecomputing will flourish when it is easy, through e-mail, bulletin boards, and databases, to share documents that include illustrations and data, mixed with text, all freely able to be edited by participants using readily available software. This is more than simply an aesthetic requirement. Students, perhaps without fully developed reading skills, who are struggling to learn difficult concepts, need as few distractions and as many forms of representation as possible. This is why illustrations, drawings, boxed items, underlining, and italics are an important part of textbooks.

Design

The requirement that students be able to create text documents, or data files off-line and share them with peers using a different microcomputer platform, implies that there must be user application software for each of the types of files supported on the network. At a minimum, this requires a text editor, graphics editor, and a data analysis package for each type of computer supported.

Although there are several ways to accomplish this, we plan to integrate the applications for text, graphics, and other file types with the telecommunications software. The idea is to supply applications that are powerful enough for most educational functions but without so many features that they are confusing, expensive to code, and difficult to support. We can create a consistent user interface and make the telecommunications functions seamless and as easy as accessing a disk. Students generally will find the applications familiar and sufficiently powerful to meet most of their needs. If they prefer, they can use their own, more familiar application (for example, Word) and either send that file or convert it into a file format that other Alice users can access, regardless of the microcomputer being used. An important bonus of this approach is that every school provided with Alice will also have an inexpensive set of productivity tools.

Significantly, we have a way to integrate the text editor and data analysis applications into a simple integrated document that is a long scrolling message divided into segments, each attached to a different application. A typical message might be a text section, followed by an illustration, more text, and finally a graph. This simple way to create an integrated document is easy to implement and support and it is modular, easily accommodating additional applications and file types.

The Alice software will have additional functions to support off-line bulletin boards and database access. The user software will know and have an updated directory of the bulletin boards and databases to which the user has access, so queries can be generated off-line. Database search and selection functions will be available for data resources located on the network and on the user's computer, so a request can be generated to download a limited selection of data (e.g., send all acid rain data for the Northeast since 1990), and then these data can be further analyzed on the user's computer (e.g., select all sites having a pH below 4.5). Creation of bulletin board and database searches while on-line will also be supported.

A number of functions will be built into Alice to simplify telecommunications. The software will automatically access a host computer; sign on; check for remaining credit; upload any outgoing messages, files, and requests; download any incoming messages, files, and results from prior requests; and sign off. Included will be a set of functions to simplify the collection and posting of outgoing messages and distributing incoming messages among multiple users of one account (e.g., members of a class). LANs will be supported to simplify the collection and distribution of mail to individual students. The single-user telecommunications software will also support a terminal emulation mode with features to simplify exploration of the Internet.

In summary, Alice user software will be a set of applications supporting multiple file types that will work together with a powerful, flexible telecommunications package. These functions will be fully implemented on Macs and IBM and partially on the Apple IIGS.

Functionality

To provide user software functionality that supports educational telecomputing, we designed Alice around four basic modules. The first set of these are editors: text, data, and graphics. The last is the telecommunications module that facilitates connecting to the network and the sharing of information. Below is a description of these modules and the functionality that they provide.

The Journal

The journal is our word processing module that supports standard functions including character attributing, section titles, and page formatting. The journal is also an integrated document environment that allows teachers and students to link graphs, tables, and sketches into their text. With the integrated document, users will be able scroll through the report and add or edit text, graphs, or sketches. Each component of the integrated document can be modified with its own editor.

Data Analysis

The data analysis component of the software is based on a column-oriented spreadsheet called a data table. Teachers and students enter, edit, and review data via the scrolling data table. Each column within the table has a definition that includes a title, a description, and a type (integer, number, string, category, formula). As an example of a formula column, a Degrees Centigrade column can be filled in automatically as a result of a calculation on the Degrees Fahrenheit column. The data module provides the following additional functionality:

> **Support of data templates.** Templates are data tables directly connected with curriculum activities whose format cannot be altered, thus ensuring compatibility with data from other classes. Teachers and students can enter data into existing templates and create their own templates.
>
> **Cutting, pasting, and merging.** Teachers and students can easily combine data from collaborators on the network into a composite set of data.
>
> **Statistics.** Summary statistics can be calculated and displayed for each column in the data table, thus facilitating data analysis. Count, sum, max, min, and standard deviation are a few of the statistical calculations available.
>
> **Querying.** Teachers and students can define a query in order to create a subset of the data. The query is built using the Query By Example interface standard and supports multiple column criteria connected by AND and OR statements.
>
> **Sorting.** Users are able to sort data based on multiple column criteria.
>
> **Graphing.** The software supports the range of graph formats commonly used in education, including pie, bar, line, histogram, and scatter plots. Multiple data sets are displayed on a single graph. These graphs will be incorporated easily into the integrated document.

Sketching

The sketching environment, when fully developed, will allow teachers and students to express their ideas in a format other than text. The environment will resemble MacDraw and will be object-based. Templates will be provided to facilitate the creation of calenders and other common forms. These sketches can be saved as individual files or included as part of the integrated document.

Telecommunications

The telecommunications module provides an easy, flexible, and powerful tool for connecting educators to the network. Specific features include:

> **Address Book.** This feature facilitates the addressing of messages and eliminates many of the typographical errors that can cause a message to be undeliverable.

Entries in the address book can be either individual addresses or lists containing multiple addresses.

Automatic Asynchronous mode. We believe that this model will be the most commonly used. Teachers can specify which network activities they wish to complete during the upcoming session. The software then automatically establishes the connection to the host server and completes the network activities. A log of the session is generated for review by the user.

Manual Synchronous mode. When developed, this feature will allow users to manually connect to the Alice-Internet server and then create database queries in real time. Once connected to their local server, students and teachers can then begin a manual exploration of the Internet.

Off-line database query generator. When developed, this query-by-example interface will link directly with the user's personal directory of on-line resources. The directory of on-line resources will include the fields contained in the database as well as its Internet address. Users can add to this directory of resources by editing their copy of the directory or by requesting updates from the on-line version. Queries generated in this manner will be sent to the on-line database via e-mail.

Quick Connect. This feature facilitates connecting to remote hosts. Users can record the steps required to access a host and can save those steps as an entry in their connection directory. To return to the host, users simply click on the entry in the directory, a connection is automatically made to their server, and they are logged onto the remote host.

Network Software

The Alice user software alone is not sufficient to realize the full potential of telecomputing in the K-12 community. In addition there must be a mechanism in place that provides two essential functions: access to the Internet and a set of network services. The access function permits users to connect to Internet and from there to each other. The network services include e-mail, bulletin boards, news, databases, and list servers that support the educational community and promote instructional uses of the system. The proposed Alice network software is described below.

Design

Like the existing Internet, Alice will be a decentralized, distributed network environment composed of Internet servers with value-added features. With this distributed network, all Alice-Internet servers will share Internet protocols and a common functionality, but each server in the system will be administered independently to meet the needs of its local community.

A server without unique services might be used primarily for the access features, providing a point that remote users can call to get on the system. This server, configured for access, could be quite near the users, so a school district or other organization establishing the Alice server could minimize dial-up costs to the end user.

Other organizations might use the server primarily to provide a service rather than access to the network. An example might be the National Geographic Society, which could use a server to provide the network services of the NGS Kids Network, available only to paid subscribers. A state or district might establish several dozen servers, providing both points of access and educational services that were developed for its students and then made available to all educators.

The Alice environment assumes that primary servers will be directly connected to the Internet but that secondary servers, or subservers, will be connected to the larger networked community via a dial-up connection to a nearby Alice-Internet server. The distributed architecture allows subservers to be physically located in schools or district buildings in order to minimize costs to the end user. In time, the need for subservers will disappear and all Alice servers will be directly connected to the Internet.

Users at an Alice-Internet server can access the system asynchronously; they can also access the system synchronously and set up a TCP/IP session and use Internet resources. In addition, the Alice-Internet server supports access to its resources to the Internet community. Figure 1 shows the various connections supported by Alice.

Functionality

The Alice server will provide the following functionality:

Access to the Internet. Although it is a long-term goal for each school to be directly connected to the Internet, teachers and educators need access now. Alice servers will provide access to the Internet by allowing teachers to use dial-up lines to connect to a host, which is in turn connected to the Internet.

Storage. There will be a facility for storing incoming messages until the user reconnects to the server. Without this storage facility, teachers and students would only be able to receive messages that were delivered during the few minutes of the day that they were actually connected to the network.

Request Monitoring. Because users are connected to the server over a short period of time, there will be a facility that monitors the status of a user's requests, such as sending electronic mail and querying a remote database. This system will re-attempt delivery when necessary and will notify the user via return mail if the request cannot be processed.

Electronic mail, structured bulletin boards, news and list servers. These functions represent the most commonly used services for sharing information across the Internet. The Alice-Internet server will support both public and private access to

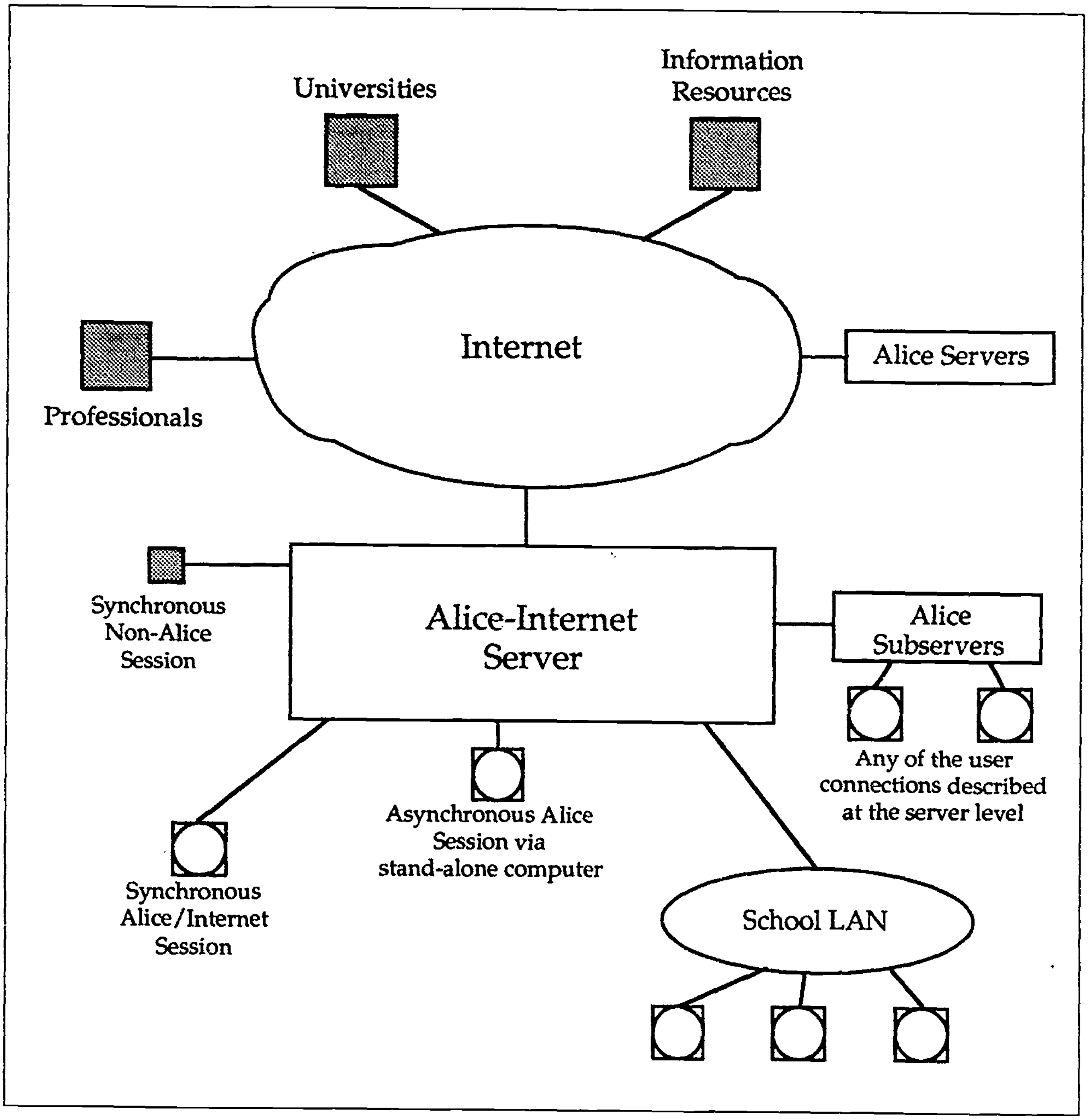

Figure 1. Connections possible with Alice.

structured bulletin boards and news groups. Electronic mail and structured bulletin boards will support multi-formatted files and will be consistent with current Internet standards; thus, others in the community who are not using the Alice user software can join in these exchanges.

Databases. The server will provide a facility that supports local databases that are accessible to a private group of users, as well as national databases accessible by anyone within the community. The software will support automatic shadowing of remote databases to databases on local hosts. Database queries will be generated remotely via the user software or interactively via an on-line menu-driven interface.

Gateways to existing networks. The Alice environment will not eliminate or exclude already existing educational networking communities. It will support gateways to these existing networks allowing their members to collaborate and share resources with users of the Alice system while at the same time allowing Alice users access to these existing network resources. Gateways to these existing networks will be provided via the Internet.

Commercial services. The Alice host will support "pay-gateways" to commercial information services. These services include: specialized databases; conferences of interest to small private groups; projects similar to the NGS Kids Network; and information providers like Dialog. In this way, the Alice system is merely facilitating access to, not replacing, commercial curriculum and information providers.

Multiple models for user interaction with the host. There is no single model for interactions between the user and the server that will fit the needs and styles of all teachers and students. Many teachers will want automated access to the host environment. Others will want generic tools so that they can explore and discover the resources within the Internet for themselves.

For this reason, the Alice environment will support several user interfaces. The first is the easy-to-use, automated, asynchronous connection that we believe will be used by teachers and students for the majority of their telecomputing needs. Another interface will support Alice users in their manual, free-form investigation of the Internet. In this case the host environment will interact synchronously with the Alice software, setting up a manual, standard TCP/IP session. A final interface will support UNIX users, such as scientists and academics, in their access to the Alice resources.

Summary

From its inception, Alice has been designed with educators in mind, and educators will find it to be a very attractive software package. Its strongest features include:

- Excellent user interface. On the Mac and IBMs using Windows, Alice will have full "point-and-click" simplicity applied consistently across a range of flexible applications, including telecommunications.

- Integrated documents. The system will handle documents that mix text, graphics, tables, and graphs, permitting a new level of expressiveness. This will make electronic publishing possible and will be especially important for young children and learning disabled students.

- Telecommunications options. Automatic telecommunications saves students the time of sitting in front of a screen while messages are transferred, and avoids the frustrations usually encountered during computer-based communications. This automatic mode is a boon to teacher users, because it frees them from both mastering the complexities of telecommunications and from having to sit by the computer while files are transferred. The manual option, while requiring more expertise, will allow teachers and students to interact with Alice and other Internet resources on a real-time basis.

- Low cost. The user software, designed to minimize connection times and permit off-peak access, will be made easily available through educational service suppliers. The wide spread distribution of Alice-Internet servers will minimize long distance charges. Thus, most users will find that the only cost of using Alice will be modest, local, off-peak telephone charges.

- No limitations. The adoption of Alice will not create any limitations to user access to telecommunications: The Alice user will not be restricted to communications with other Alice users since the software can be used to access any other host or network connected to the Internet; the non-Alice user will be able to access Alice users and files; and both synchronous and asynchronous access will be permitted.

TERC believes that the creation of the Alice software will foster an increase in new curriculum materials and services, and will encourage educators to implement telecommunications more widely in their schools.

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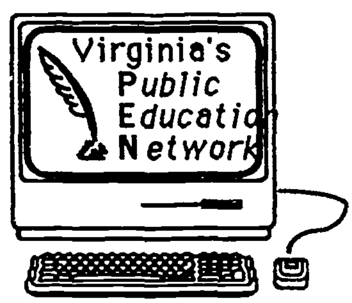
CONSIDERATIONS UNDERLYING THE ARCHITECTURE OF A STATE PUBLIC SCHOOL TELECOMPUTING NETWORK

by Glen L. Bull, Cameron M. Harris, and Harold Cothern

Virginia is perhaps the first state to guarantee access to the Internet to every public school educator at no charge. This paper outlines some of the considerations which affected design of this public school network. Virginia's Public Education Network (PEN) is designed to provide an infrastructure uniting the public school system and linking it to institutions of higher education. The acronym, PEN, emphasizes the role of the network as an instrument of communication. The network icon serves as a reminder that although technology from the time of the Jeffersonian quill to the advent of the information age has changed, the goal of an educated citizenry has not.



Establishment of Virginia's PEN took place against a background of exploration of the potential role of educational technology within the Commonwealth of Virginia. The Report of Virginia's Commission on the University of the 21st Century (1989) concluded that advanced computing and telecommunications capabilities should be used to increase the learning capacity of faculty and students. Similarly, a *Six Year Technology Plan* developed by the Virginia Department of Education recommended that an electronic network be established to provide interactive links between school divisions having abundant resources and school divisions lacking adequate resources. The report noted that such networks "can provide access to information by students through a vast array of media formats designed to promote inquiry, critical thinking, and lifelong learning" (Virginia Board of Education, 1989, p. 4).

Initial specifications were developed at a symposium jointly sponsored by the Virginia Educational Computing Association and the Virginia Department of Education (Bull et al., 1989). Representatives from public schools, universities, and the Virginia Department of Education developed goals and design guidelines for the network at this meeting and several subsequent planning sessions. After implementation of a prototype system to assess its feasibility, establishment of the network was announced in *Superintendent's Memorandum 236* (Spagnolo, 1990) the following year.

Goals and Background

The design of the network was based on the following goals:

- provision of a system that would provide electronic communication links for transmission of administrative data, and
- provision of unlimited instructional access by teachers to a worldwide academic computing network.

Establishment of the state-wide network was preceded by nearly a decade of experimentation with networking and telecommunications by central Virginia school divisions through public school/university partnerships. During this period the Academic Computing Center at the University of Virginia established a policy of providing an electronic network account to any public school teacher who requested one. This policy was established with the thought that, as a public institution, the University had a responsibility to the schools. Through network accounts, teachers had access to services such as electronic mail, electronic conferencing, and electronic databases.

During this time the faculty of the Curry School of Education also worked closely with local school divisions to identify and support instructional uses of networks. Teacher-LINK was the designated name for this series of initiatives linking teachers to the Academic Computing network. The goals of Teacher-LINK were to foster school/university partnerships and to explore instructional uses of telecomputing. Support from the Academic Computing Center made it possible to experiment with a variety of electronic mail and conferencing systems and interfaces. This included use of Profs, Unix mailers, the CONFER conferencing system at the University of Michigan, Special-Net, Apple-Link, Caucus, USENET, and electronic mail and conferencing interfaces developed by Academic Computing at the University of Virginia. Local school divisions were also able to participate in pilot telecomputing programs and software developed at the University of Virginia, including the National Geographic Kids Network and the TERC Star Schools telecomputing project.

This period of unlimited access and experimentation with telecomputing made it possible to identify patterns of usage that might emerge under ideal circumstances. For example, the electronic mail interface had a profound influence on acceptance and use by teachers in public schools. Different interfaces required as little as two or as many as twelve hours of training before users achieved the same levels of proficiency. Mail interfaces that were readily accepted by engineering students linked to the network via a high-speed Ethernet connection were less effective when accessed from a classroom via a 1200 bytes-per-second (bps) modem. Other interfaces violated teachers' intuitions about microcomputers: In some cases it was necessary to use the tab key in place of the return key; in other cases the backspace and arrow keys did not function, requiring use of <Control>–H instead. We learned that factors considered minor by technically-oriented users had a significant effect on acceptance by teachers.

It became clear that under ideal conditions telecommunications use by teachers could reach significant levels. A teacher who accesses the network for 15 minutes in one class per day generates more than 1 hour of usage per week, or 30 to 40 hours per school year. After initial pilot studies demonstrated the benefits of such access, Centel provided funds to partially underwrite the costs of extending phone lines to the classroom, while IBM provided support for provision of portable computers for use either in the classroom or at home. The Curry School also provided a full-time telecomputing facilitator who worked with technology coordinators and teachers to provide support for network use. Under these conditions, levels of use by many teachers considerably exceeded one hour per week.

Uses ranged from development of instructional applications to peer support. For example, a first-year teacher asked the advice of other teachers about the issue of retention; a fifth-grade teacher in Charlottesville, Virginia, developed an instructional unit based on interactions between her class and a class of native Alaskan children on the Kenai Peninsula. Many of these uses have been described elsewhere (Bull & Cooper, 1989; Bull, Harris, Lloyd, & Short, 1989; Bull, Hill, Guyre, & Sigmon, 1991; Bull, Harris, & Drucker, 1992; Bull, Cothern, & Stout, in press), and contributed to beliefs about the nature of an ideal public school computer network.

During this time, Texas was also planning development of a public school telecomputing network. Consultations with Connie Stout, communications specialist in the Division of Educational Technology of the Texas Education Agency, with responsibility for design and implementation of the state electronic network, also influenced the design of Virginia's PEN. Although the requirements of the two systems differ somewhat, it is not surprising that development of the two parallel systems in a similar time period influenced one another, and there was a definite intent to ensure that the two public school telecomputing networks would be compatible with one another. (See "TENET: Texas Education Network" by Connie Stout.)

Considerations Underlying the Network Architecture

Based on several years of experimentation and experience with telecomputing in public schools, several principles emerged that guided the development of Virginia's PEN. Some of these principles are applicable to any public school network, while others may be specific to conditions and circumstances in Virginia. These guidelines generally fall into two categories: network architecture and user interface. Network architecture refers to the design underlying the basic network links and transport mechanisms, while user interface refers to the screens and menus with which users interact directly. Although the two are to some extent interrelated, it is often possible to modify the user interface to meet the requirements of a particular audience even though the underlying network architecture remains the same. The network architecture of Virginia's PEN was designed by Tim Sigmon, associate director of Academic Computing at the University of Virginia, and implemented through a collaborative effort with the Virginia

Department of Education, which now administers the network. This paper focuses primarily on issues related to the architecture of the network.

The first and most important design guideline was compatibility with the existing inter-university network, or Internet. The Internet is actually a collection of more than 2,000 networks in more than 40 countries that all obey a common communications protocol (Coursey, 1991; Quarterman & Hoskins, 1986; Quarterman, 1991). Almost all major universities today are linked to the Internet, effectively providing an inter-university network connecting educational institutions in many other countries in the world as well as in the United States. The Internet also connects government agencies and commercial firms as well as educational institutions.

The intent was to create a single, seamless network from kindergarten through graduate school (rather than two incompatible networks). Extending the inter-university network to public schools in Virginia was intended to facilitate school/university partnerships. Linkage to the Internet also allows teachers to tap into a wide variety of resources, many of which extend beyond the boundaries of Virginia. It also allows teachers in Virginia to communicate with teachers in Texas, California, New York, Florida, and other states which are establishing public school networks linked to the Internet.

In some states, establishment of public school networks incompatible with the inter-university networks has created the equivalent of an electronic *cul de sac*. Our experience has suggested that teachers rarely have time to log on to multiple networks on a regular basis. Hence, it is desirable to use a common communications standard. This does not imply that every state must use the same network, but simply that each system should follow a common communications protocol so that it is possible for information to move transparently from one network to another. Adoption of an existing communications standard also simplifies implementation of the networks, because the communications protocols already exist and need not be reinvented.

A Distributed Computing Network

Telecommunications costs pose one of the more significant barriers in most educational networks. This cost is often addressed by limiting access, developing macros to upload and download documents created off-line, or through a combination of strategies. However, one goal for the state network was unlimited instructional access for teachers.

Prior experience indicated that teachers successfully accessing telecommunications for instructional use could use the system for an hour or more per week. Assuming this level of use for up to 5 teachers in each of Virginia's 2,000 public schools yields a combined usage of more than 10,000 hours per week. Projected telecommunications charges of $5 to $15 per hour would produce charges of $100,000 per week. This model was clearly unviable.

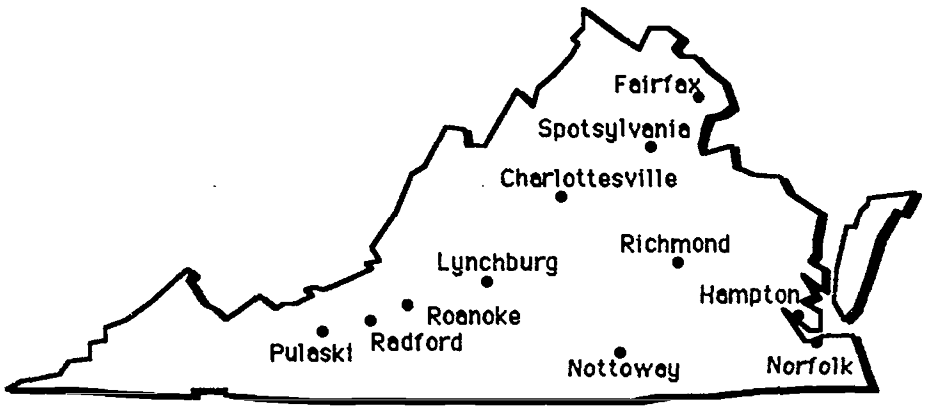
The solution adopted was based on the general model of the Internet itself. One model for telecommunications access consists of a single host computer that is accessed by all participants via long-distance telecommunications links. Many commercial services, such as Compu-Serve, are based on this model. However, the concept of all university faculty accessing a single host computer in the center of the country for electronic mail makes it clear that this is not a viable academic model. No existing host computer would have the capacity to serve all university faculty in the United States, and telecommunications charges would be prohibitive.

Instead, a distributed computing network is used as the model for the inter-university electronic mail system. Network servers distributed at the various universities are linked together in a common network. This model allows faculty to log onto computers placed at each individual university. Then the electronic message is sent to another university. However, transmission capacity of long-distance links is many times greater than that of an individual typist. Even a 2400 bps modem can transmit 240 characters per second, or 14,400 characters per minute. A typist's speed is a fraction of 14,000 characters per minute; someone who can type even 300 characters per minute is considered a good typist. Of course, many electronic messages are not sent to another university and remain on the host system within the same university. Similarly, news groups and electronic conferences can be downloaded from a distant computer once and then accessed many times by different faculty at a single university. Therefore, telecommunications charges in a distributed computing network are a fraction of those in a network that makes use of a central host.

The advantages associated with the inter-university network are equally applicable to a public school network. Accordingly, the network architecture adopted for Virginia's PEN was that of a distributed computing network. This involves a strategy of placing network servers in major population areas, making it possible to access the network with a local phone call in those locations. Currently, Virginia has been divided into eleven regions, each served by a network node. Users who are not within a local phone call of these servers can access the network through a toll-free 800 number. As usage increases in other areas, additional servers may be added. This approach addresses both cost containment and load balancing needs.

Aside from the cost-containment benefits, a distributed network has other advantages. Local administration makes it possible to allow customization and address regional needs and requirements. Regional servers can serve as localized laboratories, making it possible to field test different approaches before implementing them on a statewide basis. This geographic distribution also places network administrators in closer proximity to the region's superintendents, principals, and teachers. The node administrators collectively serve as a network policy council which influences the future directions and growth of the network, reporting to the central administration in the Virginia Department of Education.

As the network grows, extending this cadre of node administrators may become unwieldy. A council of a dozen node administrators has proven to be a manageable size and been able to function effectively. In the future, the existing network servers may be supplemented by centrally administered terminal servers and other strategies dictated by future technologies.



Nodes of Virginia's Public Education Network

The network software was implemented at the University of Virginia Academic Computing Center in 1989, when an initial system of three servers was established to verify the feasibility of the concept. Network servers consisted of Intel 80386-based microcomputers with a Unix operating system. One advantage of this particular approach is that servers can be replaced with more powerful Unix systems as additional capacity is required.

Two factors prevented prior implementation of a distributed public school network. One was the cost of hardware. In the first part of the 1980s a minicomputer was required for establishing a network node linked to the Internet. The cost of a minicomputer was too high for many school districts, particularly those in rural districts, making such a plan impractical. However, an Intel 80386 or 486-based microcomputer with a 450 megabyte disk drive can now be used for the same purpose. The current cost of such a system is a more affordable $4,000 to $5,000. In the future, the hardware cost of the network server will become a smaller and smaller part of the overall cost.

The other question that was unanswered until recently was whether school personnel could successfully administer a network server. The principal duties involve backing up the system on a regular basis and providing network IDs to teachers who request accounts. The local administrator also serves as a point of contact for personnel at the Virginia Department of Education in the event of a hardware failure.

In tests at pilot sites, network administration presented no difficulties for local school personnel. On average, administration has required approximately a half-day per week. In some instances, administrative computing personnel in the central school office handle this chore, while in other instances teachers with some technical interest or background (such as a science teacher) serve in this role. In the event of a hardware failure, spare servers at the Department of Education make it a straightforward matter to replace the damaged system and reload it with backup files while the original system is undergoing repairs (provided that backups have been properly maintained).

The original rationale for installation of a distributed computing network was economic. It was the only economically viable means of providing teachers with the level of instructional access desired. However, there are other benefits as well. One benefit is administrative. Assuming that 10,000 Virginia teachers have network IDs (based on the estimate of 5 teachers per school in each of approximately 2,000 schools), the problems involved in administering this many accounts from a central location are formidable. If only a small percentage of teachers encounters questions or difficulties with their accounts, this would produce several hundred calls per week, many of which would be difficult to resolve centrally. Our experience has been that typical problems range from forgotten passwords to incorrect modem cables. Availability of a local administrative facilitator makes it possible to resolve difficulties which might be addressed less efficiently from a central location.

Another advantage of a distributed computing system is that it becomes possible to customize some menus and screens to address the needs of individual school divisions. While the overall interface will remain consistent throughout the entire state, space has been provided on the main menu for a sub-menu customized by the local school division. Development of a network architecture that places computing power nearer the end user mirrors a trend that has been developing in all computing environments, and this trend is likely to continue for the foreseeable future.

Alternatives to a Distributed Computing Network

One other alternative was considered and rejected in Virginia, but may be suited to the needs of some states. This entails development of software that allows users to create electronic messages off-line and then upload the message and download waiting mail through a series of macros. A number of educational telecomputing networks are based on this model. However this approach has several limitations.

Inefficient Retransmissions of Data

When a network server is accessed via a long-distance carrier, certain inefficiencies are inevitable. Under these circumstances, a message sent to a person across the hall may make a several hundred mile round-trip. Macros that capture personal mail messages which are read off-line may minimize these inefficiencies but cannot eliminate them.

The problem worsens when conferencing and news services options are added to personal mail. In the case of a distributed computer network, news is transmitted once from the remote site to the local server. After the initial transmission, news groups may be read repeatedly through a local phone call. In contrast, when the news resides on a remote host, news groups are repeatedly retransmitted over a long-distance carrier each time they are accessed. Macros that capture news so that it can be read off-line do not address this fundamental inefficiency in the architecture of the network.

Interactive versus Batch Mode

Given a choice, all users prefer to access news and databases interactively. It is the difference between being required to submit requests for books to a librarian and being allowed to browse directly through books in the stacks. If the information is transferred to a local host, there is no penalty for interactive access. Batch requests may be required to access information on a remote host in order to reduce costs.

Practical Problems Encountered with Off-Line Systems

We have also encountered a host of practical problems with macros that are developed to capture information which will be read off-line. Line-noise may interfere with the successful operation of the macro, and the software is not always sufficiently intelligent to recover gracefully, leaving users baffled. In other cases the software works properly only with certain hardware configurations. The scripts of such macros are dependent upon consistent behavior of the host computer, and even seemingly trivial changes in the telecommunications software or operating system of the host computer can require revisions in the macro. Distributing updates to macros proved to be a problem with even a few hundred users; with a base of 10,000 users the problems become even more pronounced. Each revision generates numerous calls from users who were not aware of the update, did not receive it, or were not successful in getting it to work properly. More significantly, our past experience has been that users may simply vote with their feet and stop using the system when their software ceases to work.

Because of high ongoing programming and maintenance costs, high costs associated with system updates, and less than satisfactory results from the standpoint of many users, this off-line mode of interaction was rejected for Virginia's PEN. A distributed computing system has all the economic benefits of an off-line system without many of the corresponding disadvantages.

Unix and Usenet

Unix was chosen as the operating system used to develop the network software. There were several reasons for this decision. One of the most significant involved providing for future growth and expansion of the system. Other operating systems that could have been chosen for development of network software for Intel 80386-based file servers included MS-DOS, OS/2, and Zenix (a Unix variant). During evaluation of the 80386-based servers, it was determined that they can readily accommodate up to 16 simultaneous log-in sessions and have sufficient disk space to meet the needs of several hundred users. However, as the user base increases, some of the larger school systems may require larger servers. Use of Unix to develop the network software will allow these school systems to migrate from microcomputer-based servers to workstations such as Sun or the IBM RS-6000 system, or to minicomputers or mainframe systems with Unix operating systems if further processing power or capability are required.

Another significant reason factored into the choice of Unix as the basis for the operating system. Usenet—a Unix-based system—was selected as the conferencing system adopted for Virginia's PEN. In contrast to electronic mail, which is the equivalent of a private letter sent from one individual to another, electronic conferencing provides the capacity for an ongoing public conversation among a number of individuals. Usenet was selected for several reasons. It provides access to a rich base of academic resources, including more than 1000 national "news groups" in which scientists and academicians from around the world participate.

Usenet is also the conferencing system adopted by the Texas Education Network (TENET). This use of a common conferencing system will permit teachers and classes in the two states to collaborate on joint instructional projects. For example, in one project the Consortium for Interactive Instruction in Norfolk posted sightings of marine mammals on a news group established for this purpose. With similar Usenet subscriptions by teachers in Texas, it would be possible to add similar marine sightings off the coast of Texas. This would allow science teachers in both states to discuss similarities and differences between the two areas with their classes. Since Usenet is an academic network, marine scientists at universities and government agencies would also be able to contribute to this discussion, using the same conferencing system and network that they normally use for their academic work and collaboration.

Because Usenet is a Unix-based system, the adoption of Unix as the operating system of choice not only provides a ramp for future growth and expansion, it also provides access to a worldwide academic conferencing system. From past descriptions of Virginia's PEN, we have become aware of a frequent misconception that use of Unix on network servers also requires use of Unix software on microcomputers accessing the system. This is an incorrect perception. The operating system of the network server does not restrict the operating system of microcomputers accessing the server. In fact, one of the design specifications for Virginia's PEN was a requirement that it be accessible to all microcomputers and operating systems in common use in Virginia's schools, including Apple II computers (DOS 3.3 and ProDOS), IBM and IBM-compatible computers (MS-DOS), and Macintosh computers.

Selection of Usenet news groups does require some judgment on the part of local network administrators. Some news groups in "alternate," unmoderated conferences are not suitable for a public school environment. In addition, some news groups are very large. More than ten megabytes of information are distributed via national Usenet news groups each day. Indiscriminate subscription to news groups can quickly fill a hard disk and incur considerable telecommunications charges if access is via a modem and phone line.

A number of different interfaces are available to read Usenet news groups. Many of the commonly available Usenet news readers such as "RN" or "ReadNews" were developed for use by technically oriented subscribers. They have a plethora of options and switches, but tend to overwhelm a novice. In the first year of Virginia's Public Education Network, educators experienced great difficulty in using the RN newsreader. Therefore a revised user interface was developed which has been well received. In the process, a comparable user interface was adopted for both mail and conferencing to reduce user training requirements.

On Virginia's PEN, selected BITNET list servers such as Bob Carlitz's "Kids-Net" are also cross-fed to Usenet news groups. A list server essentially provides a mechanism for broadcasting electronic mail to multiple users. Broadcast mail is less efficient than a news group both from a user's standpoint and from the perspective of the network administrator. From the standpoint of individual users, transmissions from list servers become intermingled with private mail and may even overwhelm other messages sent from individual users. This may make it difficult to reply in a timely fashion or identify important messages that should be answered promptly. From the perspective of a network administrator, a news group requires a single transmission for each posting, while broadcast mail results in multiple transmissions. The same document is re-sent to each individual subscribing to the list servers, increasing telecommunications charges. Further, even after it has been transmitted, the broadcast mail from a list server is stored multiple times on the hard disk in each private mailbox, rather than once in a single location, as in a news group.

High-Speed Connections

One issue facing administrators and developers of Virginia's PEN is establishing an orderly upgrade path for expanding access to a wider range of services. University faculty sometimes confuse Internet access with high-speed network access. The more than 2,000 networks and subnetworks that collectively constitute the Internet share a common communications protocol known as Transmission Control Protocol/Internet Protocol (TCP/IP). When the network is accessed via a high speed connection, programs such as "Telnet" and "rlogin" (remote login) enable the user to use remote computers in other cities just as though they were in the same location as the user. Hence, high speed access provides a higher level of functionality.

This level of access and functionality is taken for granted in university settings. However, it requires a high speed router and communication lines, which significantly increase costs. To reduce costs (and therefore make the network affordable for all school divisions), Virginia's PEN was designed with 2400 bps MNP 5 error correcting modems as the basis for transmission of data to network servers. Consequently, it is not possible to Telnet into other computer systems in the manner possible in most university settings. This capability could provide the basis for searches of university electronic on-line library catalogs and access to other databases and electronic documents housed at universities and similar institutions. It might also serve as the basis for a state-wide public school electronic catalog and provide direct access to services at other institutions around the world. This type of access has proven extremely popular with teachers with access to high speed connections, but currently is available to only about half of the network servers on Virginia's PEN. In the future these connections will be upgraded until all locations have high-speed Internet access.

There are several possible approaches to upgrading the service of all Virginia's PEN nodes to this level of functionality. In the short term, public school nodes near universities with high speed Internet connections could take advantage of this access by attaching the network server directly to the university local area network. Since there is no additional cost to the university once Usenet news groups have been transferred, this immediately provides local schools with a much wider range of news groups than they might otherwise access.

Some cost does accrue to the university for transmission of electronic messages from teachers that are sent to other sites. However, the actual cost to the university should be put into perspective. A high resolution digitized X-ray developed by a medical researcher can easily occupy 5 to 10 megabytes of disk space. Such a digitized image can be transferred from one university to another via the Internet in a matter of seconds. To provide a basis of comparison, everything which Shakespeare wrote in an entire lifetime can be stored in 6 to 7 megabytes. (Possibly a new unit of information is needed to express large quantities of information to make them comprehensible; "this 650 megabyte CD-ROM holds 100 *Shakespeares of information*.") In other words, a medical researcher in a few seconds might easily transmit more information than a teacher might write and send electronically in an entire teaching career. Hence the cost to the university for support of the public schools is relatively small in comparison with levels of use by university faculty.

In cases in which Internet access is via a high speed university connection, network servers play another important role. For training purposes it was considered vital that all teachers throughout Virginia share a common network interface on Virginia's PEN. This makes it possible to develop a single set of training materials for support throughout Virginia and to provide the same type of support no matter where the user may be located. When access to the Internet is via a university connection, the network server for Virginia's PEN acts as a front end that maintains a common interface for all users. In other public school networks in which teachers access the university network directly, the interface varies from school division to school division, creating a patchwork quilt of different interfaces and greatly complicating the task of providing user support and training across the entire school system.

In the short term, linking servers to university networks will provide high speed Internet access in many areas of the state and may facilitate development of high speed connections in community colleges and other institutions that could not otherwise justify such access. In the long term, Virginia's Department of Information Technology is in the process of developing plans for establishing high speed connections that will link all areas of the state. It is possible that these high speed connections may provide access points for school divisions. It is also possible that technologies such as cable television connections or satellite downlinks may provide a means for high speed transfer of such information in the future.

In the interim, school divisions which have sufficient funding or which place the issue sufficiently high on their list of educational priorities can establish high speed Internet links themselves. The cost of a high speed router is approximately $5,000, a one-time expense. In addition, the cost of leasing an appropriate high speed line is approximately $5,000 per year. Although this is a relatively high cost, it still may be within the reach of some school divisions. As a less expensive alternative to a continuously leased high-speed line, a 19.2 kps modem may provide some of the desired functionality at a lower cost. In this scenario, the modem would provide direct Internet access on demand, connecting at the time a service is requested, and dropping the connection when no longer needed. The specific methods used to achieve increasing levels of functionality on Virginia's PEN will probably depend upon the specific mix of future technologies available as the network expands.

Summary

Virginia has established a Public Education Network known as Virginia's PEN. The purpose of this network is to provide the infrastructure for electronic transfer of administrative data and to provide unlimited instructional access to educators in all 2,000 Virginia schools. The extension of the Internet to Virginia's public schools via Virginia's PEN was intended to establish a single, seamless network from kindergarten through graduate school. Virginia's PEN is perhaps the first statewide public school network to guarantee access to the Internet for every public school educator at no charge.

Virginia's PEN is a distributed computing network that consists of regional servers providing access via a local phone call in major population areas and toll-free access in other areas. The network software was developed for the Unix operating system, providing a ready upgrade path for school systems that may require greater capacities in the future. The conferencing system used on Virginia's PEN is based on Usenet news groups, a national Unix-based distributed conferencing system.

In 1991 Texas established a comparable statewide public school network, the Texas Education Network (TENET), linked to the Internet. A number of other states such as California, New York, and Florida also provide at least some public school educators with access to educational networks linked to the Internet. In 1991 the Consortium for School Networking (CoSN) also issued a policy statement sent to the U.S. Secretary of Education which called for extension of the Internet to public schools on a nationwide basis. (Consortium for School Networking, 1991). If this recommendation is adopted, a national K-12 public school network could become a reality.

References

Bull, G. and Cooper, J. (1989). New technologies in teacher education. *American Association of Colleges for Teacher Education Briefs, 10* (2): 8-9.

Bull, G., Cothern, H., & Stout, C. (in press). Models for a national public school computing network. In D. Carey & R. Carey (Eds). *1992 Technology and Teacher Education Annual.* Charlottesville, VA: Association for Advancement of Computer Education.

Bull, G., Harris, J., and Drucker, D. (1992). Building an electronic culture: the academical village at Virginia. In M. Waggoner (Ed.). *Empowering networks: Using computer conferencing in education.* Englewood Cliffs, NJ: Educational Technology Publications.

Bull, G., Harris, J., Lloyd, J., and Short, J. (1989). The electronic academical village. *Journal of Teacher Education, 40 (4),* 27-31.

Bull, G., Hill, I. Guyre, K., & Sigmon, T. (1991). Building the electronic academical village: Virginia's Public Education Network (PEN). *Educational Technology. 31 (4),* 30-36.

Bull, G. L., Shidisky, C. J., Creasy, G. F., Phifer, J., Caffarella, E. P., Bartley, R., Booz, W.H., Lawrence, D., Weller, B. J., and Morgan, T. (1989, May). *Designing a cooperative public school-university network for Virginia.* Symposium conducted at the meeting of the Virginia Educational Computing Association, Virginia Beach, Virginia.

Commission on the University of the 21st Century. (1989). *An open letter to the people of Virginia.* Richmond: Commonwealth of Virginia.

Consortium for School Networking. (1991) Internet recommendation: Position statement to the U.S. Secretary of Education. (Available from John Clement, Educom K-12 Networking Project, 1112 Sixteenth Street N.W., Suite 600, Washington, D.C. 20036.)

Coursey, D. (1991, February 4). Riding the Internet. *Infoworld,* pp. 48, 57.

Quarterman, J. S. (1991). Which network, and why it matters. *Matrix News, 1 (5),* 6.

Quarterman, J. S. and Hoskins, J. C. (1986). Notable computer networks. *Communications of the ACM, 29 (10),* 932-971.

Spagnolo, J., & Henry, G. (1990) *Statewide electronic network: Virginia's PEN.* Superintendents Memorandum 236. Richmond: Virginia Department of Education.

Virginia Board of Education. (1989). *A six year technology plan for Virginia's schools.* Richmond: Virginia Department of Education.

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TENET: TEXAS EDUCATION NETWORK

by Connie Stout

Texas is a diverse state with more than 1,050 school districts that range in size from student populations of more than 190,000 to less than 10. More than 3.2 million students and over 200,000 teachers, support staff, and administrators work in Texas schools each day. The Texas Education Agency has long recognized the need for effective and low-cost communication among and between the more than 6,400 public school campuses, the 20 regional education service centers, colleges and universities, and other educational professionals in Texas. Since 1985, the Agency has contracted for an electronic network with THE ELECTRIC PAGES, a commercial network operated by GTE. The TEA-NET (Texas Education Agency Electronic Network) provided electronic mail and bulletin boards to approximately 650 of the administrative offices in school districts in Texas. In November 1988, the State Board of Education adopted the *1988-2000 Long-Range Plan for Technology*. Incorporated within the plan was a request to establish a K-12 statewide communications network to link all school districts and their campuses. The requests were incorporated into Senate Bill 650 which was passed by the 71st Legislature in 1989. Senate Bill 650 (Section 14.042 of the Texas Education Code) authorized the establishment and maintenance of an electronic information transfer system, the Texas Education Network (TENET).

The Agency evaluated alternatives for the acquisition of services necessary for the creation and maintenance of an enhanced electronic communications network capable of transmitting information among and between the members of the public education system in Texas. Agency staff conducted a nationwide review of telecomputing networks, telecomputing hardware, software, and training. The telecomputing networks reviewed included: proprietary networks such as GTE, Compu-Serve, AT&T, AppleLink, America Online; statewide networks such as Pennsylvania's PennLink, Florida's FIRN, Virginia's VA.PEN; and other "grassroots" networks like FrEdMail and K12 Net. In addition, input was solicited from teachers, administrators, the regional service centers, and the educational organizations that had been utilizing the TEA-NET network.

Review of existing and proposed networks resulted in the formulation of three essential requirements:

- Network standards which would allow this network to scale as growth and new advanced technology demanded.
- Network standards based upon TPC/IP and OSI protocols to permit inter-operability between networking systems.

- Network standards for a UNIX-based operating system to permit multi-tasking for educators utilizing the system.

Following a Request for Proposal process, which did not result in an award, the Agency staff met with staff at the University of Texas System to consider using the Texas Higher Education Network (THEnet) as the network carrier. THEnet, currently providing connectivity to the majority of the major postsecondary institutions in the state, is an NSF regional network connected to thousands of other networks worldwide through the Internet. Analysis of the available networking alternatives showed that an approach based upon interagency contracts with The University of Texas System for telecommunications services was the option which would realize both the most cost-effective system and increased services to Texas K-12 students and educators. Several other states including Virginia, California, and Florida are considering adopting similar models to bring connectivity to their public school educators.

The configuration of TENET is based upon a distributed design. The local hosts are a series of message processing and storage units (MPS) which are Unix systems with 24 Megabytes of memory, 1 Gigabyte of disk, and backup tape. The Office of Telecommunication Services of the University of Texas System houses one system which functions as the central host. Local phone access as well as 800 line service is provided in Austin. Seven other message processing and storage (MPS) computer systems are distributed across the state at university sites to store messages and support applications.

The Computation Center of The University of Texas at Austin provides help-desk services for the public education community in the use of the TENET through the expansion of existing THEnet information center operations. Applications on the system are designed and implemented by The University of Texas System, Office of Telecommunication Services, in cooperation with the Texas Education Agency.

By contracting with the existing distributed network of The Higher Education Network (THEnet), public school educators are brought onto an electronic network with rich resources that include online library catalogues, educational computer archives, public databases, and instructional hypermedia libraries. The distributed computer system, when fully implemented, will permit local access from fifteen major metropolitan centers in the state. Toll-free lines are available to educators located outside the local calling areas. As the traffic increases on the network, local access will be expanded through additional nodes. Utilizing THEnet also recognized and supports national efforts to link higher education with public education and offers the potential for expanded access and extended services over the network.

Another key component to successful networking involves adequate training and support. The Texas Education Agency worked with the Texas Center for Educational Technology to design curriculum for course delivery through a mix of expertise available at the Center, other universities, and regional education service centers. TENET training is now being conducted statewide through the 20 regional education service centers, using a training of trainers model.

The interagency approach offers the following advantages to the K-12 community:

- Utilization of an existing tax-supported network.
- Increased access to other state agencies serving public education.
- Increased access to the wealth of resources available in the university community.
- Training designed to meet unique needs and resources available to the state education community.
- Access to network services at minimal cost to Texas educators.
- Rapid implementation of networking services.
- Extension of the potential use of the system to include curriculum-based projects as well as administrative projects, thus expanding the benefits of the network to teachers and students.

The basic components of the TENET network include:

- Electronic mail: The TENET network utilizes the PINE mailer designed by the University of Washington. The mail service extends beyond the community of educators in Texas to educators using other state, national, and international networks.
- Electronic bulletin board: The bulletin board, with capabilities for indexing and searching, makes it possible to post information from many locations within the state for educators to access.
- Electronic conferencing: Conferencing differs from a bulletin board in that it establishes a climate of interaction, allowing educators from different locations to discuss important topics.
- Electronic databases: Electronic databases contain information accessible by all Texas educators.
- Workstation communication software: Software which permits educators to edit and prepare files for transmittal, as well as request or send information to and from bulletin boards, conferences and databases, prior to actually connecting to the network, is an integral part of the design. This minimizes the time each educator is directly connected to the network and reduces the cost of telecommunications time. Currently the TENET network is using Kermit. However, there are plans in place to customize the communication software.

- Telnet: A capability that permits resource sharing between networks is an important part of the network design and allows educators to have access to many resources on the Internet.
- Remote file transfer - ftp: This capability permits sharing computer files from many networks.

The benefits of the electronic network extend beyond just electronic mail and computer conferencing. The network supports collaboration between K-12 educators and postsecondary educators. For a nominal fee of $5 per year and no online cost, Texas administrators, teachers, and students have the capability to extend their communications to thousands of educators and students throughout the United States and countries around the world. By using the TENET network, not only are they able to use many major university libraries, but they also have access to resources such as NASA's Spacelink in Huntsville, Alabama. By accessing NASA, teachers are able to communicate with astronauts and scientists as well as retrieve classroom materials for their own use. Other resources on TENET include UPI news, CNN Newsroom lessons, and Newsweek Lessons. In addition, the network will soon feature an online encyclopedia and a study skills guide.

The capabilities of the TENET network also include electronic mail gateways to many other major networks. Some of these networks include AppleLink, Compu-Serve, MCI mail, AT&T Mail, FrEdMail, and Fidonet. These capabilities are available to Texas educators without an additional charge.

Forty Texas educators, representing a broad range of expertise,were selected as TENET Master Trainers. They received training in three areas: use of the network, conference moderation, and curriculum integration. Twenty of the trainers were from each of the educational service centers. The additional twenty trainers represented school librarians, math supervisors, computer coordinators, and representatives from professional organizations such as the Texas Computer Education Association, the Texas Association of School Boards, the Texas Association for Supervision and Curriculum Development, and the Texas State Teachers Association.

The TENET network uses USENET conferencing software on the system to create Texas-specific conferences. All of the TENET conferences are moderated by educators so that as telecommunications is introduced into the classroom, an understanding of how to create an environment for learning and of network etiquette can be established. All the educators functioning as moderators on TENET have had training to help nurture and guide conference participants as they begin to explore the use of telecommunications.

Since the network began operation on August 26, 1991, more than 4,300 users have accessed TENET. They average 10,500 log-ins per week, and more than 75 new users apply for an account each day. Telecommunications projects are an ongoing part of many Texas classrooms and bring students, teachers, and members of the community together through collaboration across state and national boundaries. During the past several years, the Agency has provided support for projects tailored to specific needs by classroom teachers. Examples include projects which enabled handicapped students to share their writing with other geographically dispersed students throughout the state and nation. In addition, the Induction Year pilot supported new teachers as they were inducted into the profession of teaching. Thus through a collaborative effort with educators in the state, the Agency supports the use of telecommunications as an instructional application which extends learning beyond physical barriers and time constraints.

Connie Stout is the Director of Programs at the Texas Education Agency where she supervises and manages the Texas Education Network, TENET. She has played a key role in the design, the development, and the implementation of the State's K-12 education network.

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NETWORKING THE FUTURE: WE NEED A NATIONAL 'SUPERHIGHWAY' FOR COMPUTER INFORMATION[1]

by Al Gore

Throughout American history, liberals and conservatives have argued about the proper role for government in stimulating economic progress. But they have generally agreed on one thing: the need for an ample infrastructure. In times past, that meant building highways and railroad lines, water pipes and sewers, bridges and tunnels, libraries and schools. It is now time to update our definition.

Just as the interstate highway system made sense for a postwar America with lots of new automobiles clogging crooked two-lane roads, a nationwide network of information superhighways now is needed to move the vast quantities of data that are creating a kind of information gridlock.

Our information policy resembles the worst aspects of our old agricultural policy, with grain left rotting in thousands of storage silos while people were starving. Similarly, we now have warehouses of unused information while critical questions go unanswered and critical problems remain unsolved.

For example, the Landsat satellite is capable of taking a complete photograph of the entire Earth's surface every two weeks. The information contained in the photographs taken over the last 18 years is invaluable to farmers, environmental scientists, geologists, educators, city planners and businesses. Yet more than 95 percent of those images have never been seen by human eyes. They are left to rot in their digital silos in Sioux Falls, South Dakota.

In a sense, we have automated the process of gathering information without enhancing our ability to absorb its meaning. The amount of data now available—somewhere—to answer almost any question imaginable is staggering. But the sheer volume we have collected on almost everything now threatens our ability to provide a definitive answer on anything. We're forced to deal not only with information, but also with "exformation": data existing outside our conscious awareness which nevertheless keeps us slightly off balance because we know it exists, even if we don't know where or how to use it.

Yet we have the tools necessary to cope with this vast surplus of information: supercomputers. Cheaper and more powerful each year, they are ideal for finding

[1] This article first appeared in *The Washington Post*, July 15, 1990, and is reprinted by permission of the author.

needles in haystacks and for turning information into knowledge. But we're not using them, largely because they require communications links we don't yet have.

The Image of the Future

Part of what's so special about supercomputers is their ability to translate endless rows of eye-glazing numbers into visual images easily understandable to the human mind. Millions or trillions of binary digits (bits)—which in their raw form seem no more than a bewildering chaos—can be made to reveal meaningful patterns by assigning a color or shape to certain ranges of data (i.e., 3 through 5 will be red, 7 to 9 blue, and so forth) and then displaying the result as a graphic on a computer screen. Not only is one picture worth a thousand words, one three-dimensional, moving graphic is worth a trillion bits.

For example, aircraft designers now depend on supercomputer graphics to understand the complex aerodynamic patterns of modern aircraft. Similarly, chemists creating new materials use three-dimensional graphics to scan through thousands of potential molecular combinations.

I tried one such system during a demonstration of a top-of-the-line Cray supercomputer. By moving a "mouse" to select atoms from a table of elements displayed on the screen, I "created" a new molecule, which was then depicted as a brightly colored three-dimensional model. I watched as it resolved itself, stage by stage, into its final thermodynamic state. Then at the top of the screen appeared a menu of properties for which the new molecule could be tested in seconds. The computer allowed a layman to do in a few minutes what might have taken a trained scientist weeks in the laboratory.

Trial and error, throughout history our most powerful teacher, has—until now—been an always slow and frequently painful process. No longer. Supercomputers, properly used, give us the ability to instantly create elaborate visual models of the world around us and watch the way its elements interact, without the limitations of time and space imposed by the real world. As Sheryl Handler of Thinking Machines Corporation—the Cambridge, Massachusetts, supercomputer firm—testified recently before a Senate subcommittee:

> It is hard to understand an ocean because it is too big. It is hard to understand a molecule because it is too small. It is hard to understand nuclear physics because it is too fast. It is hard to understand the greenhouse effect because it is too slow. Supercomputers break these barriers to understanding. They, in effect, shrink oceans, zoom in on molecules, slow down physics and fast-forward climates. Clearly, a scientist who can see natural phenomena at the right size and the right speed learns more than one who is faced with a blur.

Unfortunately, most of the people who could benefit from this revolutionary technology don't have access to it. You can direct-dial Fairbanks, Alaska, from your breakfast nook. But you can't use the full power of a supercomputer without being in the same building—because our current network of telephone lines will not carry the elaborate graphic images that make supercomputers useful. Today's networks thus suffer from what one expert calls "graphic jams."

If we had the information superhighways we need, a school child could plug into the Library of Congress every afternoon and explore a universe of knowledge, jumping from one subject to another, according to the curiosity of the moment. A doctor in Carthage, Tennessee, could consult with experts at the Mayo Clinic in Minnesota on a patient's CAT scan in the middle of an emergency. Teams of scientist and engineers working on the same problem in different geographic locations could work together in a "co-laboratory" if their supercomputers were linked.

Yogi Berra once said, "What we have here is an insurmountable opportunity." Supercomputers that sell for $20 million today will, within four to five years, cost only a few hundred thousand dollars. Almost every medium-sized business in America will want one.

Medicine will benefit enormously. The "Human Genome Initiative" has already begun to store huge volumes of data about the sum total of all the genetic information that makes up the human species, including details about the three billion nucleotides in human DNA. Before the end of this century, doctors will routinely use this digital information to diagnose genetic-based diseases.

Our ability to understand the environment will be similarly transformed. The stunning pictures from the Voyager mission to Neptune represented more than one trillion bits of data; but that's nothing compared to the data about our own climate system that will be produced in the "Mission to Planet Earth" program. If you quantify all the scientific information which currently exists about Earth, that much data will be beamed down from orbiting satellites every day during the mission's peak years.

These are only two of the dramatic changes expected. *Scientific American* recently reported that experts in the field have concluded: "The developed world is experiencing a transforming convergence of computing and communications technology whose impact will rival that of the replacement of muscle power by machines." Some have even gone so far as to suggest that the new field of "computational science" is nothing less than a third domain of knowledge creation—co-equal with inductive reasoning (theory) and deductive reasoning (experimentation).

Simultaneously, we are witnessing the emergence of a truly global civilization based on shared knowledge in the form of digital code. The ability of nations to compete will depend on their ability to handle knowledge in this form.

How do we as Americans prepare for this new world? How do we learn to drink from a fire hose?

The On-Ramp to Tomorrow

Eleven years ago, I first proposed a nationwide network of fiber-optic "data highways" to link supercomputers and digital libraries throughout our nation. This legislation, now pending before Congress, would not only create the network needed, it would also create digital libraries, stimulate the development of more powerful supercomputers and increase the number of trained scientists and engineers capable of helping us make the best use of supercomputers. Whereas current information lines transmit 56,000 bits of information per second, this network will accommodate several billion bits per second—an entire Encyclopedia Britannica every second.

It has become one of the most thoroughly studied proposals in recent years. Several years of hearings convinced Congress to pass my Supercomputer Network Study Act—introduced in 1985 on the 30th anniversary of the signing of the Interstate Highway Act. This legislation required a complete executive-branch analysis of the original legislative proposal. In 1987, the Office of Science and Technology Policy formally completed its analysis with a ringing endorsement. In spite of that report, the Reagan White House declined to endorse the idea. Last September, in another OSTP study, dozens of the administration's own advisers urged that these proposals be accepted. The Bush White House says it likes the idea a lot, but not enough to pay for it. Like most infrastructure issues, this one is not partisan. Republicans as well as Democrats support the idea. But, like any bold, national proposal, it requires leadership. If President Eisenhower said he liked the interstate highway system in concept only, we'd still be riding on two-lane roads.

Fortunately, Congress is moving forward in a bipartisan way. Four separate Senate committees—Commerce, Budget, Energy and Armed Services—recently endorsed the network. Even Ronald Reagan's former science adviser, George A. Keyworth, now supports the project: "We're really missing the boat. We have the largest telecommunications system in the world. We have the biggest computer market. And we have the biggest domestic market overall. We should be using our domestic strength as a springboard for our own technological leadership. But we're not. The fiber-optic network should be looked at as a prolific tree, and the fruit will be the new businesses that will hang on that network. And both history and current observation tell us that our major competitor, Japan, will not approach this new technology with a fragmented domestic market."

Indeed, Japan has announced plans to connect every factory and even every home to a high volume network over the next two decades, estimating that when it is completed, as much as one-third of Japanese GNP will come from new goods and services made possible by the network. Europe, soon to be unified, is not far behind Japan in its plans. But this is one area in which the United States still has a large lead—if only we act to exploit that lead before it disappears.

Currently, U.S. companies and their overseas subsidiaries dominate the $30-$40 billion world market for designing and integrating computer systems. More than 60 percent of the $65 billion world software market is controlled by U.S.-based suppliers. And U.S. computer manufacturers still control more than half of the $135-billion computer systems market.

All of these are growth markets. In fact, according to a 1988 Office of Technology Assessment report, more than 40 percent of all new investments in U.S. manufacturing plan and equipment are now in a category called "information technology," twice the rate in 1978. But here's the rub: While we make more supercomputers than anyone else, we don't use them. We make two-thirds of the supercomputers in the world—but the real benefit comes from using them. That's where the network comes in.

The private sector can't build it any more than a turnpike company could have financed the interstate highway system. But, like the interstate highway system, once it is completed, the demand for its use will skyrocket. And, as user fees are collected, private operation will be feasible. However, right now, it is a classic "chicken-and-egg" problem: Since there's no network, there's no apparent demand for its use; since there's no demand, there's no network.

One thing is certain: The information revolution is changing our lives and we need to prepare ourselves to cope with its promise and potential. Our challenge is to process data into information, refine information into knowledge, extract from knowledge understanding and then let understanding ferment into wisdom.

Steam locomotives weren't much use until the railroad tracks were stretched across our land. And that didn't happen until the federal government made it possible. Supercomputers are the locomotives of the information age, but we haven't laid down the tracks. It's time to drive the digital golden spike.

Getting the Big Picture

Building a nationwide network of information superhighways will not involve construction in the traditional sense. Rather, it will entail the development of high-technology switches, software and digital libraries that will allow us to use existing fiber-optic cables to carry billions of bits of additional information each second.

Most telephone lines are still made of copper. But the telecommunications industry has already installed numerous fiber-optic cables—generally running underground between cities. Metal wires carry electrical signals. Optical fibers carry light signals, making it possible for a single hair-like strand to carry more information than hundreds of the thickest copper wires. Moreover, optical fibers are the first transmission lines whose capacity can be expanded without laying down additional lines.

What is needed to exploit this resource is a new generation of electronic equipment at either end of existing fiber cables (and new ones that the network would encourage): high-technology switches, high-speed computers and special software to keep track of the billions of bits of data moving around the system.

Today, dozens of separate computer networks link more than 500 universities, laboratories and hospitals throughout the nation. But these networks are presently unconnected and can carry only a fraction of the information that needs to be made available. Soon after the passage of the information superhighway bill, this network could link more than 1 million computers at some 1,300 locations in all 50 states. Just as the interstate highway system led to new access roads, beltways and feeders, the anticipation of an information superhighway network already has state and local governments planning for trunk lines to connect their information industries, schools, universities and libraries to the system "backbone."

At first, the network would be supported by the federal government; but user fees would make it viable as a private enterprise that would grow exponentially. Eventually it could reach into homes, providing anyone with a personal computer access to a whole universe of electronic information.

Senator Albert Gore (D-Tennessee) chairs the Senate subcommittee on science, technology, and space.
Albert Gore, U. S. Senate, Washington DC 20510.

IGC NETWORKS AND EDUCATION

by Bill Leland

The Institute for Global Communications: Background and Mission

The Institute for Global Communications (IGC), a division of The Tides Foundation, a California-based nonprofit corporation, houses two principal networks: EcoNet and PeaceNet. These networks have more than 6,000 subscribers and are growing rapidly. (For convenience, in this paper IGC refers to EcoNet, PeaceNet, and a few smaller networks that make up the IGC networks.) IGC is a computer-based communications and information sharing system whose mission is to encourage the effective use of computer telecommunications by all individuals and organizations that are working for environmental preservation and sustainability and for peace (including human rights and social justice). IGC is an educational (not an advocacy) organization.

IGC provides people throughout the world with essential computer telecommunications tools and helps these people gain the personal, professional, and technological skills necessary to use those tools effectively. Given the relative infancy of this technology, it is not enough to provide the computer network and even to get people on-line. We must work with users to help them learn the most appropriate technology applications, and we must address those human factors, which, if not addressed, stand in the way of developing collaborative relationships.

IGC Hardware, Software, International Connectivity

IGC runs its own hardware and Unix-based software, providing the full range of telecomputing services: electronic mail, electronic conferences, and on-line databases. The system is accessible from the Internet, SprintNet, and direct dial. We are also part of the Association for Progressive Communications (APC) which consists of IGC and seven other coordinated networks in Canada, England, Sweden, Russia, Australia, Nicaragua, and Brazil. Users in those countries, and some neighboring countries, connect directly to those seven machines to participate in electronic mail and conferencing with all APC partners. The total APC user community is more than 10,000 users. The APC machines phone each other periodically throughout the day and night to exchange new information over high-speed modems. At the completion of the phone call, all e-mail is immediately routed to e-mail boxes/user accounts and all networked conferences are automatically updated. The APC is realizing one of its main purposes in making international telecomputing affordable to organizations and schools.

Telecomputing and Education

At IGC most of our work is educational, but this paper focuses on K-12 formal education. Also, for the purposes of example, the paper focuses more on environmental education and EcoNet, since it is in this area that IGC's formal education applications are more highly developed. At the same time, peace education in its many forms, including cooperative learning and conflict resolution, is finding an increasing presence in K-12 education and is of vital interest to IGC.

Regarding formal K-12 environmental education, students and teachers generally use EcoNet as a global laboratory taking advantage of the information and human resources in the more than 200 on-line conferences committed to environmental issues. In some of these cases, students read relevant literature and discussions that would be difficult or impossible for them to get elsewhere. In other cases, they actively participate on-line. For example, an eighth-grade student involved users in the recycling conference in his project on the most ecological way to deal with spent laser printer toner cartridges; a sixth-grade class discussed their plans and follow-through as they initiated state legislation banning the release of more than six helium balloons into the atmosphere.

Teachers and students also share resources and ideas about the development of environmental curriculum and other ways of advancing environmental education. The Alliance for Environmental Education and the North American Association for Environmental Education, among others, use EcoNet. The Alliance is supporting all (60 at this time) of their regional environmental education centers (most of them university-based) to use EcoNet. Apple Computer has recently granted 60 Macintosh systems to the Alliance to support these efforts. TERC uses EcoNet to support their Global Laboratory and other activities.

More specific formal education applications of EcoNet are demonstrated by the Global Rivers Environmental Education Network (GREEN) based at the University of Michigan, Ann Arbor. GREEN has developed an extensive curriculum and field study guide that instructs teachers and students how to conduct nine water quality tests on local waterways. After conducting the tests, the students share their data and reports with other local schools studying different parts of the same watershed. One watershed group, for example in Michigan or Texas, then shares its approach and findings with a partner study group, for example in Germany or Mexico. The students share not only environmental but also historical and political information about their regions. The GREEN program has obvious merit in itself; and, by using computer telecommunications, students manage a geographically dispersed watershed project and also gain knowledge and perspective by sharing information with peers in other countries. This networking brings vitality and excitement to learning and produces world citizens who will be contributors to global stability.

Summary and General Observations

While there are already some meritorious examples of successful educational telecomputing, the educational community is only beginning to realize the exciting potential of this medium.

Some of the most notable educational telecomputing successes include international connectivity.

Students and teachers need increased access to telecomputing, as well as better and easier-to-use telecomputing tools.

Getting people on-line is not enough; they need to understand and value the educational purposes for which they are on-line.

- Training support needs to be present to produce more effective users.
- Educational/program goals are the driving force behind effective educational telecomputing. Even the best and easiest-to-use tools cannot and should not replace the creator of the learner's environment.

It may be appropriate to create special-purpose networks in some cases. However, when they are created, this should be done in such a way that, should wider or global connectivity become desirable at some later point, it would be easy to establish the connection.

Finally, collaboration among all segments of the educational telecomputing community is essential to provide the greatest benefit. Such collaboration needs to allow for and support decentralization and individual differences when appropriate.

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INTERNATIONAL TELECOMPUTING

by John Foster

Educational telecomputing is very much part of the European scene. Connectivity is being achieved both among systems and among nations. There is a sufficient number of users for carriers to offer schools fixed charges per annum and for vendors to offer gateways to their services at discount rates. (Sometimes the carrier will provide gateway services as a value-added part of its main service.) In the United Kingdom, premium services on Campus 2000, British Telecom's service to schools, add attractive extra information services on a pay-as-you-go basis to the approximately 50 databases available on the standard service or to the approximately 200 on the full Campus Plus service. Governments throughout Europe have a policy of connecting schools, and curriculum developers can assume there is access to telecomputing.

The UK service first began via the telephone system before de-regulation and therefore was well established before the first rival company set up. Within the system there are two electronic services. "Gold" is a dialcom e-mail service with gateways to various electronic databases and conferences (text based, 80 column screens and a not very friendly interface). "Prestel" is based on a standard "viewdata" videotex format—a consumer information system with a limited messaging service (text and color, block graphics, very easy to use with a limited keyword-search facility). Public and private sector companies pay Prestel to display information or pay for private gateways for their "CUGs" (closed user groups) to have access to the companies' data on the same format. Gold is paid for by subscription and use. It has a large number of gateways to worldwide commercial services. Prestel has a subscription charge and, for access to some pages, a per-page charge (by which the information providers [IPs] can re-coup their costs). British Telecom (BT—the now privatized telephone company, split off from the UK postal service) gets revenue from the use of its lines to access the on-line services and also from renting out dedicated data lines. From almost everywhere in the country the access nodes are only a local call away, so the telephone bill element of connection to the services and, through them, to their gateways is minimal.

BT marketed Prestel to education. Free educational pages were offered to encourage curricular use. Paper-based, Prestel-related curriculum materials were sponsored (mathematics through the rail and air timetables; economics through the stock exchange prices; geography through the travel pages and Foreign Office health and visa information; language arts through writing to the viewdata format on Prestel simulators, and so forth). There was a reduced subscription rate for schools and a periodical news sheet to school subscribers passing on creative ideas to increase the usefulness of the service to schools (and the revenues to BT). However, schools were wary of the blank check they were signing when they took out a subscription (especially when the students were given free access). Students quickly learned two popular games: (1) change the password and lock out the teachers, and/or (2) see who can find the most expensive page.

The Gold route was taken up by the Times Newspaper when it launched the Times Network for Schools (TTNS). TTNS used Gold's e-mail format but gave it a more friendly, index-based front end. It had its own keyword-searchable, free-text databases and allowed local authorities to develop their own systems for their schools. It, too, had news sheets to communicate ideas and to encourage collaborative learning and it, too, went to the kind of organizations that were IPs on Prestel for support to schools. (This, in the early days, resulted in quite a few bad, downloadable, inappropriate worksheets being put on the system by well-meaning but misguided businesses.)

Although BT benefited from TTNS activity, it soon became aware that a marriage of the rival educational services was necessary. "Campus 2000" was born in January 1989 to provide an integrated service. The merger of TTNS and Prestel provided a service that was truly more than the sum of its parts. It enabled the kind of support that neither service by itself could command and led to the single-minded pursuit of connectivity with the rest of Europe and the world, with each national service giving added value to its subscribers with every connection.

Schools, according to size and required service, pay an annual fee from £359 (about $650 U.S.) for the largest school on Campus Plus service down to £134 (about $241 U.S.) for the smallest school on the basic Campus service. This entitles schools to limitless use of the service to which they have subscribed, for the additional cost only of the local calls to their access node (which schools typically access at 1200/1200 baud, though the system will support faster baud rates). Subscribers to the basic Campus service have access to all the "educational" pages (broadly defined) of Prestel and about one-third of the databases on TTNS. Those paying for the higher Campus Plus subscription have access to the full service of Prestel and TTNS. Both Campus and Campus Plus subscriptions allow access to Campus Premium services for which there is an extra charge, dependent on usage time. The most expensive premium services can cost 60 pence (about $1 U.S.) per minute of connect time plus the cost of the local telephone call to the access node. These services are protected by password and it would be difficult for a school to run up a bill on a premium service "by mistake."

The roles of UK government departments and the organizations that they fund must be mentioned. The United Kingdom's Department of Trade and Industry, originally responsible for half the computer bill for every school in the country, went on to supply a free modem to every secondary school (numbering approximately 5000) and to a large number of the 25,000 primary and middle schools as well. The Department provided funds to local education authorities to help offset the cost of bringing separate telephone lines into schools for modem use. It also funded the establishment of a National Educational Resources Information Service (NERIS) available through Campus, which was originally free while it was building its database, and now is offered as a "premium" (pay-gated) service with unlimited use, for £120 (about $216 U.S.) per year. (It is also available separately on-line and off-line as a CD-ROM, revised three times a year. Between issues one can perform the original search on the CD-ROM and then, with the same search parameters in place, go briefly on-line for any updates that may have been made since the CD-ROM was published.) NERIS is a fully searchable database of educational resources, now linked also to National Curriculum attainment targets, indexed by subject area, format, price, and availability, and including ready-to-use resources downloadable directly from the system.

The Department of Education and Science (DES) is the disseminator of the UK government's educational policy, but not a major funder; this is the responsibility of the local education authorities. The DES places its press releases and publication lists on the system as searchable databases and was originally responsible for the setting up of the Educational Counselling and Credit Transfer Information Service (ECCTIS), a database of some 60,000 Further and Higher Education award-bearing courses throughout the United Kingdom. ECCTIS is now a premium service, and is also available on CD-ROM. However, the DES's prime role has been to provide advice and support, mainly through the bodies it funds, like the Microelectronics Education Support Unit (MESU) of the National Council for Educational Technology (NCET).

For example, MESU/NCET ran a research program, funded by the DES and the British Library, on the uses that schools would make of access to large commercial databases. This resulted in Campus offering a subset of "Dialog" information services (85 databases) to schools as a premium service at an attractive negotiated rate. "Profile," an on-line database, also proved popular and a rate for a slightly modified version was negotiated as a Campus premium service. In the Profile version now available, schools have access, via keyword searching, to the complete text of articles from leading UK periodicals and newspapers over the previous three years.

MESU/NCET also set up a "Communications Collaborative Project" to run throughout the United Kingdom in 1989–1990, again using Campus. This encouraged collaborative learning among schools across the curriculum, across local educational authority boundaries, and across international boundaries, and saw telecomputing pass beyond the electronic pen-pals stage. The project coordinator, Ros Keep, scattered ideas and enthusiasm (and a little money) around the country and wrote a timely newsletter, keeping the various sub-projects updated on each other's doings and giving valuable case studies to those not yet taking part. A group of primary schools in the east of England undertook collaborative story-writing with a professional author "in residence" on the network. Another project involved schools along major rivers that each monitored their bit of the river and then compared results (and in the process located polluters!). Modern Language departments paired with classrooms in Germany and France. Schools in and around London linked with schools in and around New York City and in and around Sydney, Australia, making useful comparisons of urban life, views, size/age differences, prejudices, and so forth. Children of Berkshire talked Spanish to children in the Bronx. The link between Sheffield and Florida to examine differences in teaching about the Revolutionary War/American War of Independence was unsuccessful due to technical problems. Links were made with Russia and Sweden, and with Portugal and Luxembourg. Some even linked with the school across town!

Many in-person visits resulted. E-mail collaboration is still developing further, although NCET funding and coordination have since stopped.

The "Chatback" project, supported by NCET and IBM, linked special needs children through e-mail, in which children were, among other things, asked to quiz their grandmothers (typically) about what it was like in the "old days." Then, with whatever help necessary and with work prepared at their own pace off-line, the children shared their findings. Their audience had no prejudices about them; many experienced the joy of success for the first time in their lives.

The European Community New Information Technologies in Schools (NITS) program has also gotten into the act, for example, by linking Catholic students in Northern Ireland with Flemish-speaking Belgians and Northern Ireland Protestants with French-speaking Belgians.

Campus now has available approximately 200 specialist databases, of which one-quarter are available through the ordinary Campus subscription and the rest available without premium through a Campus Plus subscription. A Special Educational Needs database, the National Environmental database, and a general Primary database are among the services available on the basic Campus subscription. Dynamic databases on vacancies in university and polytechnics, careers data, and specialist secondary school information services are typically among those available only on the Campus Plus service. There is linked activity with Sky Television from the Astra satellite (which has a footprint that covers the European Community) brought in through the Times Newspaper link which formally involves over 1000 schools. "Campus World," which is published annually, studies curricular activities and services, and produces editions of "Campus Forum," which gives news of the rapidly developing scene. A yearly "Newspaper Day" competition is held among schools (with categories for primary, secondary and international subscribers), in which a participating school becomes a newspaper office for the day, taking the news from Campus, from television, from radio, from Reuters, and from other sources, including local interviews. By the end of the school day, schools have to put their newspaper "to bed" and out "onto the streets." The winners, nowadays incredibly sophisticated and professional, are recognized at a highly publicized prize presentation. For once, education is good news!

Because BT owns Dialcom and Tymnet, with access nodes all over the world, Campus has been able to make comparatively easy links with the telephone companies, which use these systems or other compatible systems. So there are easy links and local call connect charges only between the United Kingdom and Australia, Belgium, Denmark, Germany, Holland, Hong Kong (one can get Hong Kong and Australian weather forecasts as part of the Campus Plus service!), Ireland, Japan, New Zealand, and other countries. Recently, over 100 German schools were brought directly onto Campus, with prospects of the German equivalent of Profile being available to bilingual British and German students, so they can compare and contrast the handling of the same news story in different newspapers in both countries.

France has a different and rather incompatible system to most of the rest of Europe. Links between French and British schools have, until quite recently, encountered a great deal of technical difficulty and the expense of providing one of the linking schools with an account on the other's national system. There is also the expense and difficulty of long-distance telephone calls and international operators. However, a trial program began recently where a software patch allows 36 French and 36 English schools to fully access one another's system simply by typing "CAMPUS" from a Teletel (the French system) account or "TELETEL" from a Campus account. The problems of French accents are solved. The technicalities are overcome. There remain only details concerning who will pay what to whom for what services. When these are settled, the French and British users will be fully connected. As with so much that has resulted from telecomputing, the "entente" seems to be becoming extremely "cordiale"!

John Foster is the Director of the Science Center at TERC. He came to the US in 1991 from the United Kingdom, where he was the Director of the UK Department of Education & Science's program to introduce computers across the K-12 curriculum. In his role as Director of the Microelectronics Education Support Unit and later as the Deputy Chief Executive of the National Council for Educational Technology, Foster worked extensively across Europe within the European Commission's "New Information Technologies in Schools" program.

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INTRODUCING TELECOMPUTING TO SOVIET SCHOOLS

by Boris Berenfeld

Introduction

When I wrote this paper for the Consortium for Educational Telecomputing Conference in April 1991, it was entitled "International Telecomputing in Soviet Schools." In February, 1992, as the conference papers were about to be published, the Soviet Union no longer existed. So I was asked by my editor if I wanted to rename the paper. I decided the term "Soviet" still has meaning.

For the foreseeable future, students, teachers, and educational authorities in the former USSR will remain "Soviets," a time-honored term that encompasses the values, views, and fears accrued by the average citizen over seventy years of Communist rule. Whereas "American" refers generally to the nation of origin, the term "Soviet," as used within the USSR, did not imply a nationality but a way of behavior under a dominating ideology, an all-embracing loyalty, and sometimes a xenophobia inflamed by military hysteria. Much of the society has yet to shed this mentality.

I have begun with this political observation because the implementation of international telecomputing confronts not only technological and financial problems, but in the case of the former USSR, political and psychological obstacles as well. In this paper, I will describe some of the problems that American and Soviet educators tackled when introducing telecomputing to Soviet schools.

Opening the Telecommunication Gates

> Hurrah! Today we have a great holiday! Our Apple IIGS is switched on at our school. Now we can communicate with the whole world without leaving the classroom. Write to us as soon as possible. We are waiting for letters from all of you. Yours, the team of school 1173, Moscow.

With these words, excited students of School 1173 in Moscow were linked through the wonder of telecomputing to the global community. This school and some thirty others in Moscow, St. Petersburg, Kiev, and more remote sites enjoyed free access to schools around the world, a feat accomplished by five years of intensive efforts by persistent scientists and educators.

Lest we underestimate the significance of this achievement, imagine not long ago equipping a Soviet class with a modem for conversations with unknown peers in distant lands. In the pre-Gorbachev days, all international contacts were strictly controlled by the state, and Soviet citizens faced seven to eight years of prison for "collecting and disseminating information that could 'compromise' the political system." Such laws were used to punish dissidents, even when the data they circulated were proven to be accurate. Prestigious scholars and researchers, let alone mere students and educators, were routinely denied access to the world beyond Soviet borders.

The Soviet scientific community, particularly Eugeney Velikhov, Vice-President of the Academy of Sciences and a top Gorbachev advisor in defense science, first recognized the pressing need for international telecommunications. After widely promoting both scientific and telecommunication education, Velikhov was instrumental in supporting the first open, satellite-based, telecommunications link between the US and the USSR—the San Francisco/Moscow Teleport (SFMT) sponsored by Henry Dakin of the Washington Research Institute. Despite rumors that during the first year it had a KGB officer on its staff, the line had about 200 subscribers, mostly large Soviet organizations like the Ministry of Culture and the Moscow offices of Western companies. Though Dakin's intentions were idealistic, the Russian and American partners finally established a joint venture to make the line more commercial. Yet in 1986-87, possessing an e-mail address to send and receive messages still appeared incredible and perhaps not very safe.

Concurrently, Velikhov launched the experimental School Project within the Academy of Sciences that in some ways resembled America's educational projects of the 1960s in response to Sputnik. He invited young, enthusiastic computer scientists, engineers, programmers, linguists, biologists, etc. to establish a model for future education based on emerging new technologies such as computers. Among the very first goals for the School Project was establishing a telecommunications capability. Velikhov initiated the first Soviet/American educational telecommunications project, VELHAM, which was sponsored by the Carnegie Foundation. This long-term project focused not so much on the linking together of a large number of schools but on studying the impact of such a telecommunications grid. Sasha Belyaeva from the Institute of Psychology of the Soviet Academy of Sciences and Michael Cole from the University of California-San Diego were the project coordinators whose energy and enthusiasm were indispensable.

In 1987, another big telecommunications project, Kids' E-mail, was initiated to link via e-mail twelve Moscow schools with twelve New York State schools. This project is supported by the Peter Copen Family Foundation of New York State and Soviet educational authorities, and today is successfully co-directed by Peter Copen and Alexander Uvarov. The origins of this project illustrate the contradictions and confusion of the period.

Alexei Semenov, a professor of mathematics and Velikhov's deputy for the School Project, was part of the official delegation of the Soviet Peace Committee that was to fly to the U.S. to discuss new opportunities for Soviet-American cooperation. He was included in the delegation even though he had not been summoned by the Party for the traditional instructions given to any citizen venturing to the West. On the night before he was to leave the country, I recall walking with him through the streets of Moscow, ruminating on how the times seemed to be changing—only two years earlier, Alexei was not allowed to go to Czechoslovakia because he was considered insufficiently loyal. We discussed the urgency of international telecommunications and thought that it now appeared possible. Next morning at the airport, the delegation was issued its passports. Everyone got his but Alexei. Even in the climate of perestroika, someone within the party apparatus had decided to deny him foreign travel. The delegation flew to New York, leaving Alexei standing on the tarmac with his suitcases...

But times really had changed. With support from Velikhov and close associates of Edward Schevradnadze, then Foreign Minister, Alexei was soon given his passport and he joined the delegation within a few days. His presence proved critical. He ended up leading the working group that discussed the communications issues, and there he met Peter Copen. Together they began to negotiate what would become Kids' E-mail.

Momentum was developing. At this time, Monica Bradsher of the National Geographic Society (NGS) and Sylvia Weir from TERC visited Moscow and recognized the enthusiasm of the scientists and educators unified around the School Project. American educators introduced their new colleagues to the National Geographic Kids Network and the TERC Star Schools Project, both recently developed by TERC. Impressed by how telecommunications could enhance science curricula in schools rather than just serve as a medium for pen pal messages, my colleagues from the School Project and I offered to pilot these promising educational endeavors within the Soviet Union. Despite skepticism by many Soviet teachers and principals, the first two Soviet teams (one from Moscow School #57 and one from the Children's Zodiac Club) joined the NGS Kids Network project by 1989, and soon six other Soviet schools—four in Moscow, one in St. Petersburg, and one in Kiev—piloted TERC's Star Schools Project.

The excitement on both sides of the former Iron Curtain was palpable. When the American students first saw the new icon representing the Soviet schools on their screens and then read the electronic messages, their enthusiasm could not be contained within simple e-mail replies or data exchanges. They promptly mailed about a thousand envelopes with personal notes, class photographs, life-style descriptions, and even invitations for dates! In the Soviet schools, which for so long had been isolated from the Western world, one letter was a cause for rejoicing, ten became a party, but no one knew what to do with this friendly flood.

Achieving open dialogue with the West was hardly only a technical challenge; it required a great struggle with top-ranked Communist officials about "direct communication." They assured participants that Soviet students could communicate, but *almost* direct because of the need for a short delay. The intent of the delay was clear: surveillance. However, spearheaded by the courageous efforts of Velikhov, and with the technical and moral support from our friends and colleagues at MIT, the National Geographic Society, TERC, University of California– Irvine, and other Western institutions, we amazingly won uncensored communications for Soviet schools. Truly, it was a turning point in the introduction of the Soviet educational community to telecomputing.

First steps

Initially, our educational goal was modest. We at the School Project and what would later be the Institute for New Technologies (INT) sought to prove not only to students but also to teachers and industry that educational telecommunications was possible within the Soviet system. Educators in particular were skeptical that the many hurdles could be overcome. Consequently, INT used different strategies to promote telecommunications in Soviet schools.

Our first strategy was fairly direct; we offered computers to schools provided that they were used for telecommunications. This approach worked particularly well with schools without computers. However, once INT instructed students and teachers on sending and receiving messages, telecommunications ceased after the first few "hello" messages. We found that students simply needed time to learn the fundamentals of computing such as word processing. Within some schools, groups of dedicated students capable of advanced computer usage would soon emerge. They wanted to telecommunicate, so this seeding worked, albeit in a rather unexpected way. More importantly, when presented with the opportunity to use computers as communication devices, they quickly pushed the limits. For example, Grigory Vodopyan, an inspiring teacher in St. Petersburg School 239, told me that his students explored new gateways, and they proudly informed him of newly discovered ways to access different international networks.

Messages to the Soviet schools from the West helped break different stereotypes that students had acquired from adults and the Soviet mass media. For example, many students believed that when interacting with foreigners, they should be formal and guarded. What they received from the West demonstrated just the opposite:

> Yo! Yo! Yo! What's up y'all
>
> How's it hanging in the Union of the Soviet Socialist Republics!
>
> My name is Robert. I'm an Afro-american and I am very proud of my ethnic background. I am a senior at Mitchell High School. I'm an actor and enjoy the performing arts. I have already been in one movie, one commercial, twelve plays and three fashion shows. Hope one day I will become well acknowledged in the field of performing arts. Who knows, maybe you'll see me on television. I also like to travel. But I don't think the Soviet Union will be on my list of places to go, not to be rude, but there are not many Afro-americans in the U.S.S.R.! I would become very homesick and would long to go home. Correct me if I am wrong! Well, I gotta end this letter so see-ya!
>
> Just me,
>
> Robert

Those Soviet students who were cynical of the domestic peace movement and did not believe in possible military confrontations encountered messages such as the following:

Hello

My name is Manolo. I am 16 years old and I live in Colorado Springs. I have brown hair and brown eyes. My hobbies are skateboarding, listening to music, and doing nothing else. My dad is in the army so I do a lot of traveling around the world. When I grow up I might join the military because I'm used to the military life. I just hope not to get into a war with you guys. I hope to receive a letter from you so I could get to know you people better.

Manolo

Sprinkled liberally throughout the messages were good intentions.

Hello:

I am Liza. I am a senior. I really don't have much to say, because I just got here to Colorado from the Philippines. I like this country, it has a lot of mountains. If you like to see mountains, you will love this place. I hope someday I will visit your country and also I hope you can visit the United States. There's a lot of things to do around here. Are there a lot of things to do in your place too? What kind? I hope you don't mind if I ask you a question. Oh well, I have nothing more to say. GOD BLESS YOU ALL, STUDENTS OF RUSSIA.

In spite of the excitement of such messages, the e-mail exchange was not an easy task. While obtaining phone lines is difficult in Western countries, it is much worse for Soviet students: long waits for phone lines, access to one or two telephones per school, one in the principal's office and one in a teacher's room. You can picture the scene when one telephone must be shared by thirty teachers, their friends, and relatives. Dedicated lines are a luxury. At School 57, students and their geography teacher Alyosha Bochiver put an Apple IIGS on a cart and moved it to the principal's office; there it was safe and "dedicated," although the principal had to tolerate a daily influx of students. Add to this hours of trying to log-in to the host computer because the phone lines are busy, noise in the line that may overwhelm the error correction software, and of course, the fact that Soviet students are communicating in foreign languages. Now you can understand the "excitement" of establishing a telecomputing link within Soviet schools.

The language problems deserve special mention. There was no "Russified" software, nor software based on internationally agreed-upon icons or commands. The professional jargon found in computer manuals was almost untranslatable; for example, Soviet teachers had no idea what strange words like "boot/reboot," and "upload/download" meant. In addition, the majority of Soviet teachers have yet to be exposed to computers, and though teachers of computer science have a curriculum, it does not ordinarily include telecommunications. As a result, the teachers and students were forced to learn computing and telecomputing mechanically, without any real understanding of the processes involved. This automatic learning tended to increase their reluctance because they could not correct their mistakes. For example, one interface instructs the user to enter "<return>.<return>" to terminate a message. Students tended to overlook the period and failed to understand its function.

That is why we were not surprised that the simple hook of "let's have a nice pen pal abroad" did not sufficiently motivate secondary school students to telecommunicate on an ongoing basis. For elementary school students, however, a pen pal abroad was exciting. Interestingly, those elementary school students who participated in NGS Kids Network were cautious about expressing their developing identities and capabilities, such as their ability to write or care for pets. Very often, they preferred to send mail with badly handwritten notes and photographs of themselves with their pets, which was much more interesting than e-mail. On the other hand, older students were motivated by challenging projects and the opportunity to belong to an international team.

Supporting Schools

It became apparent that to guide and supervise student telecommunications projects, we needed enthusiastic people versed in both telecommunications and education, a rare combination within the Soviet Union as you can well imagine. Consequently, we were fortunate to locate a group of qualified people (Deema Badeyev, Olga Galkina, Alyona Mygonova and their colleagues) who formed the core of the INT telecommunication support team. To date, the four-person INT team has achieved several successes:

Set up a local telecommunications hub

The equipment, a powerful 386 IBM clone and modems, was provided through TERC by the John D. and Catherine T. MacArthur Foundation. This hub supports the Schools' Uniting Network (SUN), a bulletin board system that enables e-mail, teleconferencing, and the data files exchanges. All schools receive free access to this machine, as well as additional financial support. To serve as more than an electronic post office, INT devotes a second computer to research and development, thus attracting some of the brightest scientists and programmers.

Improved the users' interface

We have had a variety of participants on the network (students, teachers, scientists with little experience on computers), different kinds of computers (PC-clones, Apple IIGS), and accordingly, different software. Consequently, our programmers were concerned with providing users with networking software that met various requirements.

- The single most important criterion was that the network must be easy to understand and use;
- It needed to exchange both text and binary files, as well as reliably support data exchange protocols over a wide variety of telecommunication software;

- It must have full capabilities for both private messages and public discussions;
- It must enable users to search freely for files.

SUN features a menu-oriented structure. Commands in each menu are grouped in semantic order. For example, commands are divided into the following columns in the Main Menu:

C)hange Setup	U)ser List/Search	G)oodbye (logoff)
F)iles MENU	M)essage MENU	T)ime Statistics
S)can Your Mail	A)sk Sysop	cO)nferences

Identified and equipped schools

We searched for schools that wanted to do international scientific projects. We were not offering communications with the West so much as an interesting science project that relied on telecomputing.

Participation by the Soviet schools in the TERC Star School Project was supported by TERC through a grant from the MacArthur Foundation; equipment and instructional materials for the National Geographic Kids Network project were collected by John Waitelely, Lory Warmingron, and Monica Bradsher from different sources, including contributions from California schools and private sources.

When we started, we were pleased if a school had one reliable Western computer, regardless of type, and a modem with error correction. Two or three years later, our necessary condition became a computer and modem situated every day in the teacher's classroom. Unfortunately, we do not see this often enough.

Our ideal telecommunications classroom would include a computer and a modem, a portable to allow teachers access at home, and a liquid crystal display with an overhead projector, which are still rare in Soviet schools. I can imagine students projecting their messages on a large screen, accessible to the entire class for true collaborative work. Just as they complete their work for the magical "message sent," they become imbued with a greater sense of participation on a global team.

Providing ongoing support

INT team members are available if teachers need help. Their support includes a written telecommunications guide, translating telecommunications software and teleconferences, and developing and conducting workshops both at INT and on-site in different cities. For the workshops, we ask each teacher to invite one student "hacker," knowing that hackers bring to school telecommunications their informal, sometimes underground, community. This releases the natural curiosity and inclination of interested students to begin their own explorations. Students often refine their focus from computer games to exploring the telecommunication gateways to new countries.

Recruited scientists

INT located scientists willing to work with students and teachers on the network. The conversion of the military to a peacetime economy has afforded us a once-in-a lifetime access to high-caliber scientists. Members of the Observatory of Moscow State University, to which INT gave a modem and IBM clone computer, and the Chair of Astrophysics of Moscow State University participate in the TERC Global Laboratory project, which promotes student investigations in global climate change and other environmental issues. INT has provided a special work station where scientists can send and receive data.

From E-Mail to Teleconferencing

E-mail capability was a necessary first step. Next was teleconferences and bulletin boards, which enjoy clear advantages for science education. The idea of using electronic bulletin boards to support collaborative student research was initiated by the TERC Global Laboratory project, and over the last year, some twelve Russian schools have participated.

Clear advantages of the teleconferencing model became apparent quickly. Teleconferencing projects encourage data sharing. Each student can send one message to a large number of people, as well monitor all communication within the conference. TERC proposed a working group model for Global Lab. In such a model, all participating schools receive curriculum materials and sometimes the necessary tools, and are offered a choice of research tasks, such as monitoring the tropospheric ozone, studying plants as bio-indicators of air pollution, or weather monitoring. Interested schools sign up for a particular project, becoming part of the working group, similar to the operation of an international scientific lab. For each working group, TERC opened and supported a separate bulletin board on the EcoNet network. For example, *gl.ozone* is the teleconference for the working group that is studying the scientific problems concerned with ozone. Such a telecommunications platform created an environment for very interesting educational changes and motivated students to participate in projects.

Teleconferences by their nature are in the public domain, and every participating student has a right to the entire bulletin board and its messages. It follows in the scientific tradition begun in the 17th and 18th Centuries when scientists broke from their isolation to communicate publicly their findings with each other in scientific journals.

Current Projects

TERC Global Lab Project. As mentioned above, the electronic bulletin board is the telecommunications backbone that, in our experience, motivates students' collaborative research and creates conditions for educational changes. The project is ongoing, and while it is premature to assess its impact, we have definitely observed spurred creativity and enthusiasm. Soviet students have proposed a large number of projects to their counterparts in distant lands. -Influenced by Global Lab, advanced schools have initiated their own science projects, such as the extension of the Math Olympiad Project, into the international community.

Remote Rural Sites. A current project of great interest to us is the linking of selected communities within Russia that are as rural and isolated as any within Third World developing nations. Some of these cities enjoy good schools and teachers, but all are severely handicapped by poor transportation and communication infrastructures. Telephone service is inadequate if existent at all, and roads are poor and nearly untraversable during the fall and spring.

This year with the help of the Uniterra Foundation, we will explore the possibilities of connecting these rural schools with the rest of the world by using INT's host machine in Moscow as a hub for a communications grid. To my knowledge, no one within Russia has experience running educational telecommunications supported by low-orbiting satellites and/or amateur radio operators. I can foresee a number of bureaucratic, technological, and engineering problems for such transmissions.

Two sites we particularly want to target are the so-called "academic city," Puschino-na-Oke, a small scientific town located 80 miles from Moscow on the beautiful Oke River where Tolstoy was raised, and nearby Gremyachee. What distinguishes the former from other rural cities is a very good infrastructure that was designed to support ongoing military research institutions. Yet communications remains poor, primarily because limited links facilitated surveillance by central authorities. There is both a need and desire by these communities to establish communications beyond their poor phone and mail services, and both could serve as prototypes for an expanded satellite communications network.

East-West Network for Education. Recently TERC and INT originated a teleconference that is both the electronic bulletin board on the IGC: PeaceNet and an Internet mailing list. The idea of such a conference emerged from a resolution signed by representatives of 26 nations at an East/West educational summit in Prague during the ill-fated Soviet coup attempt in 1991. We hope that this teleconference will serve as a forum for East-West collaborations, particularly on new technologies like telecommunications.

As a result of these early efforts, we proved to ourselves and Soviet society that educational telecomputing was not only possible, but a powerful opportunity for preparing students for the world to come. For those schools that participated in our projects, uncensored communications have become an ordinary experience. We now have schools in large urban centers such as Moscow, St. Petersburg, Kiev, as well as in rural areas such as a village around Tula, and we are expanding our geographical reach. Recently, we included schools in Berdyansk, a small city on the Azov Sea—in total, about twenty actively participating schools. Unfortunately, some still do not have their own modems, and must bring messages to off-site host machines. As of this writing, our schools do not yet have access to the most innovative features of telecommunications, such as data base transmission, electronic publishing, and remote log-in. Yet, I still maintain hope. I received from Moscow School 57 the following message:

> Today, February 24, 1992, with the help of God, Sasha Shen,[1] and Demos,[2] we became connect to InterNet. The school address is
>
> Postmaster @Sch57.msk,su,, my - smend@Sch57.msk.su,
>
> Sergey Mendelevich, Principal

Boris Berenfeld, who pioneered telecomputing in science education in Soviet schools, is Director of International Programs at the Institute of New Technologies and Senior Scientist at TERC.

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1 Sasha Shen, one of the most talented Soviet mathematicians, has committed himself to working with gifted students at School 57.

2 Demos is a private enterprise established by scientists from the Institute of Nuclear Energy in Moscow. About a year ago, they provided the first InterNet link to the Soviet Union.