Telecomputing as a Progressive Force in Education

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ABSTRACT

Educational telecomputing,[1], provides unique access to information, ideas, and collaboration for teachers that can help counter the isolation of classrooms and schools. It is an economical way to communicate globally and therefore offers new opportunities for the world's children to understand one another better.

Telecomputing is currently in its infancy and does not have broad application to education. The software needs to be made more powerful, easier to use, and designed to minimize telecommunications costs. Alice is a software package under development at TERC that achieves these goals.

An important priority is linking to regions and countries without adequate telephone lines. Low altitude satellites and packet radio represent potential technologies to accomplish this that should be carefully investigated.

In addition, educational applications using telecomputing need to be developed to explore its potential. Some particularly interesting applications including the Network Science idea, electronic publishing, Logo Express, and international challenges.

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[1] "Telecomputing" is a made-up word, meaning "computer-based communication". We urge educators to use it in distiction to "telecommunications" which is too broad, and includes television, radio, and telephone.

THE KIDS NETWORK

> Better learning will not come from finding better ways for the teacher to instruct but from giving the learner better opportunities to construct. (Papert, 1991)

Network Science

In April 1988 more than twenty thousand scientists throughout the world joined in an unprecedented effort to explore the acid rain problem, sharing the results of their investigation with scientists at the Acid Deposition Study at National Oceanic and Atmospheric Administration, the organization in the U.S. responsible for monitoring acid rain. In October of that year, the same scientists again shared data, this time about weather phenomena. The next spring, they began collecting data on the lead (Pb^{++}) content of water in the nation's public schools, relaying their findings to the U.S. Environmental Protection Agency. While the topics being studied were not out of the ordinary, the "scientists" were. They were all elementary school children.

These student-scientists were fourth-, fifth-, and sixth-grade students who participated in curriculum field tests for the four-year TERC Kidnet project funded by the U.S. National Science Foundation. Published as the NGS Kids Network® by the National Geographic Society in Washington, DC, this upper elementary curriculum is an exciting series of cooperative science experiments in which students use telecomputing to send results of their local experiments to a central computer which pools their data and then sends back the combined results. Classes analyze trends and patterns in the combined data, examining how their findings contribute to the overall picture. And students discuss their questions and observations with their colleagues, and with practicing scientists, using the network.

The project had three guiding principles:

- Students can explore real and engaging scientific problems that have an important social context,
- Students can and should do the work of scientists, and
- Telecommunications is an important vehicle for showing students that science is a cooperative venture in which they can participate.

The original grant was concluded with the completion of seven units. Five units, *Hello!*, *Weather in Action*, *Water Quality*, *Acid Rain*, and *What's in Our Water*, have been published by NGS, with more than 10,000 classrooms participating to date. Two more units, *Solar Energy* and *What Are We Eating*, are scheduled for publication and will be released in the next year. The NSF is now providing TERC with additional funding to develop nine additional units for the middle grades which will be released by National Geographic between 1993 and 1995.

The components of each unit include: a Teacher‘s Guide, with background information, lesson plans for core activities and extensions, and a software manual; the Kids Handbook, a richly illustrated discussion of the unit concepts; two disks containing the software; and lab materials, which include science equipment, maps and activity sheets.

The software was designed for the Apple IIGS and is now being adapted with IBM funding to run under Linkway and MS DOS. A Macintosh version will also be available soon. The software was recognized as one of the nine best educational packages of 1990 by Electronic Learning magazine, with a second award as one of the best follow-up packages in 1991.

To make the software easily used by all teachers, a highly graphical, point-and-click user interface was developed, and the telecommunications were made fully automatic, from dialing to uploading and downloading of data and letters. To keep telecommunications costs down, text editing, data entry, and data analysis are done off-line.

The software consists of a text editor, a data entry and graphing utility, and a simple mapping utility, all integrated with the telecommunications facility. This integrated software package lets students write letters, enter data, share data, and display data as tables, maps, bar charts, line graphs, and pie diagrams. The map analysis tool permits students to analyze data in map form, with the ability to zoom and scroll into a more detailed level, or zoom out to a regional, continental, or global scale. This map display was found to be a particularly effective data analysis aid for students who had difficulty working with data presented via the more traditional table and graphing formats.

The impact of the project has been profound; well over 250,000 students have already been involved. The project has spawned more than 500 articles in the media. Corporations have contributed equipment and funds for testing and training. International attention has led to the involvement of sites in other countries.

The prototype units and software were formatively evaluated in over 200 classes, with more than 5,000 children participating in the various units. The key results from this field research include:

- The vast majority of teachers, 93-98%, reported that they would use the units again.
- The vast majority of teachers (97% for *Acid Rain*, 89% for *Hello!*, 87% for *Weather*) reported that the units significantly increased students’ interest in science.
- Most teachers using the NGS Kids Network® spent almost twice the amount of time on science (2 to 3 hours) than normal (1.5 hours).

- Interdisciplinary science instruction increased at most of the sites: Letters to the research teams were written in language arts or computer periods, findings were charted and graphed during math, and follow-up measures to solve the problem (e.g., acid rain, lead in drinking water) were discussed during social studies.
- An unanticipated result reported by teachers was that learning disabled students were particularly engaged by the curriculum. The opportunities for multi-modal, rather than purely text-based, learning promoted students' successful participation and, for many, enhanced their self-esteem. As one parent of a learning disabled boy wrote: "I truly believe that his attitudes toward learning and himself have greatly improved due to the Kids Network....Mark now knows that he is not stupid... and that he can become a scientist."

NGS Kids Network® has been widely acclaimed. NGS surveyed 500 early purchasers of the published *Hello!* unit. It was rated "good" by 31% of users, and "excellent" by 64%. As one Illinois teacher has remarked: "I believe this to be the most worthwhile program that I have had the privilege to participate in in 17 years of public education."

The latest praise comes from an independent evaluation by the North Central Regional Educational Laboratory of a project to introduce the material to 49 teachers in 26 Iowa schools funded by the Roy J. Carver Charitable Trust:

> The National Geographic Society states that seven elements of Kids Network make the network "special" (Teacher's Guide). They are investigation, collaboration, geography, computer skills, interdisciplinary approach, cooperative learning, and critical thinking. The findings of this evaluation confirm this assertion and the overall success of the program. …
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> The major strengths of the Kids Network program are:
> 1. Students learn about science as a result of participating in the program, particularly about specific scientific concepts and procedures.
> 2. Students develop global awareness as a result of participating in the program.
> 3. Teachers and students learn to use and value technology as an instructional tool. (Fein, et al, 1991, pp 4-5)

The Kids Network is the first example of Network Science, a style of learning based on students undertaking collaborative research which is facilitated by telecomputing. The idea that kids are measuring something for others and that the results matter, transforms the classroom. Students become committed, careful, articulate, and surprisingly intense. Along the way they learn large amounts of mathematics, science, technology, experimental procedures, geography, and communication skills in a way that will probably last a lifetime. This is the way interdisciplinary learning should take place.

Many teachers participating in Network Science projects report that they did not know their students were so capable in science. We often hear that the units transform teachers' approach to teaching science, as the teacher who reported: "I'll never use a textbook again" (in Fine, et al, 1991).

TELECOMPUTING AND PROJECTS

Telecomputing sounds attractive, perhaps too attractive for its own good. We all want to foster better international understanding, we know collaboration is good, we see telecomputing as providing a stimulus to reading and writing. The question becomes, what is the best use of this technology? Can we learn how to utilize this technology now, before it is ready for broad use in education?

Too often, what schools do is to use telecomputing for unfocused student conversations or "pen-pals". Invariably, pen-pal projects start with great enthusiasm and end after a few relatively meaningless exchanges. Clearly, pen-pal projects alone offer little to education, although the initial enthusiasm it generates needs to be exploited in other educational applications.

At TERC, we have become deeply committed to telecomputing because it provides essential support for a **project-oriented approach** to learning. As Phil Morrison, a leader in elementary education said almost 30 years ago:

> ...I am speaking for ... a laboratory involvement which may be painfully slow, which "doesn't get anywhere." You don't "cover the material," but you spend a good many hours of the week doing [projects]... It is not impossible that [the students] could find something that nobody else knows (Morrison, 1963).

Using telecomputing, students can, indeed, learn something that nobody else knows while pursuing stimulating and motivating projects. Our projects tend to involve ecology because ecological projects are important to students, the science they involve is relatively accessible, and ecological variables students measure fit the geographical coverage telecomputing gives.

There are good theoretical reasons for the importance of the project-oriented approach. The constructivist view of learning holds that the way we learn anything, including mathematics and science, is by actively integrating observations and experiences into one's personal explanatory framework. As Dewey said, learning involves the "continual reorganization, reconstruction and transformation of experience" (Dewey, 1916). The apparently shorter route of simply being told the answer, of passively memorizing facts, figures, equations and problem types may produce measurable gains on shallow tests but is, at best, inefficient in creating understanding (Resnick, 1987). As one student participating the the TERC Star Schools telecomputing project put it:

> Normally 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 [using projects] you understood in your own way. It wasn't like somebody trying something and you just memorizing it. (student quote in Weir, et. al., 1990)

Research at TERC has demonstrated that hands-on, project-based approaches can be accessible to ALL students, countering the common misconception that only gifted or strongly motivated students can learn this way. TERC staffers Warren, Rosebery, and Conant (1989) have shown that project activities are effective with Haitian Creole-speaking language minority students in "basic skills" programs who test several grades below level. The TERC Star Schools project registered some of its best successes among students who were otherwise performing poorly (as the quote above indicates); cooperation, interest in science, leadership and performance improved for all students (Weir, 1991).

While a project-oriented instructional strategy does not require telecomputing, the technology can support it in many ways, making interesting projects easily implemented and feasible in a broad range of classrooms. In support of student projects, telecomputing can:

- Provide student collaborators worldwide.
- Enable gathering and distributing data in a timely manner between many sites.
- Give assess to databases of data and research in support of projects
- Be the medium for student discussion and publication of project results.
- Be a medium for the development and publication of project-based curriculum materials.
- Provide easy access to scientists and others to assist student projects.
- Support teacher enhancement activities.

Of course, telecomputing has the ability to support a range important educational improvements that is broader than simply student projects, from servicing of school equipment orders to electronic constitutional conventions, but I see that its most significant contribution to education will be to support original student discovery.

Telecomputing: Next Steps

The Kids Network project has proven to be very important, because it is provides a case study of educational telecomputing that works. It reliably gets students and kids excited about learning in a constructivist style and it provides a glimpse of the promise we feel telecomputing offers. As such, it has inspired renewed interest in telecomputing and generated may copies, which I encourage.

But additional work is needed:

- Less expensive, less North American, projects like the Kids Network are needed.
- Network activities that leave more of the project invention and design to students are needed.
- More research is needed on educational networks and the effect of their use on students and teachers.
- Better software is desperately needed to simplify telecomputing and hold its costs down.
- International organization around telecomputing is needed to coordinate and decentralize work.

Two projects currently underway at TERC begin to address some of these needs: the Global Laboratory and the development of Alice software.

Studying the World: The Global Laboratory

The Global Laboratory project is an ambitious effort to engage secondary-level students in original projects that result in publishable research. The goal of discovering something original and important provides the motivation and logic for the intended student learning. Students have to adopt a critical attitude, to make careful measurements, to design shrewed experiments, to generate reports, and to review their peers' reports for the same reasons scientists do–to make a scientifically acceptable contribution to our understanding of the world. In the process, students gain a unique working knowledge of the nature and conduct of science.

It may sound incredible that students could discover something original, so let me illustrate these generalities with some examples from the network:

> **Basic snow.** Last year there was some interest in measuring the pH of rain and snow in Eastern Europe. Students in Moscow expecting acid readings were amazed to find some snow that was basic. Acid snow is a well-recognized problem, but no one had ever reported basic snow! After much investigation they located a cement factory that was the cause.
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> **Nitrates in food.** There is currently great interest on the Global Lab network in the level of nitrates in fruits and vegetables. Although relatively harmless, extremely high levels due to over-fertilization are known to cause sickness. Schools in Germany, Moscow, and the have been testing their food and the U.S. school recently discovered abnormally high levels in hydroponically-grown (that is, grown without soil with the roots in fertilized water) lettuce. If confirmed this could be very significant.

Mt. Pinatubo. The Mt. Pinatubo volcano has created a world-wide ash cloud which is not well characterized. One observer in Texas has measured a 9.9% reduction in sunlight reaching the ground, so we are now gearing up to have students all over the world begin measuring sunlight to try to determine the location and density of this cloud.

While we want to incorporate research into the classroom for educational reasons, its value to research might generate funding and interest that would help sustain it. I dream of a world-wide network of schools which could have great potential to contribute to science research because they could offer:

A variety of accurate measurements. With computers and lab interfaces it is possible for schools to carry out reliable analyses using easily obtained materials, kits, and automated instrumentation.

An abundance of human resources. Schools have a large pool of researchers to draw from–teachers and students–and these researchers are well-dispersed. The use of these human resources could significantly expand and reduce the cost of field research.

Long-term studies. Continuing participation of teachers makes it possible to carry out long-term studies, in which each year's students contribute to ongoing efforts and build upon previous work.

Local focus. Local research can help to fill in the gaps in more broad-based monitoring efforts; where there is some overlap, results can be compared for consistency.

The ability of schools to contribute significant research results could attract research funding that would help supply the instrumentation and teacher support needed in such a network.

The promulgation of student research in schools is a difficult and challenging task. However, telecomputing and instrumentation technologies now promise to make the task feasible, when coupled with well-conceived educational and teacher support strategies. The major components of our strategy for this in the Global Lab project are to:

Focus on global ecology. We have defined global ecology as ecological issues with global incidence or impact with a special emphasis on climate change. As defined, global ecology research is vitally important, accessible to students, very interesting, and full of unsolved scientific questions.

Establish school research stations. To enable students to participate in global ecology research, they need the ability to undertake similar measurements and observations. We are developing an inexpensive Global Lab Research Station which will be a collection of technologies together with associated curriculum material and an experimental plot students will use as a point of departure for their measurements.

Develop shared experiments. We are developing a suite of observations and experiments in global ecology that use the research stations and can be easily implemented. The experiments are critical because they introduce students to important content, techniques, and the scientific approach.

Foster the development of student research skills. We assume students have little idea about practical research skills, and that everything from keeping records to conceptualizing an experiment needs to be learned through the process of attempting to undertake meaningful research.

Create a student research community. A community of student researchers with shared interests, techniques, and capabilities is an essential strategy, which mirrors professional research communities. Knit together through telecomputing and other shared experiences, this community may be able to become independent of funding, generate its own questions, and publish its own results.

We have encouraged international sites to pair with university centers where a staff person can provide local support and is more likely to be able to attend meetings where we can meet and make personal connections. This has been particularly successful in Argentina, Italy, Russia, Poland, and Estonia where we have strong local leadership and several participating schools at each center. This idea is turning out to be useful within the U.S., too, where sub-networks are increasingly important.

The development and application of new instrumentation, experimental apparatus, modelling, and international telecommunications will give high school students the tools and access to resources to enable them to understand global ecology and to contribute meaningfully to research in this area. The resulting material will represent a much-needed, powerful, and easily-implemented alternative to existing text-based instruction.

Alice

Over the next few years, billions of dollars will be invested in a world-wide telecomputing infrastructure widely thought to be as important for long-term economic development as cars and highways. The justification for this infrastructure will be economic, but it could be a boon to education, too. However, that impact will be slight unless the cost to the educational user is greatly reduced and the value greatly enhanced.

Cost and user software shortcomings currently inhibit the implementation of telecomputing. The poor user interface of just about all of the available networks, whether “free” or commercial, means that only the most technologically literate teachers will (or should) brave even the relatively benign combination of general-purpose communications software and the better commercial services.

Thus, software that can simplify access, reduce costs to education, and promote the development of new educational materials and services is a necessary part of the infrastructure required before we can realize the educational promise the wiring of the world.

We see the need of a telecommunications software package, which we have named Alice, designed to meet the needs outlined above. Alice is an essential *prerequisite* to the widespread use of telecomputing in education and its support of constructivist learning. It is not software for just one network or project, but rather a system design which will provide a common, powerful platform for many educational networks. The proposed technology will transform telecomputing into a far more flexible medium that will 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.

In designing Alice to meet the telecomputing needs of the educational community, six design requirements were identified which are necessary and sufficient for telecomputing to realize its potential in education. These are:

- Good user interface. All functions must be intuitive and easy to use.
- Beyond text. Graphics and data must be easily shared on the network.
- Support of commercial services. Packaged educational services must be available.
- Networks services. Mail, structured bulletin boards, and database access is needed.
- Interconnection. Educational users should be able to reach each other through the Internet.
- Low cost. Telecommunications and software costs must be minimized.

For educational telecomputing to become an important force in education, it is essential that each of these requirements be fulfilled. Alice is a major break with present telecommunications software design because it is the first package to meet these goals.

The design of Alice started with the award-winning software we developed for the Kids Network. Like Alice, the Kids Network software consists of a set of applications that work together seamlessly within a telecommunications package. Alice can be thought of as the Kids Network software generalized to fit a broad range of educational needs and different levels of sophistication.

Alice will consist of both user and host software. To keep costs down, the connection between these should be made as seldom and briefly as possible. This means the user should be able to prepare messages and requests off-line and connect only to pass messages, requests, and responses, automatically and as fast as possible.

The requirement that the user be able to work off-line implies that there must be user software that supports each of the types of files used on the network. As a minimum, this requires a text editor, graphics editor, and a data analysis package for each type of computer supported. Thus, Alice user software will be a set of applications supporting multiple file types that will work together with a powerful, automatic telecommunications package. These functions will be fully implemented on Macs and IBMs under Windows, and partially on other IBM compatibles, and on the Apple IIGS.

Alice host software is needed that can provide the required network services for Alice users. A single software package operating under UNIX will be created called an Alice server which can provide all the required network services in a decentralized manner.

Alice has been under development at TERC for some time, funded by various projects, and we now have a very primitive version operating in a Massachusetts telecomputing project. We are currently seeking more funding and hope to have a version available in September, 1992. Our goal is to keep the user software in the public domain so it can be distributed as freeware. We will also design Alice in a modular, open style and publish technical documentation that will permit others to add to it.

I hope that by the time of the next conference, Alice will have become a reality and that many interesting international telecomputing projects will be easily and economically available using it.

THE FLEDGLING COSN ORGANIZATION

We have helped create an organization called the Consortium for School Networking (CoSN) to coordinate efforts in educational telecomputing. CoSN could have a major role in improving education by representing precollege educational telecomputing interests and stimulating the provision of quality telecomputing-based learning at the lowest possible cost to schools. The establishment of CoSN represents a novel development for educational reform. It is a conscious attempt to employ a strategy of pooling interests and resources available to government groups, corporations, and others interested in education to create and share software, curricula, and expertise. It envisions essentially public dissemination mechanisms which could result in substantial savings at the school level.

The primary functions of CoSN could be:

- **Policy Articulation.** Defining and articulating the telecomputing needs of education.

- **Network connections.** Creating local and regional hosts inexpensively interconnected through a variety of networks including the Internet.

- **Curriculum development.** Sharing expertise in creating telecomputing-based curricula and also sharing material and approaches developed.

- **Teacher support.** Developing dissemination and support materials and workshops and sharing the costs of developing and offering these materials.

We see the following benefits to members of the Consortium:

Unlimited access to CoSN software. Collaboratively-developed software could be licensed for unlimited educational use by members.

Pooled curricula. A substantial body of telecomputing-based curricula could be created within the Consortium and made available to members.

Network interconnection. The Consortium members could coordinate the establishment and interconnection of hosts which support CoSN, taking full advantage of existing regional, national and international networks.

Cost sharing and reduction of duplication. Many of the educational telecomputing activities of CoSN members might be duplicated without shared development and dissemination.

A policy platform. The Consortium could be an important group of telecommunications users, providing international leadership that will be particularly important as the National Research and Education Network is being established.

CLOSING REMARK

I invite participants to join the telecomputing adventure; to try out the Kids Network or the Global Laboratory, to help us create CoSN, to undertake your own research and development projects. We feel certain that telecomputing can be a powerful force for educational improvement, but we need to band together to help make it happen.

A Glossary and Guide to Abbreviations

I have attempted to keep jargon out of this paper, but I sometimes slip, so I have gathered together the jargon for the uninitiated:

Alice. Alice, in contrast with the practice of the entire computer industry, is not an abbreviation for anything, it is just a nice name we adopted to refer to the ideas we were generating about how a telecomputing system should work.

APC. Association for Progressive Computing, An international voluntary group of operators of public access computers that have agreed to maintain compatibility and to echo each other's conferences.

asynchronous. As used in telecomputing, refers to one-way communication between one computer and another, possibly separated in time from any response the communication might generate.

CET. The Consortium for Educational Telecomputing, the name of the TERC conference in April, 1991.

conference (electronic). A group of electronic bulletin boards where related messages can be left by members as permitted by the conference generator. Sometimes conferencing has a "live" implication which is not used here.

CoSN. The Consortium for School Networking, a new coordinating and information-sharing group of states and other institutions which grew out of the CET conference

EcoNet. An ecologically-oriented electronic conferencing system operated by IGC.

educational service provider. In the Alice context, any operator of a host computer providing something of education value involving the use of electronic mail, structured bulletin boards, or databases.

host computer. In the Alice context, a computer that provides access for Alice users to the Internet and other host computers. An Alice host also provides local electronic mail, bulletin board, and database functions and can forward requests for such services to other Alice hosts.

IGC. International Global Communications, a non-profit providing general network services for a fee. Operates EcoNet and Peace Net.

INT. Institute for New Technologies, an independent group in Moscow and other Soviet cities which has a major commitment to the application of technology to improved mathematics and science education.

integrated document. In the Alice context, a single document that consists of parts logically connected to different editors. An integrated document can be thought of as a long, scrolling sheet with horizontal divisions which separate the different applications, separating the sheet into text, graphics, data display, and other parts in any order.

Internet. The present collection of computers interconnected through TCP/IP protocols including universities, the NSFnet and the regional networks

KN. The NGS Kids Network.

LAN. A local area network, an interconnected group of personal computers able to share information over high-speed data lines.

network science. A term coined at TERC to refer to telecomputing-based collaborative student projects in mathematics and science such as the NGS Kids Network.

NGS. The National Geographic Society.

NREN. The National Research and Education Network. In this proposal, NREN is used to refer to a proposed, multi-billion dollar internet network. However, the present Internet is sometimes called the “interim NREN”, implying that NREN will grow from the Internet.

server. In the Alice context, used synonymously with “host computer” q.v.

synchronous. As used in telecomputing, refers to the real-time communication between a user and a remote computer.

TCP/IP. One set of protocols which define the logic of electronic message interchange, defining, for instance, how messages are broken down, sent, addressed, identified, reconstructed, and acknowledged. The Internet is based on these TCP/IP protocols.

telecomputing. A term we use to refer to telecommunications between computers, used to distinguish from other forms of telecommunications such as video. Literally, computing at a distance.

TERC. This used to stand for the Technical Education Research Centers, but that proved so cumbersome, we have abandoned the long name in favor of the initials.

UNIX A large body of code, usually written in C, which provides functions of both an operating system and applications. A common operating system that supports TCP/IP protocols.

X.25. The network protocol standard and popular in Europe

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