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Supporting Teachers with Telecommunication: The LabNetwork

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Foreword

Connected by a computer telecommunication network, ninth-graders from eight high schools scattered thousands of miles across Alaska work together, building a robot submarine to gather samples from the floor of Prince William Sound.

In Colorado, a near-failing student, formerly more interested in her suntan than in science, comes up with an ingenious physics project that combines the two: She studies ultraviolet radiation emitted by various types of tanning lamps.

In Virginia, two students, one scientifically inclined and one artistic, together explore the mathematical and aesthetic properties of certain striking computer graphics. Their topic: "Mandelbrot sets"—mathematical constructs that are central to science's new understanding of complex, chaotic systems, from weather to the stock market.

In Arizona, suburban high schoolers design and build model cars to meet strict performance specifications. They use computers to design prototypes, collect and store data, and write reports. To assess the performance of their vehicles, they generate detailed graphs of velocity versus time using a sonic measurement device connected to the computer.

This is high school science as some teachers and educational reformers today envision it: centered on student projects that encourage learning by doing, supported by modern technology, enriched by collaboration among students and teachers—both face to face and far apart. It does not sound like high school science as most of us remember it.

These examples are drawn from LabNet, a 6-year, $4.7 million effort funded by the National Science Foundation (NSF). The project is being conducted by TERC (Technical Education Research Centers), a nonprofit educational organization in Cambridge, Massachusetts, dedicated to improving mathematics and science education. Aimed primarily at high school physics teachers, LabNet has three interrelated goals: (a) encouraging the use of student projects to enhance science learning; (b) building a professional community of practice among high school science teachers; and (c) exploiting the potential of one of today's new communication technologies: connecting teachers via telecommunication.

LabNet challenges teachers to create learning environments in which students can taste the experience and excitement of the working scientist. It challenges students to formulate their own questions, design their own research, and build their own experimental apparatus, guided by their teachers as mentors.

LabNet does not hand teachers a fixed curriculum made by "experts." Instead, the project works with teachers who want to grow in their craft, providing them with support and resources in the form of their own telecommunication network, support from experienced peers, and ongoing technical advice.

But the most important form of support comes from other teachers, members of the community of practice. Believing that educational reform works only when teachers play an active role—thinking about their work, setting the direction, helping each other change—LabNet relies on the community to provide not only support but also leadership. Teachers are partners at every stage, from planning and implementation to evaluation and dissemination. In 1991, the project gave 20 participating teachers grants totaling almost

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$350,000 to share their ideas and experience with others in their school districts or states (a fuller description follows).

The first 3-year phase of LabNet began in January 1989 and ended in mid-1992. During that time, some 562 high school teachers of physics in 37 states, Puerto Rico, and American Samoa, were involved. In August 1992, the second 3-year phase was funded by NSF. Its main objective: Expand the users of the LabNetwork to 1,500 high school teachers of all sciences.

In a follow-up evaluation of phase one, the majority of teachers said they had assigned their students more projects and had used LabNet's telecommunication network to exchange project ideas with other teachers. Most said their students were using computers more, as well as collaborating with one another more frequently and asking more questions that reached beyond standard course content.

Participants also felt more connected to their colleagues and energized in their teaching. Said one: "The greatest benefit of LabNet to me has been the feeling of confidence and a feeling of belonging to the physics teaching community." And another: "The last 2 years have been the fullest years of my teaching career, in part due to the inclusion of projects in the curriculum. I recommend this invigorating experience for everyone." From many students, the response was equally enthusiastic: "Projects have helped me understand science better. In a way, I am figuring out the answers for myself, which gives me a feeling of accomplishment." "Projects are a fun and interesting way to learn. Projects also make you think a whole lot more than if you were to just read words from a book."

This enthusiasm was reflected in a wide array of student projects. High schoolers studied the effects of dimples on the trajectory of a golf ball, and of basketball shoes on jumping ability. They studied the physics of dance and skiing. They used physical principles to construct sculptural mobiles and thermally efficient solar houses. The list goes on.

Of course, because projects—as opposed to traditional labs—are inherently open-ended and uncertain, some "failed," like the ambitious attempt of an Iowa teenager to produce holographic images of objects under a microscope, using a laser, with optical fibers as the transmission medium. But this kind of failure can be dramatic success in learning. For example, the young Iowan went on to study science in college, and by his sophomore year had won a grant from NASA to work on another original project.

The student response is impressive, especially in light of the fact that LabNet does not target the scientific elite. Its teachers touch young men and women at every level of academic achievement, from a kaleidoscope of ethnic groups, from urban, suburban, and rural communities, from poor families as well as the wealthy and middle class.

This is not to say that LabNet has been an unqualified success. Some teachers have been unable to mount many projects or to participate in the telecommunication network because they lack the necessary equipment. Others are smothered with demands on their time. Even among those who have succeeded, many had to convince reluctant administrators, scrounge for space and equipment, and struggle to find time in already overfull schedules.

And because LabNet works against the grain of established science education, it confronts ideological as well as technical and administrative difficulties. Some teachers reject the project approach outright. Said one: "I teach objective, high-level, college-prep physics. I don't want my students to get lost in social interactions or 'activities' that do not prepare for college." Only a small core of teachers seem to have fully embraced the philosophy behind the project approach. This is not surprising, considering that it is a radically different way to teach science. Rather, many seem to have integrated elements of the approach while still sticking to the traditional textbooks, lectures, and teaching of established facts and concepts.

The future of efforts like LabNet is uncertain. As several proponents acknowledge, projects are messy and demanding—often at odds with existing ways of thinking, bureaucratic requirements, and current evaluation methods. And to date, we lack longitudinal data to establish the long-run effectiveness of projects in raising the level of scientific interest and competence of the country's youth. Whether projects will ultimately transform science teaching or become another footnote in the history of educational reforms remains to be seen.

The transformation of science teaching espoused by LabNet is very much a work in progress. Teachers who are newcomers to the project approach—and most of the current LabNet teachers—still struggle with how to incorporate projects into their science teaching. The integration of key players—teachers, scientists, educational researchers, reformers—as collaborators in an educational community of practice, with the goal of improving science education, is a process still in its infancy.

An Introduction to Labnet

It is common currency that science education in the United States is not working well enough. The usual measure is a comparison of test scores with those of the past or those of other industrialized nations. But much more is at stake than test results: We are failing to excite the curiosity of young minds about the great questions of the physical universe. We therefore lose both a healthy supply of future scientists and the scientifically literate public that the times demand.

As mentioned above, three interconnected threads are woven through the fabric of LabNet. The first, and most vivid, is TERC's continuing advocacy of the use of projects to enhance students' science learning. "A physics project is an undertaking in which the student *does something*" (Vermillion, 1991, p. 7). Many teachers have responded positively to this thrust of LabNet, using projects for the first time or expanding the use of projects in their classrooms. The focus on projects arises from TERC's fundamental commitment to learning-centered education. We believe that students must be actively responsible for, and seriously engaged in, learning activities—that doing is the basis for knowing.

TERC's equally basic belief, that teachers are a critical and irreplaceable element in the learning equation, is reflected in LabNet's second thread: building a community of practice among LabNet teachers. Isolation is a fact of life for many high school teachers of science, particularly those working in rural schools. They are often solo practitioners in their schools. Although contact with teachers of other subjects and trips to professional meetings may extend the benefits of affinity, they cannot substitute for daily intercourse with those practicing the same craft. Continuous interchange about common work is the hallmark of a community of practice.

Face-to-face contact is needed to build that community. To foster such encounters, LabNet held annual workshops in its first 2 years and a conference in the third. In the third year, responsibility for advocacy and community building shifted to participants. Competitive grants were awarded to 20 LabNet teachers to allow them to share with their local colleagues both what they had learned and their own visions of science education. Their efforts extended the project to 393 new teachers (included in the total number previously mentioned) and began the process of enlarging the community of practice.

The third thread woven into LabNet—promoting the use of new technologies in science teaching and learning—is intended to support both implementation of projects and development of the community of practice.

The microcomputer is having an increasingly powerful influence on the classroom. This is particularly true in science education, well beyond the simple use of computers for manipulating numbers and writing research reports. A compelling example is the microcomputer-based laboratory (MBL). A MBL is a microcomputer equipped with one of a number of "sensing probes" for collecting the data of various physical phenomena in real time, and special software for recording and displaying the results. The MBL puts a real-time science tool directly in the hands of the learner. Although it can be used for rote labs, it is better employed as a direct arm of real science investigations. It seamlessly ties collection of data and mathematical representations like graphs to the physical phenomena being studied. LabNet made significant use of MBLs to bring substance to the project idea.

But perhaps the most notable use of new technology in the LabNet project is telecommunication: computer-to-computer communication via telephone lines. A dedicated network, the LabNetwork, has been created and made available to all participants—accessible through any school computer equipped with telecommunication software and a 2400-baud modem. The LabNetwork now uses America Online (AOL), a commercial network, as its "host." AOL provides the necessary (and very user-friendly) software free of charge for the most commonly used school computers: the Apple II series, the MS-DOS machines, and the Macintosh.

Most participants have taken advantage of this new medium to exchange project ideas, ask questions, and engage in common activities. As the first national network designed for high school teachers of science, the LabNetwork, through its public forum (an electronic bulletin board where any member can post a message) and private mail system, is a dynamic medium for building and sustaining a community of practice for teachers separated by thousands of miles.

This aspect of the project is particularly suggestive. Telecommunication is in its infancy. Both current hardware and software are imperfect instruments of communication. As the capacity of the medium increases to include easy exchange of graphics and sound as well as text, and ultimately pictures—both still and moving—it can become a formidable force to allow the teaching profession to become continually current and self-renewing. Unlike telephone communication, which is evanescent, or the mails, which lack immediacy, telecommunication is particularly suited to the schooling process. It is fast—but leaves the user choices of the timing of response. It is self-recording—so that the material can be reviewed and easily shared.

The implications of these three inextricably interwoven threads—project-enhanced science learning, a community of teaching practice, and the supporting role of new technology—are what this article briefly explores. The subtext in all of this is teacher change, although not in the usual sense. The dominant mode of educational reform has been curricular. This has been true not only in science, but across the standard subject matters. Experts write new curriculum, teachers are trained or retrained to teach it. More recently, the widespread restructuring movement has paid attention to the role and power of the teacher in the educational enterprise. Unfortunately, the latter effort has been perhaps insufficiently concerned with what students should learn (the ends of education), and how they should learn it (the means).

LabNet attempts to integrate these two approaches—combining respect for the role of the teacher with concern for the substance and process of learning. Teacher-participants are made coadventurers in the process of thinking about, defining, and giving flesh to the project idea. The LabNetwork provides an arena for support and mutual exploration. Thus, the LabNet's story is also a case study of an unusual, perhaps unique, strategy for educational reform.

We have also identified important barriers to reform. The shift from a teaching-centered to a learning-centered educational process is not easy, even though there is a long history of support for this developmental point of view. Without the willing engagement of teachers, and without a growing community infrastructure to maintain and spread the practice, reform does not work. Project science is harder to do than textbook-lecture-labs. Teachers have to give up absolute content authority, spend more time in dialogue and negotiation with their students, seek outside resources, and battle skeptics. That these barriers have been overcome in many cases is testimony to the commitment of individual LabNet teachers and to the power of the project approach.

A Short History of Labnet

In 1989, TERC launched the LabNet project as a technology-supported teacher-enhancement program aimed at high school physics teachers. The proposal to NSF had been informed by TERC's experience in developing MBLs, telecommunication networks for teachers and students, and curriculum units utilizing both MBL and telecommunication.

LabNet aimed to support teachers in implementing project-enhanced learning in their classrooms and in disseminating these concepts to others. As originally conceived, LabNet was to consist of summer workshops for teachers; a telecommunication network designed specifically for them; and the development of "exportable lab" kits—MBL, support materials, and a videotape for use by teachers training other teachers. The workshops and the network, increasingly dedicated to the service of project science, became the dominant features of LabNet.

Phase One, the First Year (1989)

The Workshops. In July and August of 1989, LabNet held two workshops at each of two sites: Tufts University in Medford, Massachusetts, and Dickinson College in Carlisle, Pennsylvania. The workshops extended a collaboration among TERC, Tufts, and Dickinson to develop MBL tools appropriate for use in high school science education. Ninety-nine high school physics and physical science teachers from across the United States attended.

Participants worked with three prototype curriculum units which aimed to help teachers integrate MBL and telecommunication activities into their science curricula. To support the MBL activities, participants were introduced to several activities developed for the TERC Star Schools project[1]—units designed to integrate technology, telecommunication, and project-based teaching. Participants were then asked to develop their own projects, either building upon one of the three LabNet units or following their own interests. By the end of the summer, teachers had compiled over 200 pages of proceedings describing their own project work.

The Beginnings of a Network. At the workshop, teachers were also trained in the use of prototype telecommunication software, which was being developed at that time for the Star Schools project. The new software provided protocols for handling the transfer of nontext files, such as spreadsheets and databases, between Apple II and IBM computers. The Star Schools electronic-mail network was organized into clusters, user groups of 6 to 10 teachers each of whom shared a common interest in a given curriculum unit. Participating teachers could also communicate with others on the network outside of their cluster. User charges were fully subsidized by LabNet project funds.

Evaluating the First Year. The first set of summer workshops was evaluated via site staff reports and participant questionnaires. Teachers and site staff reported that the MBL hardware and software had to be refined much further in order to be useful to the majority of teachers. Also, most teachers anticipated that they would have considerable difficulty integrating the LabNet activities into their existing physics curricula.

[1]The TERC Star Schools project, funded by the U.S. Department of Education, provided math and science education in an environment that combined technology with engaging, hands-on experience. Using microcomputers and a telecommunication network, students in Grades 7-12 engaged in large-scale, cooperative investigations and shared findings with other students and professional scientists across the country.

Phase One, the Second Year (1990)

During the early fall of 1989, we learned from teachers that they were having difficulty gaining access to the hardware needed to run the telecommunication software we had provided. Even after obtaining the requisite hardware, they still often had problems using the software. Furthermore, the network's structure discouraged users who participated in clusters that were not very active.

Our first focus as LabNet's second year began, then, was to make the network more effective as the main avenue of ongoing contact and support among teachers, and between TERC and the teachers. To achieve this objective, the project began a transition to a new network in the winter of 1989-1990: the commercial Delphi network located in Cambridge. The new LabNetwork offered several important additional features for users. It provided an on-line forum, it gave us the capability to develop our own on-line databases, and it required no special access software or computer platform.

The new network was also easier to administer. Because it was located on a commercial network, it could be maintained independently of LabNet grant funding. In addition, a toll-free help line was available to its users, and a self-supporting administration and billing software was already in place. Finally, the cost was competitive with that of other commercial carriers.

The LabNetwork was introduced to a number of LabNet participants who attended the January 1990 American Association of Physics Teachers conference. The Star Schools Network and the LabNetwork were operated in parallel for several months thereafter, and the project initially subsidized the entire cost of the LabNetwork for participant users; eventually costs were shared. Also, a small matching grant program was instituted to help participants acquire the hardware and software they needed in order to get on-line. Teachers could also use the funds to purchase MBL equipment or otherwise support their project work in the classroom.

In preparation for the 1990 summer program, we added two training sites to expand our regional coverage and increase our resources for training additional teachers. The University of Michigan and Northwest Regional Educational Laboratory joined Tufts University and Dickinson College as LabNet workshop sites.

Early in 1990, staff representatives from each site were convened at TERC to plan and design the content of the upcoming workshops. TERC and site physicists identified areas of mainstream physics that both lent themselves to MBL work and were rich with opportunities for further student exploration. Site staff were then enlisted to help develop activities for the summer sessions. Development continued over the months preceding the first workshop, during which time TERC and site staff maintained communication over the LabNetwork. We also used the network to solicit feedback from participants on workshop plans.

An experimental, interactive-videodisc prototype, intended to serve as a resource for teachers implementing project-based science teaching, was also developed for the workshop. The videodisc contained footage of several groups of students working on different projects, step-by-step instructions for setting up several types of MBL and telecommunication equipment, and a discussion among teachers about some of the issues involved in implementing a hands-on approach.

At this time, we also decided to develop a more intensive post-workshop follow-up program for participants. Eight teachers from the previous summer were recruited to serve as Teacher Liaison Consultants (TLCs) for the upcoming workshops. Two TLCs attended each of the four workshops to become acquainted with the participants there and to provide TERC staff with feedback on the progress of the workshop. Over the course of the year, TLCs remained in contact with the participants they had met and continued to provide them with support as requested.

The Workshops. Five LabNet workshops were held in the summer of 1990. The first took place in mid-July at Tufts University and was staffed by TERC and by site-training directors. It provided LabNet staff and site trainers a chance to test and refine the workshop materials. TLCs also attended this workshop and received additional training to prepare them for their roles on site. The remaining workshops were held concurrently at all sites in August. One hundred and eighteen teachers, including TLCs, attended the five workshops. Over half of the participants (64) returned from the first year of the project; the remaining 54 were newly recruited.

The workshops wove together five different types of sessions over the course of 2 weeks. Ten "set experiments," or activity sessions, used MBL or other technology to cover basic physics concepts, including distance, velocity, acceleration, force, impulses, Newton's second law, and heat and temperature. Several of these experiments encouraged users to create their own simple MBL probes; others, designed for teachers who did not have access to MBL equipment, showed teachers how they might improvise instead, developing useful tools with inexpensive materials. Time was set aside for eight "philosophy" sessions in which participants convened in small groups to discuss such issues as the educational value of projects, classroom management issues, the pressure of curriculum requirements, and standardized testing. A number of sessions were spent brainstorming about possible projects, and teachers also worked either on their own or in small groups developing a project of their choice. Telecommunication training sessions rounded out the workshop.

Evaluating the Second Year. The summer sessions were evaluated via reports submitted by site staff and by TLCs at the end of the workshops. It was clear that site staff's investment in the materials, fostered through their involvement in the development process, had been an important factor contributing to the workshops' success. TLCs emphasized the importance of the informal discussions among participants during the workshop, in which teachers exchanged activity ideas, techniques, and success stories. The main criticism was that more time had been allocated for discussing projects than for *doing* projects. For reasons that are not entirely clear, the videodisc prototype went largely unused at all sites.

The formal evaluation of the project was launched in September 1990. LabNet staff visited the classrooms of several local LabNet participants, documenting teachers' thinking and practice in implementing the project-enhanced approach. A quantitative and qualitative analysis of the use of the LabNetwork began. In the fall of 1990, all teachers who had participated in either or both summer workshop sessions, as well as the few teachers who had joined the network as "affiliates"—without attending a workshop—received a questionnaire on their experience with the project thus far. From then on, participants were involved interactively in the project's evaluation. Everyone who had been sent a questionnaire also received a report of the findings and was encouraged to respond with feedback.

Phase One, the Third Year (1991–1992)

Big Idea Grants. For the third year of the project, we were committed to implementing a "high-leverage" model of dissemination in which participants from the first 2 years of the project had the opportunity to run their own workshop sessions locally. Project staff fleshed out a model in which LabNet teachers were invited to apply for grants to run local workshops for their peers. The idea was to develop a process by which teachers might disseminate the LabNet philosophy of project-enhanced science learning. An advisory committee consisting of several site staff from the 1990 workshops, TLCs, and outside consultants was convened in the fall of 1990 to review the model and our implementation plans. Upon the advice of this committee, we streamlined the grant application process, in which LabNet staff would aid relatively inexperienced applicants in developing their proposals. In order to encourage the greatest number of applicants, the process was designed to be unintimidating and to require as little of applicants' time as possible.

The November 1990 letter announcing the grant program asked participant applicants to describe their "Big Ideas" in just a paragraph or two. In conceiving their ideas, applicants were asked to consider such issues as effectiveness, enthusiasm, reality, outreach to disadvantaged populations, availability of local in-kind resources, and personal professional development. We ultimately received 32 responses to this initial announcement. In several grants, a number of participants applied together. Applicants were then asked to submit a preliminary budget and a more detailed description of the project proposed. Again, guidelines were provided to help teachers plan realistically. Those applicants who were not yet on the LabNetwork received assistance in getting on-line. Applicants worked with project staff members who communicated with them regularly, largely via the network.

At this point, well-grounded proposals received preliminary approval, and development continued on the others. After most details had been ironed out, the proposal and budget were attached to a boiler-plate grant agreement provided by LabNet. This draft was reviewed and accepted by the teacher-applicant, and then a final version was drawn up and signed. In all, 20 grants, totaling just under $350,000, reached completion. In each case, the process took anywhere from 6 to 10 months of regular communication and development to complete.

The June Conference: "Communicating About Project Science." In their communications with LabNet staff during the grant development process, teachers clearly had very different understandings of what constituted a project and of how to communicate the project-enhanced learning philosophy to other teachers. To encourage grant recipients to think about these kinds of issues as they launched their own dissemination efforts, LabNet planned a conference for June 1991, the theme of which was "Communicating About Project Science."

Prior to the conference, participants were asked to read two essays on student learning and the project approach. Participants were also asked to bring sample projects with them, including student projects and ideas that they would be using in their own workshops, to share with others and possibly to serve as the focus of group discussions.

In addition, a "draft" 50-minute videotape was created to serve as the focus for a discussion. The footage, largely taken of LabNet teachers and their students in the winter of 1990-1991, was split into three sections: five students doing or describing parts of their projects; the anatomy of a single project activity, which took place in a science class over several class periods; and two teachers discussing and answering questions about some of the issues they faced in implementing projects. This tape was completed in the fall and distributed, with a discussion guide, to all LabNet participants.

Of the 20 grants, 19 were represented at the conference by 29 participants. The conference itself was organized into a series of small group meetings, which came together periodically into a large group to distill the ideas raised in the smaller discussions. Each participant was also assigned to a group that was responsible for a short presentation during the workshop. Issues to be addressed in these presentations included five dimensions of the project-enhanced science learning process: the scientific quality of a project; experiencing and learning from projects; fitting projects into the realities of the classroom; reconciling the project approach and traditional science curriculum; and projects, politics, and the educational community. Guest lecturers and conference staff led daily brown-bag discussions centered around these and related issues.

In the end, both staff and participants felt that the conference effectively helped participants to reflect on the meaning and nature of the project-enhanced approach to science teaching and learning. In communicating these ideas to others through their dissemination programs, these teachers have continued to refine and develop their thinking about such issues.

Evaluating the First Phase of LabNet (Fall 1991)

Although formal evaluation began in the fall of 1990, it became the major focus in the fall of 1991 as project staff attempted to assimilate and communicate what we had learned from LabNet. There were two basic assumptions that informed the design of the evaluation.

First, each teacher works in a unique setting, and every innovation takes on a local life of its own. A new educational practice, such as project science, is inevitably shaped by the teacher who applies it and by the context in which that teacher works. Evaluation must take into account the diverse ways in which innovations are introduced in different classrooms. For this reason, our approach to evaluation strikes a balance between questionnaire data—which generalize across the LabNet project as a whole—and narrative accounts of the experiences of individual teachers, which convey a sense of the rich diversity underlying the generalizations, and also contain concrete examples of teaching practice that readers who teach can adapt to their own local needs.

Second, change is about learning. In our view, change agents need to think of themselves as educators. Education is most effective when "students"—teachers, in this case—are active, responsible collaborators. For this reason, the evaluation process included opportunities for teachers to work closely with project staff at every step, helping to identify and shape what we learned from the LabNet experience. Teachers were involved in the design of most instruments; in most cases, data analysis was carried out together with teachers; and, finally, all of the reports were shared with the teachers and their feedback was sought and incorporated.

At the same time, we experimented with the use of the LabNetwork for evaluation. For example, the assessment of the TLC program was carried out primarily on the network. This enabled the TLCs to share their experiences on the network, to converse about it, and to write the evaluation report as a joint effort with the project's evaluator.

The evaluation drew primarily on six sources of data:

TLC Reports. An assessment of the TLC program was completed at the end of the 1990 academic year based on TLCs' reports of their experiences. As indicated above, the evaluation made intensive use of LabNetwork to gather the data, to conduct a shared sense-making session regarding the data, and to write up the findings.

Spring 1991 Teacher Questionnaire. To follow up the fall 1990 survey, a questionnaire was sent to all participants in the spring of 1991. Results were carefully analyzed by LabNet's evaluator in collaboration with two LabNet participants.

Student Questionnaire. Students of selected participants responded to a questionnaire about their experiences, which was analyzed by the project evaluator and a LabNet participant.

Big Idea Grants Site Visits and Workshop Questionnaire. Three Big Idea Grant sites were visited by the project evaluator in July and August of 1991 and Big Idea workshop participants completed a short questionnaire during the fall.

Case Studies. In November 1990, LabNet's evaluator visited two participants in order to take a closer look at the influence of LabNet on their practice.

Network Analysis. Collection of data on both the extent of use and the content of the LabNetwork continued during 1991.

These evaluation results are reported in detail by Ruopp et al. (1993); here, we provide a sketch of these results. First, we have found that a community of practice can make a difference for teachers by providing them with opportunities to explore with each other new teaching methods and the integration of new technologies into their day-to-day practice. The community of practice was also an effective mechanism for providing teacher-teacher support, through network messages and face-to-face interactions. Telecommunication provided two modes of supportive communication: "shop talk" and "teaching activities" discourse.

Second, we have also learned that a critical factor in the successful formation, sustaining, and growth of the community of practice is teachers taking leadership roles. Our findings also show the slow and evolving developmental process of change required for effective dissemination of new teaching approaches and use of technology. The dissemination and actual use of the technology, we found, was influenced to a large degree by local context, which dictated style, pace of change, and the way technology was used in the classroom. Furthermore, it demonstrated the critical role of teachers in molding innovations in ways that make sense to them, conditioned by their expectations and work practice.

The Second Phase: LabNet2 (1992-1995)

In August 1992, NSF funded LabNet for an additional 3-year period. Here, we briefly consider the major elements of LabNet2.

Expand Project-Enhanced Science Learning (PESL). The TERC staff of LabNet2 is continuing to challenge teachers to create learning environments in which students can taste the experience and excitement of the working scientist.

Expand the network. Over the 3 years we want to increase the LabNetwork membership from 150 to 1,500 science teachers. We are not interested in network building per se, but only in a network that can become a high-leverage instrument for supporting the efforts of the science teaching community of practice to extend PESL. We have switched from Delphi to America Online. There was a need for a network that is easier-to-use; supports MS-DOS, Mac, and Apple II computers; provides file transfer; is less expensive; and is a gateway for Internet e-mail.

Enlist Teacher Moderators (TMs). The new TM role was built collaboratively with the 13 TMs at a workshop in the fall of 1992. We expect that TMs will assist with recruitment, help shape and energize the network, and perhaps build state-level forums.

Engage states. States like Virginia and Texas (and others) are actively pursuing the linking of teachers by telecommunication. We are carefully exploring ways in which the LabNetwork can support and be supported by such state initiatives.

Continue research. A number of important insights came from our research and evaluation activities: about project-enhanced science learning, telecommunication, the Big Idea Grants, and so forth. LabNet2 is continuing these important research activities.

Design Initiatives. We have launched four design initiatives during LabNet2, which, if successful, will be incorporated as regular features of the LabNetwork.

1. Include other high school science teachers. Many LabNet teachers also teach subjects other than physics. We have opened the LabNetwork to teachers of biology, chemistry, etc. who want to explore or extend the project approach.
2. Expand student use of the network. Over the past 3 years, students have used the network in marginal ways. A number of teachers have expressed interest in more opportunities for students to pursue project-related activities via the network. We are shaping this initiative with interested teachers, and have created a separate experimental student forum.
3. Collaborate with informal institutions. Places like the San Francisco Exploratorium and the Philadelphia Franklin Institute are important science education resources. We are investigating ways of including them as real-time collaborators on the network.
4. Incorporate student teachers. A consulting teacher-scientist is working at Tufts University with a small number of student teachers who are destined for science and mathematics teaching careers. We think they can be an asset on the network and also learn from working teachers.

Because expanding the network is the principal thrust of the second phase, we now turn to a more detailed look at some key network issues.

Networks for Teachers

Telecommunication for teacher enhancement, such as that being explored in the LabNet project, is unique among so-called "new educational technologies" in that it affects what happens in the classroom indirectly. That is, unlike various audio-visual aids that have been added to the classroom, and unlike language laboratories for the study of foreign languages, this particular kind of telecommunication is for the teachers first and foremost. In this sense, it is comparable to membership in a professional society, rather than to some piece of educational equipment.

This characteristic—the focus first on the teacher as the agent of change in the classroom—dictates many of LabNet's ideas about the shape and functionality of a telecommunication network for a community of discourse about science learning. In fact, we believe that this community includes other members beyond science teachers themselves; but if the technology does not serve the teachers, its value is lost.

Until now, networks for educational use have fallen into three general categories. Each of them has points of value, but none yet fully satisfies the need for a medium to support the creation of an electronically communicating community of practice—a community that is in the business of real change in the classroom.

The first category is the administrative network, which ranges in size from a local area network of connected computers within a school building, to a countywide or statewide network. (See Bull, Harris, and Cothern [1992] for a description of the Virginia PEN network, a system with a wider range of intended application than usually envisioned for other systems.)

A network is a very efficient tool for administration, and a whole industry has grown up to supply software and other resources for networks whose principal aim is educational management. Although LabNet and similar networks have found telecommunication a natural medium for logistics, we will not discuss this particular use further.

The second category is exemplified by networks like FrEdMail, K-12Net, the Kids Network, PSINet, and many others. These networks are multipurpose, and by design, mix teachers and students. This mixture has stimulated much interesting and enjoyable discussion on the networks and in the literature, although each model has its drawbacks (see Riel & Levin, 1990; Weir, 1992).

The third type of network, focused primarily on teaching and established for the benefit of teachers, to which LabNet belongs, is rarer and has existed as part of experimental projects. Harvard's Educational Technology Center experimental network, Common Ground, is an example of an important precursor to LabNet. Many of the elements that we find valuable to our purposes are found there. The most important is the explicit commitment to an examination of practice, as one basic focus of discussion, and one part of the teachers' "shoptalk." For an analysis of the network and its implications for communications among teachers, see West and McSwiney (1989) and West, Inghilleri, McSwiney, Sayers, and Stroud (1989).

Another fascinating experiment was the development of the Quill network in Alaska, created as a teacher-communication network to support a project on "writing as problem solving." A thorough study of this experiment touches on many aspects of technology and educational innovation, including a careful consideration of the factors affecting teachers' use of a network, and its role in building a community of practice (Bruce & Rubin, 1992).

The Teacher's Dilemma

With the good press that telecommunication gets and with the cheerful reports in the educational literature about the availability and value of technology in the schools, one might think that technical issues are melting away. In fact, however, our experience with large-scale telecommunication projects gives us a very different view of things. For a teacher new to telecommunication, every step has its own pitfalls.

Below is a portrait of a teacher's progress that is not at all uncommon. This composite portrait is closely modeled on actual cases, involving good and intelligent teachers trying to hit a moving target.

> The teacher, Erica, reads about LabNet in The Physics Teacher in April, and decides to sign up for the next year. To get off on the right foot, she attends the summer workshop, and spends some time learning about telecommunication, but most of her attention is focused on other skills that she sees will be really valuable for her classes—learning some new productivity software, some computer-interfacing stuff, some new Science Olympiad ideas. The interchange with colleagues is invigorating, and Erica looks forward to continuing over the network.
>
> Now Erica goes to her administrator, and asks permission to install a phone line that can be used for telecommunication. This seems to be a practical necessity, because all other phones in the building are fully deployed for voice communications. After a little discussion, Erica makes the case that having a line with a modem on it, which she would only be using a very few hours per week, might be of value to the librarian and to other teachers. The administrator can see that this is the wave of the future, and wants to go along, but all appropriations for this kind of thing have been made months ago.
>
> With much ingenuity, the administrator finds the installation money, and touts the addition to the school's repertory, but admonishes the teacher that she must be frugal, that the thing must pay off soon, and that she must seek supplementary funding.
>
> Meanwhile, Erica has been getting equipment together. She has an Apple IIe. What modem will work with it? The librarian, who is looking forward to access to several on-line ser-

vices, has a PC clone—how about a modem for that? Could they share? How about cabling? And where will the modem live?

Erica then seeks advice about software, in her workshop manual and from friends who know about such things. In order to make sense of that, she has to figure out details about baud rates, parities, file-transfer protocols, stop bits, carrier services, and more. It has now been 3 months since the summer workshop where Erica learned to use one public-domain "telecom" package. The telephone company has put on a burst of speed and gotten the line in, and Erica finally seizes half an hour to get on-line, and let people know that she is still alive and interested. After three attempts, the software claims that she has connected, but all she sees is hieroglyphics. She consults the manual, which has no index entry either for hieroglyphics or "What to do if...." Her half-hour is up. She calls the LabNet number, and asks for help. The network person interrogates her, makes a guess at the problem, and tentatively suggests a fix. Erica tries it the next day.

It seems to work—she gets to log on at last! But now what? The system tells her that she has 14 mail messages, and that the forum contains 875 items; the number of the message she last read is 1. All Erica has to do now is (a) learn how to get into Mail, (b) learn how to use Mail, (c) learn how to get out of Mail, and (d) learn how to do the same things with the Forum, so that she can sort through the 800+ messages she has missed. After an hour of work, a conservative estimate is that doing all this will take her another 5 hours at a minimum, and then she might want to learn how to upload and download files—ASCII text? Graphics? Compressed or not?

When will this begin to pay off?

The LabNet project aims at transforming the science classroom, and is committed to the use of telecommunication as a primary means to that end. While keeping the ultimate goal in view, however, we are quite aware of the teacher's painful situation nowadays, as she or he meets successive waves of demands for change and improvement.

The teacher who is supposed to learn a complex piece of software is also, in the current climate of educational ferment, supposed to be learning the uses of other technologies, integrating them with the computer, restructuring the curriculum in concert with the rest of the faculty, and (as we advocate) changing his or her style of instruction to incorporate a more observant, learning-centered, constructivist epistemology. And all this on a shrinking budget.

It must be stressed that this is not just a new, nightmarish visitation upon the teacher. In every decade, some societal crisis has focused attention on the schools, most often on secondary school, after the "output" from the system has been examined by various shiny, analytical instruments. The curriculum in most subjects has gone through many "revolutions" in this century, each reaching a high-water mark, only to recede, leaving a line of wrack behind. As technological developments have taken a directive role in the quotidian (as opposed to the industrial or scientific) world, schools have been expected to incorporate the latest information transfer and management systems (Cuban, 1986; Sarason, 1990).

The teacher's working conditions rarely include adequate time for the acquisition of new technological or other knowledge. In-service training is not well designed for learning and integrating such skills into the teacher's routine—not just classroom preparation, but the teacher's practice overall.

Further, science teachers tend to be isolated from teacher colleagues on the one hand, and from colleagues in their science on the other. Therefore, the community activities that support and stimulate change in practice—shoptalk, advice, and example—are little available.

With these very real and pervasive obstacles as a backdrop, we turn to the LabNetwork from the user's point of view.

Professional Exchange on the LabNetwork

Here we detail teachers' use of the LabNetwork as a medium to support their professional activities. This section does not specifically address LabNet's rural population of teachers. We did not have our universe broken down that way. However, it does give a sense of the kind and pattern of usage that is likely to be more or less applicable to all populations of network users.

To examine teachers' participation on the network, three quantitative and qualitative longitudinal studies were performed: The first network study was from September to late December 1990, the second covered January 1991, and the third was from October 1991 to February 1992. Two basic analyses were performed: The first focused on patterns of network "logins." Login data (user name, date, time of day, time on-line) were automatically gathered and sent each day by Delphi, Inc., the network host. These daily reports were entered in a specially designed program that performed statistical analysis of the data (e.g., to generate the average time on-line per user during a certain period).

Second, qualitative studies of all network messages sent to the Forum were carried out between September 1 and December 26 of 1990 (311 messages or 81 per month) and between December 27, 1990 and January 31, 1991 (98 messages or 87 per month). Forum messages were downloaded and saved on a specially programmed Hypercard stack. The messages were coded by categories, such as content of message, sender and receiver, time period, and links with other messages (threads).

Participation on the Network

Every network relies on continuous use. Users need to stay up to date and frequently check on network activities, and most important, contribute messages. LabNetwork use increased dramatically during the period of the study, from 71 to 123 teachers. Fifty-two new teachers joined as a result of workshops in the summer of 1991. To an extent, two groups of network users formed: LabNet veterans and newcomers. Their patterns of use were different and reflect important trends of network growth.

Throughout the 18 months (September 1990 to February 1992), most LabNet veterans (70%) persistently kept up with the network. Veterans who got on-line in 1990 continued to use the network during the whole period, on average once to twice a week. Among them, there was a small group of more intensive LabNetwork users, some of whom logged on to the network almost daily.

The newcomers joined the network mainly in the beginning of the 1991-1992 school year. During the 4-month study covering the time of their network activities, they averaged one to two calls a month—about half the rate of the veterans' group. The newcomers, it must be realized, joined on their own behalf without any direct assistance from TERC. Being aware of the difficulties in setting up and starting network communication, it can be considered an achievement to have them on-line.

The Forum: LabNetwork's "Piazza." The LabNetwork has been designed for teachers to contribute to the network in any way in which they feel comfortable. There is no "right" approach. For example, a user can simply login to read personal and public messages. Another can limit his or her use to private mail to send and receive messages. A third can both contribute to the public Forum and send/receive personal messages. These options reflect various levels of interest and need, or, perhaps, willingness for public involvement (and exposure).

Of the multiple ways to use the network, public network dialogues via the Forum are most important because they serve as a basis for establishing a broad-based community of science teachers. The Forum is the *public domain* of the network. Metaphorically, it serves as the network's city "piazza"—a place where people gather to talk to each other—where teachers from many states can meet. This is where LabNet teachers with diverse interests can post messages, read and respond to the messages of others, ask questions, receive answers, and provide assistance to fellow teachers.

In January 1991, 25 veteran teachers, representing close to one third of the veteran group of users, contributed at least one message to the Forum. In the final study about 1 year later, the number of teachers contributing messages to the Forum grew to 32. The additional members, perhaps, show a growing sense of the utility of the network.

Newcomers added very few messages to the Forum. Only five of them posted messages on the Forum. The slow growth of participation raises the question of what could help make teachers feel more comfortable in contributing their expertise sooner.

Professional Discourse on the Network

Messages on the Forum reflected the professional interests of teachers at work. During the first period of the qualitative content study, 120 "threads" initiated by LabNet participants over the Forum were analyzed. A thread consists of all the connected messages on a given topic displayed on the Forum. Threads are started when at least one message is posted, with the intention of eliciting responses from other network members. Taken in sum, threads create the texture of the community of practice's professional discourse.

Teachers' professional discourse can be roughly divided between teaching activities and "shoptalk." Network dialogues in the teaching activities category are those directly related to classroom work—for example, a conversation between two teachers whose classes are collaborating on a project. Teachers also spend much time "talking shop"—gathering information about science activities and teaching aids, improving technological expertise, and seeking additional financial and technological resources. Such shoptalk is similar to that of auto mechanics, who ask each other about new places to buy reliable and reasonably priced tools, call another mechanic to discuss engine problems they cannot diagnose, and so on. Examples of shoptalk are common in the sociology-of-knowledge literature. Shoptalk among scientists and the theoretical perspective related to this approach can be found in Latour and Woolgar (1979) and Traweek (1988).

Professional discourse is a unique and important kind of community support. This support is not organized and planned in advance. Rather, it is shared everyday knowledge and expertise offered on call. This kind of support rarely culminates in a big "Aha!", but rather in know-how that is immediately relevant to the business of the day.

Networks are particularly helpful in facilitating shoptalk discussions: The medium lends itself to short, concise, and informative discourse in response to a specific request. Unfortunately, most schools are currently not organized to support such activities throughout the day. Nor do they recognize the importance of such network activities to the professional growth of a teacher.

The Forum offers a place where quick suggestions and opinions can be gotten to a posted question. Below, we present an example of one teaching activity and a few shoptalk messages. The network messages are left as they were posted. The attempt is to preserve the pragmatic, rough—sometimes messy—yet very much to the point, everyday language used in professional network discourse. Its purpose is to get the job done.

Teaching Activities: The Eratosthenes Project. Eratosthenes, a Greek mathematician and astronomer who lived in the third century AD, accurately estimated the circumference of the earth. His method was to determine, at exactly the same time, the angle the sun's rays make with the vertical in two locations different in latitude. For students, such a project is intriguing. Several LabNet teachers provided their students with an experience of this method and its implications, using the network to coordinate the process of data collection and to share their findings.

On August 31, 1990, Mary Nickles, a science teacher from Mercy High School (New York), posted a message on LabNetwork's Forum inquiring about another school "within a 10 degree latitude band, to exchange data for calculating Earth's circumference using Eratosthenes' method." Mary received no replies through the Forum. But a month and a half later, Bruce Keyzer, a physics teacher from Guilford High School (Illinois), again posted a message seeking school partners to perform the Eratosthenes experiment:

```
Eratosthenes Anyone?

I have two students who as part of a project
wish to determine the circumference of the
earth. They would like to find a student or
group of students in a location having a
latitude much different from Rockford,
Illinois.

The cooperating students need only determine
the angle the sun's rays make with the
vertical at local noon and the time of local
noon. We will need the latitude and
longitude of your location. Anyone inter-
ested please respond via e-mail to BKeyzer.
```

Three days later, Tom Bross from Moravian Academy (Pennsylvania), expressed an interest in the experiment. He suggested setting a day to do the experiment and added an idea, "Maybe several locations can agree to do the experiment on the same day?"

There was a problem, however, in having Tom as a partner. Tom's school is located at a latitude too close to create a measurable difference in the sun's angle. Five days following his original message, Bruce responded to Tom's message through the Forum:

```
Tom would be glad to try Eratosthenes. I have
two students whose objective as part of a
larger project is to determine the circum-
ference of the earth. I was hoping to find
someone from a much different latitude and
use the angle difference at local noon to
determine [circumference]. Our latitudes
are nearly alike as we found experimentally
last year. Maybe we could use our local noon
time difference to get the circumference. I
suspect this may be more difficult. Dave
Button wants in too. Lets all set a day after
[Thanksgiving Day] to give it a try. We can
collect data [and] see what can be made of
it. I have some students who would enjoy the
challenge.
```

Bruce refers in his message to Dave Button, a physics teacher from Osbourn Park High School (Virginia), who responded to his earlier message that he was "game too." On the same morning, Harold Lefcourt from Morris Knolls High School (New Jersey) also joined the project. Soon after, Mary Ethel Parrott of Milton Academy (Kentucky) joined as well.

Now there were five teachers whose activities Bruce Keyzer had to coordinate. In his next message, 2 weeks after initiating the joint experiment, Bruce sent a message to coordinate the activities of the participating teachers, setting a date and time for observation, and suggesting that the communication channel be through the private Mail, "[to] avoid cluttering the Forum." He also inquired whether more teachers would like to join. He wrote:

```
Eratosthenes Project Update


Harold Lefcourt, Dave Button, Tom Bross, and
Bruce Keyzer have indicated an interest in
the project. I am suggesting we try to take
```

```
data on Tuesday Dec. 4, 1990. If the weather
does not cooperate on that day try for the
nearest sunny day. We could send results via
MAIL to one participant and carbon copy to
the others. Using MAIL will avoid cluttering
the FORUM. Please let me know if you plan
to measure on Dec. 4. Anyone else inter-
ested? Join us! Just determine the angle the
sun's rays make with the vertical at local
noon and the time of local noon (when shadows
are shortest).
```

Between this message and the actual experiment, four additional teachers joined the project: Curtis Miller (Colorado), Sandra Rhoades (Georgia), Jack Cadigan (Alaska), and Bruce Seiger (Massachusetts). They communicated their interest to Bruce Keyzer through the private mail. The Eratosthenes activity now involved nine teachers.

Bruce Seiger asked for an important clarification: "How will you be determining angle of sun's rays [from the shadow]?" About 30 minutes after Bruce Seiger posted his message, Bruce Keyzer posted a message on the Forum explaining his method for making sure when it is high noon (shortest shadow). He suggested that students measure the shadow made by a vertical object set in a school window every 5 minutes from about a half hour before noon time. When the shadow is the shortest, students should measure the angle: shadow length divided by object height.

On December 4, 1990, as planned, the students performed the experiment. Early the next morning, a disappointed Bruce Seiger posted a message on the Forum:

```
NO SUN for us! Rain rain and more rain with
a chance of snow! We would like to try again
next Tuesday due to our rotating schedule!
Anyone else had success?
```

Other teachers *were* successful. That night, Curt Miller, Tom Bross, and Bruce Keyzer posted their students' data on the Forum. They included the latitude and longitude, the angle of the sun, and Tom added the data showing the shadows' length as measured every 5 minutes. A week later, Dave Button added his students' findings. By now, however, most of the discussions took place on the private Mail. The promised report of Bruce Keyzer's students was posted on the Forum, making it available to those that were following the experiment. This project demonstrates how the network can facilitate science learning through the design of a project, the coordination of data collection, and the sharing of results.

Shoptalk Examples. The shoptalk examples below show the date and time of the messages. These serve as place markers. They also help provide a sense of the pace of network activities and show when teachers find time to work (usually late at night or early in the morning). To understand the potential benefits, one should ask while reading these examples: Where can I receive such information at my workplace? What ways do I currently have to assist me in knowing about resources, and for testing new ideas?

The first example is a teacher seeking information about new curriculum activities:

```
1295 6-DEC 22:19:17 Curriculum Issues
     Subject: PRISMS
     From: GLOCKETT
     To: ALL

Our district would like to adopt an activity-
based science curriculum. We have material
about the FAST program and are exploring it.
I know that there is another program out
there called PRISMS. We can't seem to find
an address or phone number for a represen-
tative of this program. Anyone have that
magic information near at hand? I'd love to
hear from you. I'd also love to hear from
any of you who have experience with these
programs or another activity-based program.
I'm a hopelessly free-style artist, but the
district and some of the other faculty
members feel the need for a little more
structure. I applaud the fact that they have
let go of the idea of a basal text centered
course and would like to help them as much
as I can. Greg

1296 6-DEC 22:41    Curriculum Issues
        RE: PRISMS (Re: Msg 1295)
        From:BKEYZER
        To: GLOCKETT

Greg;

A good place to get info re PRISMS is: Roy
Unruh University of Northern Iowa, Cedar
Falls, IA 50614. I attended four 1 day
workshops on PRISMS. I have the materials
that accompany the program and have dabbled
with some of the activities. The program uses
a learning cycle approach similar to Hewitt.
I tend to agree with the philosophy but find
some of the activities a bit too "corny"—the
program did originate in IA after all! If
I can be of any more help let me know. Bruce

1320 10-DEC 23:16 Curriculum Issues
     RE: PRISMS (Re: Msg 1295)
     From: RELYON
     To: GLOCKETT
```

There is something called the National Diffusion Network. My guess is that each state has a facilitator. The NDN is offering a summer institute for PRISMS at Willamette University in Salem, OR–all expenses paid. This is for folks in the 15 western states. I don't know the dates.

The Washington State office is at the Highline Educational Resources and Administrative Center at 15675 Ambaum Blvd. S.W. Seattle, WA 98166. The phone is 206-433-2453. They also are having an institute in the Mechanical Universe. Hope this is of value.

Dick Lyon, Nooksack, Washington

Next, the subject is software:

1322 10-DEC 23:30 Hardware/Software
RE: LCI (Re: Msg 1280)
From: ERNESTYOUNG
To: DBUTTONOPHS (NR)

Dave, can you send me a copy of the info on importing into a spreadsheet from the LCI (RE MESSAGE 1275 AND 1280)? That's one of those things that I didn't master quite as well as I would have liked last summer. Remember that I have those dreaded IBM's (clones, not the real things) if that makes any difference. Ernest

1316 10-DEC 20:25 Other
Microsoft Works
From: DSONCORNY
To: ALL

Microsoft has a great offer for Works users. For $2.50 they will send a training package containing a workbook and disk on putting a computer to use in the classroom. It normally sells for $20. The offer is good until Dec 31, 1990. Send a check to Microsoft Works Booklet Offer, 21919 20th Avenue SE, Box 3011, Bothell, WA 98041-3011. Indicate you want a 3.5" disk for the MAC or a 5.25" or 3.5" disk for a PC. It is fairly basic but is great for anyone getting started plus it does have some good pointers. For more info call 1-800-227-4679.

David Sonday offers a story about how he used paper clips to get across a lesson about data points:

1889 23-SEP 20:04 Other
From: DSONCORNY
To: ALL

Last year I was surprised at how many groups and individual students arrived at conclusions to their projects with so little data. We looked at regression lines and the number of data points required for a good correlation, but nothing seemed to help. This year, before anyone got started with projects, I used the following activity to illustrate the idea of collecting enough data.

As students walked into class, I greeted each of them with a paper clip. Every question about the clip received a response similar to "everyone needs a paper clip to take physics." After [they sat] through class for most of the period wondering what the clip was all about, I asked them to open the clip and break it by bending back and forth–keeping track of the number of bends to break the clip. I recorded their data on the way out the door.

The next day, I repeated the sequence but would not tell them why we were doing this activity. Their comments were great and soon other teachers began asking me what's with the paper clips. Each evening I plotted their data on a bar graph. Soon they just held out their hand as they came in the room.

The series of graphs showed a gradual shift toward the mean, which was not evident until several hundred clips were broken. Now, when anyone shows me insufficient data I can say, "Remember the paper clips?"

And Adam Edmundson details procedures for a heating degree day project:

1999 31-Oct 15:26 Student Projects
From: AEDMOPA
To: ALL

To all heating degree days participants. Several people have asked about what type of data is to be collected. I will try to answer with the following format:

Step 1. The students are to collect the High and Low temperatures in degrees F on a daily basis.

Step 2. The students then record the average of the High and Low temperatures.

Step 3. The students then subtract their average temperature from the standard temperature value of 65 to arrive at the Heating Degree Days.

Step 4. The students are asked to calculate the total square feet of heated space in their homes. It may include heated basements or attics.

Step 5. The students are asked to determine the monthly cost for heating their home through monthly electrical, natural gas, coal or heating-oil bills.

Step 6. The students are asked to convert their amount of fuel usage to BTUs through conversion factors, which are listed as follows: (1) Electricity, number of kilowatt hours x 11,600 = BTUs consumed; (2) Natural Gas, number of cu.ft. x 1,030 = BTUs consumed; (3) Fuel Oil: number of gal. x 138,690 = BTU's consumed; (4) Coal, number of tons x 24.5 million = BTUs consumed.

Step 7. The students are asked to compile their data to answer the following questions: (1) What is the monthly BTU consumed per square feet of heated space? (2) What is the monthly energy cost per square feet of heated space? (3) What is the monthly BTU per heating degree days value?

I have placed a copy of a student team project on the common workspace for interested parties to download. The name of the file is Heating. I hope the above directions answer some of the questions pertaining to the collection of data and the writing up of the report for e-mail purposes.

Not all exchanges on the network were about specific projects. Sometimes discussion went to underlying issues and at the same time displayed a refreshing candor:

2149 5-JAN 14:52 Curriculum Issues
philosophy
From: BKEYZER
To: ALL

Conceptual vs. traditional.

I would like to start a dialog regarding how to best prepare students for further study of physics. What is better, a course with emphasis on mathematical problem solving, one that emphasizes lab skills and research projects, or one that emphasizes concept development (such as PRISMS or Hewitt's Conceptual Physics)? Should we offer the Sears and Zemansky type of physics to the better math students and Hewitt for the kids who barely manage a C in Algebra 1? Or is a conceptual approach better for ALL students as a first course and leave the mathematical treatment for a second course where the student will get, in Hewitt's words, "computation with understanding!" How do instructors at the college level feel? What about future employers? Is there any research relating to these questions?

I am embarrassed to admit that I have been teaching students about physics for nearly 15 years and, although I feel that I am fairly good at motivating students to learn, I am not sure of what approach will do the students the most good. I am sure many of you on the network have had experience with both approaches. I value and respect your views. Bruce Keyzer

2155 13-JAN 21:37 Curriculum Issues
RE: philosophy (Re: Msg 2152)
From:WEDDING
To: HLEFCOURT

I was pleased to see the question Bruce brought up because I am grappling with it myself. I teach four huge sections of trig-based physics and one AP (B) course. The AP course just gives me the hebee jeebees because [the students] don't understand anything but can number crunch until the world looks level! I get really frustrated with them because they don't seem to care about the concepts anyway. There is hardly any time for labs with the APs and they are such grade junkies that I can sometimes feel my hair turning gray as I stand in front of the class. Their projects were pathetic.

In my trig-based classes, however, I am doing a lot of project-based teaching, lots of thought labs where there is very little given information, and they are having a great time and seem to be learning a lot. They understand the concepts much better and their mathematical abilities are only a bit behind the AP students. Until the past 4 weeks, the classes were neck and neck, but I had to assign heat and gas laws for AP over the holidays in order to get through the materials.

Egad, I've gone on and on....The point I am making is as follows: My trig students have a better time, do a lot more labs, think a bit better and do just about as well as the APs. The APs plow through and can calculate anything but understand almost nothing....I believe in lots of gloriously off-the-wall labs where they have to THINK, problems in class, and as much in the way of concepts as I can get into them through discussion and labs. Kelly

What we see here is a wide array of topics that have one thing in common: They are all about the art and craft of teaching; discourse designed to improve practice in the community. Let's turn now to what we discovered in our study of network activity.

Patterns of Network Discourse

Network discourse often took the form of threads, or, strings of messages dealing with the same topic. In the first qualitative study of Forum messages (September 1 to December 26, 1990), there were 108 threads (about 26 per month). Teachers, not surprisingly, initiated most of the threads (86, or 80%). Project staff initiated 7 (6%), and students, who joined the network in the last month of the analysis (December 1990), initiated 15 (14%).

To begin a thread is to want to share an issue with a wider audience. Nearly half (46%) of the teachers who used the network started at least one thread. However, as might be expected, only a small number of teachers showed a high level of activity in the public domain.

The content of the threads represents the teachers' interests and needs across the school year. Table 1 summarizes the threads shared over the network during the first 3 months of the study, which coincided with the beginning of the school year.

During this period, the focus of interest seems to have tilted toward shoptalk. Although almost one third of the threads dealt with teaching activities (such as individual student projects and classroom activities like the Eratosthenes project), more than half (57%) of the threads dealt with teaching resources, planning curriculum and teaching activities, and technical assistance—i.e., shoptalk related to teaching activities.

Teachers wanted to know about resources available for teaching (25%), to learn about MBL computer interfaces, and about places to acquire lab equipment. They also sought information about various teaching methods and related curriculum (19%). For example, teachers communicated about kinds of physics textbooks, the design of new physics courses, ways to demonstrate new physics concepts, and detailed information about ongoing student projects. Teachers were also concerned with effective implementation of the new electronic tools in their classroom (13%). They wanted to know about ways to access additional state and nationwide educational networks, how to download messages more efficiently, and about appropriate setup of MBL sensors. LabNet administrative messages were 11% of the threads—most often project notices about available grants or free network time.

The second study of the Forum (December 27, 1990 to January 31, 1991) revealed 26 threads (9 continuing threads and 17 new threads). It showed a similar ratio between teaching activities and shoptalk. This is not surprising. Teaching requires teachers to prepare, to learn about new ideas, and to improve their technical expertise. The network effectively fostered shoptalk—a distinct virtue in the support of the teaching craft.

Many of the threads were one message long—reminiscent of a bulletin board format, and also consistent with shoptalk. For example, when a teacher encountered a technical problem, wanted help, and decided to post a query on the network's Forum, another teacher might post a response on the Forum (or answer directly through the network Mail). But when one teacher had responded publicly, others tended not to join in unless they had additional or different information. Responses tended to be quick and concise.

Table 1
Kinds of Threads Initiated on the Network Forum (9/1/90 to 12/26/90)

Kind of Thread	N	%
Teaching activities	34	32
Teaching resources	27	25
Planning curriculum and teaching	21	19
Technical assistance	14	13
LabNet administration	12	11
Total	108	100

The average number of participants in a thread was two, and the average number of messages three. The most common pattern was one initiator and one or two respondents (Table 2). Half of the threads lasted 1 day (Table 3). In fact, there were threads that ended within minutes. For example, in Message 1296 (see above), BKEYZER responds with information about the PRISMS project 22 minutes after GLOCKETT posted his message inquiring about it.

Table 2
Number of Participants in a Thread, and the Number of Messages in a Thread (12/27/90 to 1/31/91)

Participants in thread	%	Messages in thread	%
1	46	1	48
2	30	2	24
3	8	3-5	19
4	8	6-10	7
5-15	5	11-15	2
16+	3		
	100%		100%

Table 3
Time Period of Thread - (12/27/90 to 1/31/91)

Day	%
1	51
2	9
3-10	19
11-30	9
31-59	6
61+	6
	100%

The time period was longer, and the number of participants and of messages were higher, in threads dealing with teaching activities. For example, in the Eratosthenes project, the participating teachers exchanged 14 messages over a 28-day period.

A similar pattern took place during the Descent of a Ball National Contest, which was initiated over the network. In the contest, teams of students had to design a paper-and-tape structure that slowed the descent of a ping-pong or golf ball. There were three cycles to the competition. In the first month, five teachers joined the competition, carried it out, and shared their results. They then started a second round of competition involving an additional six teachers. And, 2 weeks later, a third cycle of competition was carried out by another group of three teachers, who used the first-round teachers as experts to provide them with the necessary guidelines for the project. Other projects, such as moon-watching and meteor-shower observations, exhibited the same kind of cycle.

Patterns of Community Participation: Conclusions

LabNet has proven useful in connecting teachers to one another as a community of practitioners. It provides ways for teachers to support one another as they experiment with new ways of teaching, and it provides pathways for some teachers to emerge as leaders, disseminating new educational ideas to others. More specifically:

LabNet's support system strengthens connections among teachers in the community of practice. Through the use of telecommunication and summer workshops, most participants have become active members, to varying degrees, of a community of practice of science teachers. This community is able to provide teachers with diverse kinds of support, from solving technical problems to information about curricular issues and scientific content. It also enables teachers to make use of a wide range of learning opportunities.

Most of the teachers utilize the LabNetwork to support their teaching. The LabNetwork serves as an effective carrier of teaching activities, shoptalk about teaching, and collaborative research.

The community of practice creates opportunities for teachers to take leadership roles. Teachers have taken active roles in the community of practice in multiple ways—some through involvement on the network, others in creating changes in their classes, and still others through assistance to other teachers. In most cases, the leadership role has been experienced as personal growth and has produced a greater commitment to the community of practice.

Perhaps the most general and important suggestion we have to make, based on these conclusions, is to adopt a collaborative approach in which teachers function as both change agents and equals—as opposed to a top-down approach in which teachers are passive recipients of other people's ideas. And to equip teachers with tools like telecommunication that can effectively support collaborative activities.

Elements like telecommunication were built into LabNet because of one fundamental assumption: A supportive community of practice can help to sustain the slow, stepwise process that eventually leads to a fundamental transformation in teaching philosophy and practice (Shahaf Gal returns to this theme in his commentary later in this volume). We believe that our findings to date, although far from conclusive, tend to confirm our basic assumption and offer hopeful signs that a genuine transformation is under way among a small but growing group of LabNet teachers.

The LabNetwork has been used effectively by teachers to give and receive technical advice, encouragement, and project ideas. Suitably modified, telecommunication should play a valuable role in future reform efforts. What is more, for many network users, the process of reflecting on their own practice in order to help other teachers seems to have crystallized their thinking and increased their commitment to project-enhanced science learning—a "bootstrap effect" of profound importance for educational change.

Perhaps the most compelling testimony of this process is to be found in the teacher essays that follow. We invited five teachers from rural areas, or who work with rural teachers or students, to write of their experiences with telecommunication. We start with success stories from two rural places in Oregon—Elmira and Sheridan—as told by Geriann Walker and Tom Thompson. Then Sandra Rhoades discusses a failure in rural Georgia, and Jack Cadigan reports on distance learning in Alaska. Finally, Norm Anderson sets forth his experience in Iowa.

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