Chapter 1: Introduction

We cannot speak comprehensively about our education and life, what we do, and how we learn, in the United States without reference to the impact of recent advances in computer technologies. Computer networking technologies provide the most vivid examples of real and hopeful changes in the way we work and learn. Connecting the tools we use to materialize our thinking transforms the practices and processes integral to the production of thought itself. As such, the study of the development of networking technologies and their subsequent deployment in education deserves a central position in the study of technology in society.

This is a case study about the work of teachers and researchers in the production of a set of computer network technologies intended for educational use. The focus is on the social processes related to the development of the technology, the production by university researchers and schoolteachers of the technology, and the impact and deployment of the technology in local school classrooms. The case is the Learning in Networked Communities (LiNC) project directed by The Center for Human-Computer Interaction (CHCI) at Virginia Tech, the grant supporting it, and its dissemination and execution in Montgomery County Public School classrooms in southwest Virginia.

As a researcher of social processes, I do not pretend to be able to describe this project as a simple and singular process. This study by no means is the final word or the only story to be told of the process, and this account does not in any way attempt to capture the full extent of the implications of the process. Rather, it is *an* account of the processes, one told by me. Moreover, it is not the only and the most comprehensive account I could tell about the processes. It is situated among a variety of circumstances and constraints. Other accounts of the development of this technology have failed to describe the social and political context that surrounded the development.

It began as a dissertation for a program at the same university supporting the project that is the subject of the study, for a particular audience that is my dissertation committee, and over a particular span of time. As such, it reflects the same incomplete and provisional characteristics typically expected of any such account.

That being said, I have attempted to provide an account that respects the participants' voices and my own understandings of the events in the contexts in which they occurred. I have probably misrepresented people, places, and events, but where possible, I have tried to engage those people represented in order to gain feedback and correct my errors related to their views. The stance I took shaped the account I provided.

The account could be otherwise. My account is partial in that I have chosen which events to describe. That choice involved judgments about which events were deemed important or unimportant. This requires reasoning on my part about how events were causally related, what qualified as appropriately descriptive, and even what should be censored. My account is temporary in that it would be different had I written it years earlier or later.

The present state of things determined what in the account was important and of interest. While I was in a somewhat vulnerable position with regard to the telling of the account, I occupied a particularly good vantage point from which to provide a relatively comprehensive and contextual account of the technology development processes. I shared work experiences and professional background experiences with many of the participants, especially the teachers and the investigators involved in the project. While I cannot claim to be objective since I did have interest in the processes, outcomes, and my own employment, I did not have a vital interest in the project since I came to be part of it in the later stages. I was somewhat aware of the project early in its life when I was asked about my interest in getting involved in related research and development as a teacher.

Because of my goals and affiliations, the account I provided occupies a moral position. I have made an effort to respect the wishes of the participants of the study before, during, and *after* the descriptions were written. This position is reflected in the account given. My understanding of my social relationship with the participants, be they employer, colleague, collaborator, or research subject, influenced the way that I conveyed and the meanings of events, names, and aspects of the study. That does not mean that the account is erroneous, corrupt, or illegitimate. Dates of events, technical descriptions, and the beliefs and behaviors of people are all, in principle, verifiable by other accounts, documents, and evidence. While my account is fallible, it is not fabricated. Nevertheless, it does reflect biases that affected this particular telling of the account.

Background

Science education researchers and national science education standards, especially in the 1980s and 1990s, advocated "new ways" of collaborating with respect to approaches to teaching and learning (NRC, 1996). This interest spawned a number of efforts aimed at encouraging collaborative learning and teaching in schools. Recently educators became especially interested in collaborative and cooperative learning strategies (Slavin, 1987; Johnson and Johnson 1991), and teachers faced pressure from National Standards and administration to collaborate with each other.

Internet technologies were lauded for their potential to bring distant teachers and students together (Stencel 1995, Johnson and Johnson 1996), and recent advances in capabilities allowed for the development of usable "collaborative technologies," computers, software, and networks that allowed people at distant sites to work together. In addition to the focus on collaboration in the learning processes of students, researchers were beginning to ask how teachers could collaborate better. Technologies assisted teacher collaboration in a variety of ways including support for the sharing of resources, team teaching, or even development of a common conceptual language.

The National Science Foundation (NSF) funded grant titled Leveraging Networks for Collaborative Education in the Blacksburg Electronic Village, which came to be known as Learning in Networked Communities (LiNC) project (Carroll, Burton, Rosson, and Shaffer; see also Koenemann, Carroll, Shaffer, Rosson, and Abrams 1999) exemplified the development of theoretical and practical justifications for science teaching reforms involving computer technology and collaboration. In this project researchers, developers, and teachers created and implemented a computer tool that allows middle and high school science students at different locations to collaborate.

The project developed Java based software tools for networked computers. The tools, known as the Virtual School, consisted of user side applications and a networked server. The system allowed users to create and store collaborative work and coordinates group activity in classrooms at dispersed schools connected to the Internet. Students and teachers in several Montgomery County Public School (MCPS) science classes in southwest Virginia used the Virtual School to collaborate on science projects or activities.

Purpose of the Study

The purpose of the study was to provide a retrospective view of an extensive, long-term project funded by a large grant. The view was from my perspective as a researcher involved in the project and as one having had experience working very similar (and even the same) professional positions as the participant teachers. The hope is that the research presented here will be useful to future researchers intending to study, develop, and implement technologies for schools, specifically in the course of a long-term study that intends to engage teachers, developers, and researchers in design and development of collaborative computer technology.

To this end, I situated the LiNC project in the larger social, political, and technical context that shaped the social and technical infrastructure associated with the LiNC project. The boundaries of the project were fuzzy. The context involved an era and events that extended well beyond the few classrooms involved, the offices of developers, and the years authorized for the execution of the grant and the project. My focus, of course, was on the events and things that I took to be most illustrative of the unique contribution this project made, and on that subset that I am at liberty to disclose. This focus significantly limited the available material to a rather small set, that is, what I knew, what I deemed valuable to the account, what I was given consent to use, and what I had the space to tell about the project.

Methods: Case Study and Action Research

I had particular interests in changing outcomes related to the study, and I had a particular political relation to participants in the study. Thus, there was some tension between my interests in providing some details about my understanding of the events and my political position vis-à-vis my role as employee, researcher, colleague, collaborator, and friend.

I interacted with teachers and researchers in their work over a relatively long period of time. My prior professional experience as a teacher in the same district and subject areas (and in some of the same classrooms) as the teachers, and my own view of the research processes as a researcher obligated me to a certain extent to explicitly and purposefully intervene in their work, and as such, the present work is most appropriately labeled “action research.”

Participant observation represents one important type of fieldwork, and I was a participant in the project that I described here. While I did fieldwork, study of work, and especially participant observation, there were many occasions where I sought by action and intention to change the outcomes. I took an active role in engaging teachers and researchers involved in the study. I along with others had an interest in, for example, insuring that the teachers were successful in implementing the computer technology in their classrooms; however, during the observation of student activities, I made an effort to remain in the background of the classroom. While I did help students with technical problems and questions, and on occasion with content, I tried to avoid intervening in the teaching and management of the classroom. This was because I wanted to avoid radically changing the classroom dynamics and authority of the teacher. I realized that my mere presence changed student and teacher behavior, and on some occasions my intentional interventions also significantly changed student behaviors. Moreover, the research team including myself did not make concerted efforts to *avoid* intervention into the teachers' behaviors. Rather, we made concerted and sustained efforts to change the teachers' behaviors and shape the outcomes attributable to the LiNC project and the present study. This explicit stance placed the present study in the realm of action research.

Action research refers to a variety of related methodologies or investigative stances that seek both change and research simultaneously. Rather than attempting, as much as possible, detached and objective understanding and description of a research situation, action researchers intentionally and explicitly seek to improve the situation being studied. These situations often revolve around the work of the participants, and the research often revolves around problems and questions defined and generated by the participants. Because teaching work can be particularly idiosyncratic and socially motivated, action research has been applied extensively to research involving teaching (Bennett 1994, May 1993, Cochran-Smith and Lytle 1992, McKay 1992). Action research has also been applied to studying and changing teachers' views of, among other things, collaborative work and STS education (Pedretti and Hodson 1995). Action research commonly involves an iterative process of planning, taking action, observing, reflecting, and then revising the plan, taking action again, and so on (see Kemmis and McTaggart 1990). Schön (1983, 1987) provided important models for understanding reflective teaching practices. These models recognized the need to integrate knowledge and practice or knowing and doing as they relate to teaching. My approach to action research was not as formal or rigid as many other approaches. Rather, I tried to take advantage of emergent and casual opportunities to engage teachers and other researchers in dialogue about technology, teaching, and STS, and I tried to better understand their practices and views in relation to my own appreciation of STS understandings of teaching, technology development, and their intersection and union.

To this end, I made consistent attempts to engage the teachers as investigators in the study. This was done formally as part of the LiNC project research through the use of online discussion forums, meetings, discussions, and contextual inquiry described below, and it was done informally through casual and general conversation, interactions, email, telephone, negotiations, and other exchanges. Informal processes added highly significant value to my observations. The daily dialog with colleagues, chatting with teachers after class and school, my routine work as a member of the project, and my interactions with the groups in the formulation of project goals, methods, and outcomes conveyed the most crucial information about the social processes of the LiNC project.

My role as a researcher in the project also entailed political tensions in my interactions with participants in the project. As a researcher, I was not a teacher. I had been a teacher, but once I became a member of the research team at Virginia Tech, I took on a different political disposition with respect to my relationships with the participant, as well as other, teachers. I also took on a particular political disposition with respect to other researchers both as an accepted member of the researcher team and as former teacher who, for example, was at times empathetic with the teachers' situations. These roles and perceptions shaped my interactions and thus my account.

Data

Since I was a participant observer studying the LiNC project *and* acting as an investigator for the LiNC project, there were several sources of data to which I was privy. First, there were the data, formal observations, and interviews conducted as a researcher for the LiNC project. I collected much of these data along with our team of investigators beginning when I became part of the research in fall of 1998. Second, there were a great number of published papers, surveys, websites, observations, emails, other correspondences and documents that were generated and collected by other investigators prior to my joining the project. Third, there were a wide variety interviews, conversations, emails, documents, and literature collected by myself directly for the purpose of studying the LiNC project, separate from products resulting from my role as an investigator *in* the LiNC project. All of these sources together constitute a wide array of rich data that was crucial to formulating my understanding of processes related to the LiNC project.

Participant Observer in the LiNC Project (Primary Sources of Data)

As a participant observer, I took an active role in the fieldwork. In the course of observed student activities, I answered questions posed by students about curriculum and technology, questioned students in the context of their work, and carried on discussions of curriculum and activities with students and teachers. As a former science teacher in Montgomery County, I had experience with the curriculum, teachers, students, and the general culture of the classroom and social conditions of teaching in MCPS. I am very familiar with each of the sites of the four science teachers in the LiNC project, and I actually taught several years in one of the classrooms and substitute taught in others. In addition, I worked with at least one of the teachers as a colleague and tutor of some of his students. During this time, we had met in staff development meetings and even negotiated textbook adoption and curricula. As a research associate in the LiNC project, I had access to all data collected, the classrooms, and the teachers involved in the project.

In the course of observations of the Virtual School project activities, I offered technical support and instructional help to teachers, and I spent a significant amount of time after class and after school talking formally and informally about the LiNC project, the computer technology, teaching, and other generalities.

I was in every sense a member of the LiNC project. I was hired as a research associate and participated directly and intimately in the research and development of the collaborative technology, grant, report, and paper writing. I carried out research in the classroom as a field observer. I shared in the instruction and technical assistance of students using the technology while involved in field observation. I met extensively with, argued with, and conversed formally with, met informally with, and interviewed, superintendents, school principles, teachers, students, co-researchers, project managers, investigators, government officials, and other community professionals and members. I became friend as well as adversary to teachers, administrators, colleagues, and others involved directly or indirectly in the project. I presented findings at conferences, and workshops. I published papers, co-authored reports, and became co-principal investigator on grants with project managers and other investigators. In sum, I socialized and associated as a legitimate and central representative and member of the LiNC project.

The LiNC *project* is the subject of the study. The LiNC project represents a study or series of studies in its own right. The project studied student and teacher collaboration involving network computer supported learning, but the LiNC project is itself an interesting case for Science and Technology Studies. Insofar as this study concerns the examination of the development of methods for documenting and evaluating computer-supported collaborative learning, it represents a meta-methodological study, that is, the investigation of how research methods are developed and used. But as the study of the social process of the LiNC project in general, it extends well beyond meta-methodological analysis. Figure 1.1 below shows the “primary” data collected as part of the present study.

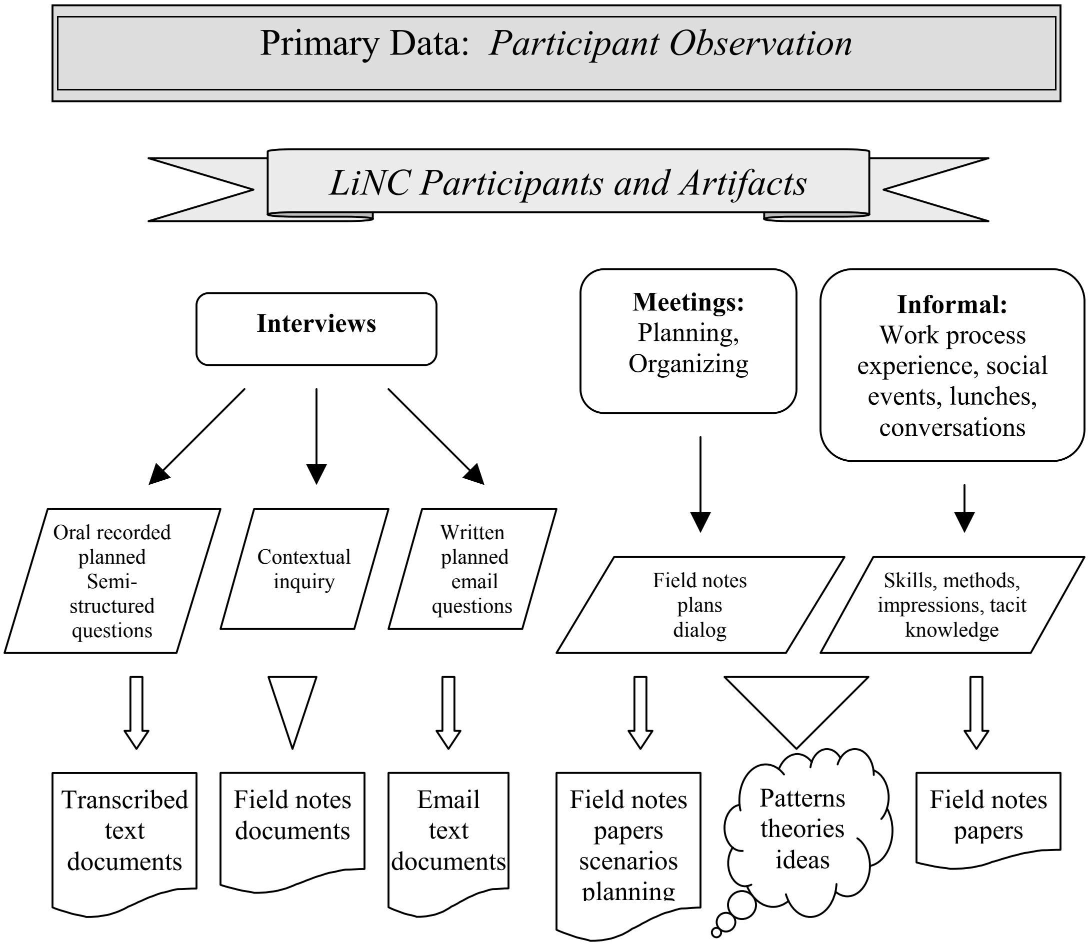


Figure 1.1. Sources of primary data as part of participant observation in the LiNC project. The top layer represents processes (interviews, meetings, and informal events). The middle layer represents different kinds of data, and the bottom layer represents final documents and resulting objects.

The LiNC Project Research (Secondary Sources of Data)

Data Collection and Recording Procedures

Collecting rich forms of data from dispersed collaborative sites required complex and innovative methods. We collected data through five basic mechanisms: audio/video recording of participants, questionnaires, field notes, computer server logs, and web-based discussion forum. All data tapes, documents, notes, and results were saved whenever possible after transcription and were labeled using a naming convention noting source, type, and date of activity.

Formal interviews were recorded on portable cassette and then typically transcribed to text. Field notes were transcribed to text; reflective notes distinguished from descriptive notes or "observer comment." In many cases, field notes were taken at teacher meetings, student activities, and other relevant events. Visual and audio recordings were made of student activities. Student group collaborative meetings were captured in two ways. In each classroom involved with a particular collaborative arrangement, 8mm video camera recorded a long shot of a group of students using the Virtual School software. Their respective computer screens were also recorded at each site by splitting the monitor signal, converting the scan rate, and recording on portable 8mm-video tape machine. Thus for each dispersed collaboration recorded in this manner, four tapes (two long-shot and two screen capture) resulted. Computer server logs captured and recorded all chat, email, and notebook activity in the Virtual School. Participants also engaged in a web-based discussion tool based on critical incidents in the project. This discussion was recorded on the web server. All of this information had to be coordinated into an analyzable form.

As participants or subjects in LiNC project, all students and their parents were appropriately informed according to the university rules for informed consent by signing informed consent forms filed with the Virginia Tech Internal Review Board (IRB). In addition, I further informed teachers and received their approval on a second IRB approved informed consent form, which they all signed. These were filed in the IRB office. All students were informed about the video and all other recording of their activities according to IRB regulations. Their video recording was prearranged, consensual, and obvious, and they were informed of the logging of their computer interactions, email, etc. beforehand and then periodically reminded.

The conspicuous presence of the video camera and the knowledge that some of their computer use was being monitored affected student behavior. Occasionally this effect on the students appeared minimal and insignificant, especially as time progressed and they became accustomed to the camera, such as in longer-term activities. Moreover, students knew that their teachers were present in the classroom and remote teachers might be monitoring their computer interactions in the remotely connected classrooms; however there were occasions where students explicitly pointed out their awareness and even discomfort with the videotaping. Similarly, investigators noted occasions where students commented and behaved in ways that suggested that they were very conscious of being broadcast in videoconference. In some cases, students attempted to avoid the attention of the videoconference camera and microphone. For example, students would point the camera away from themselves, and they would pass the microphone in order to avoid speaking to their remote members. Students also used the videoconference tools in a mirror-like fashion to adjust their appearance and comb their hair, for example.

On the other hand, there were a number of incidents that suggested, or that we inferred, that students may have forgotten or been unaware that they were being videotaped or that their email was being monitored. Investigators made explicit efforts to document and interpret such behaviors when transcribing video observations, and they also made repeated periodic efforts to announce and remind students that their computer activities were being recorded and monitored. Thus, in some cases it appeared as if students clearly noticed they were being monitored and consequently changed their behavior. In some cases it appeared that they noticed but lacked concern, and in some cases we inferred that they appeared somewhat unaware or totally lacked concern about investigators monitoring sensitive material such as email. In all cases, we attempted as far as possible to respect confidentiality and identity of all monitored activity and to appropriately inform participants of the data gathering procedures.

LiNC Project Data Analysis

The identification and discussion of critical incidents (delGaldo, Williges, Williges, & Wixon 1987; Flanagan 1954; Shattuck & Woods 1994) in the student activities guided a portion of the analysis. Since teachers took part in the identification and the dialogue about the nature, causes, and implications of critical incidents, understandings of how teachers interpret classroom practices was inferred from their talk about the activities. Investigators in their field notes identified critical incidents, and those incidents deemed important or instructive were posted to the collaborative critical incident web-based discussion forum tool (CCIT). The tool allowed participants to rate the degree of criticality of each posted event prior to engaging in a threaded discussion.

Student collaborative activities were recorded, transcribed, and combined with computer-generated information about their computer activity. Each long-shot audio/video tape of the student activity was transcribed as one side of the collaborative activity. The video was transcribed. CVideo (Roschelle 1996; see also Roschelle 2000) video analysis software allowed the transcription of passages of dialog to be time-stamped. All of the transcribed video with added descriptive and reflective field notes was collated with transcripts of the computer activity log for each collaborative group. Corresponding sides of the collaborative events were collated into a single integrated document. These "scripts" of the interaction include local and remote group dialogue, computer log data of Virtual School activity, and observer or transcriber descriptive and reflective comments. These integrated scripts were imported into qualitative analysis software (NVivo) along with interviews, meeting field notes, and other relevant text documents. Figure 1.2 below shows the “secondary” sources of data, which was gathered as *part* of the LiNC project research (as opposed to “primary” data that was a result of my study *of* the LiNC project).

Secondary Data: *LiNC Project Research*

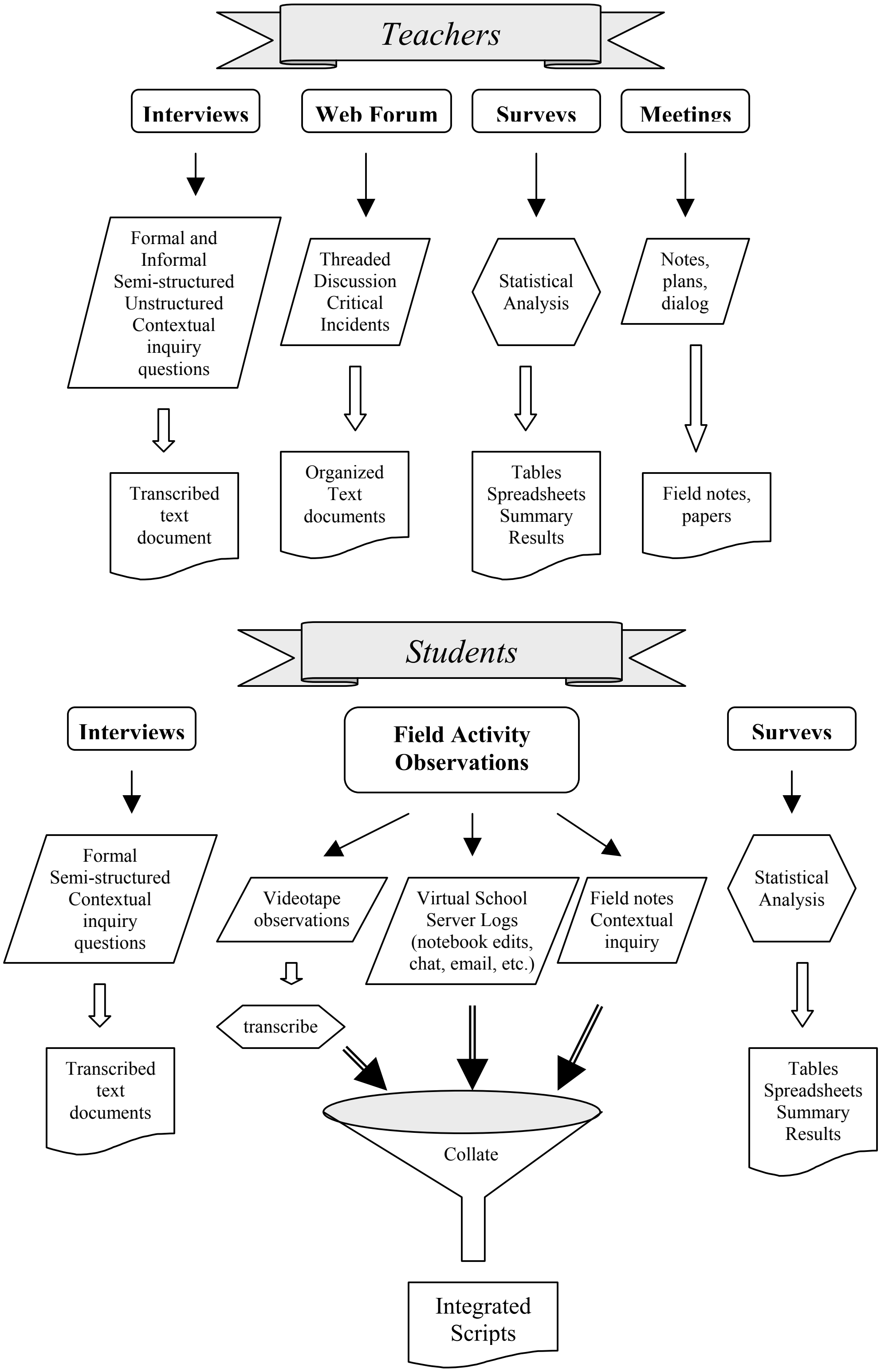


Figure 1.2. Secondary data gathered as part of the research done in the LiNC project. Data about teachers was collected from interviews, meetings, web-based discussion forum, and surveys. Data about students was collected through videotaped observations, interviews, surveys, and computer logging with the Virtual School.

Technology Studies

In providing an account of technical development, one is immediately faced with important problems and struggles of historians and sociologists of technology. There are at least three important issues that I have tried to address in the present study of technical change. Staudenmaier (1985) describes in detail some of the major issues facing recent historians of technology in their attempts to steer clear of past shortcomings. The challenge of providing comprehensive and meaningful accounts of technical change have led recent scholars to consider alternative approaches to thinking about the causes, descriptions, and implications of technological development. Staudenmaier contrasts several basic approaches and describes an alternative that synthesizes the options.

Internalist history may be the most traditional and common sense way of thinking about technology development, but it has been one of the most criticized approaches for failing to recognize many aspects crucial to explaining and describing important mechanisms related to technological change.

> 'Internalist history' receives its name and heritage from the centuries-long tradition of interest, and indeed fascination, with the design characteristics of human mechanisms. It is 'internal' history because the focus of attention is centered almost completely on the artifact itself rather than on how the artifact relates to its external social context. (Staudenmaier 1985, p.9)

Internalist history contrasts sharply with “nonhistorical analysis.” These scholars represent a somewhat reactionary stance. “Their style stood in sharp contrast to internalist history. The demand of quantitative, systematic analysis common to both disciplines [sociology and economics] precluded attention to the design of individual technologies” (Staudenmaier 1985, p.11). These scholars consider “technology,” in a more general sense than “individual technologies,” for example, technology as a “socioeconomic force.” “Externalist” historians, in more direct contrast to internalist approaches, “study the context of technological events but do not discuss the design of function of the technologies in question” (Staudenmaier 1985, p.13).

Contextual history represents yet another, but a more holistic, approach. Scholars representing “contextual history of technology,” according to Staudenmaier (1985, p. 11), “created historical syntheses of technical design and historical context.” These authors “conceived of the internal design of specific technologies as dynamically interacting with a complex of economic, political, and cultural factors” (p. 11). But these scholars, through the opening up of the larger contexts of technology development to scrutiny of historians and other scholars, raised a large number of very difficult questions and dilemmas. For example, what is the appropriate balance of context and technical design, how should the historian demarcate and treat the relationships between context and technical detail, and what are the relevant factors one should describe and explain? One positive outcome of these conversations about historiography was in the recognition of the problems associated with “Whig” histories, that is, histories that focus solely on the “winners” or just the successful artifacts, for example, those representative of or advanced by dominant western culture. One important effort at addressing such issues came from scholars interested in the "social construction" of technology (for a review of this work, see Pinch 1996).

The Social Construction of Technology (SCOT)

Bijker and Pinch (1987) contend that the social constructivist views prevalent in the sociology of science might be very beneficial to the social study of technology. Specifically, they describe how the Empirical Programme of Relativism (EPOR) (Collins 1981) from the Sociology of Scientific Knowledge (SSK) can benefit the emerging field of Social Construction of Technology (SCOT); however, this move is not without its detractors.

Woolgar (1991) criticizes SSK in general for failing to exploit the analytical ambivalence inherent in its claims. He suggests that the application of SSK to the social studies of technology (SST) is nothing more than a move sideways to a new object (technology), a move that continues to avoid taking a reflexive position with respect to SSK's own practices. Button (1993) arrives at a slightly different conclusion about the importance of relativist-constructivism to the study of technology. He suggests that, despite explicit promises to the contrary, "technology" in fact "vanishes" from these accounts, accounts explicitly aiming to describe technological change. One slight corollary that can be added is that "the social" can ironically fail to fulfill a proper and reflexive role in some of these accounts.

Woolgar (1991) describes four essential components of the SSK mode of argument. First, the sociologist selects the account to be studied. Second, the sociologist raises the possibility of there being different accounts of the phenomena in question. Third, the sociologist portrays these as alternative accounts of the "same" "reality," and finally, the sociologist "explains" the disparity in the accounts in terms of differences in social and cognitive interests, group activities, and so on. Woolgar then points out that the sociologist's own account is not "subjected to move 2; attention is not drawn to the fact that it is possible in principle to supplant the sociologist's own 'explanatory' account with another." "The relativist argument ironically depends on a practical (that is, 'discursive' or 'textually embedded') realism, both with respect to the purportedly extant reality underlying scientists' constructions and with respect to the antecedent circumstances recruited as explanations. We see that the programmatic relativism gives way to realism in practice" (Woolgar 1991, 24-25). SSK's turn to technology relocates these shortcomings of SSK in a new arena, technological change.

Button (1993) acknowledges Woolgar's position and further argues that "technology vanishes" from some descriptions posited by the relativist-constructionist positions because some sociologists fail to appreciate that "technology is a social production" itself. The distinctions and categories that are used in the production of technology can get traded, subsumed, or ignored in favor of categories and theories used by the sociologists describing the processes. The artifacts can be reinterpreted as a *function of* the social network, antecedent causes, interests, and the like. The technology can become the content to be explained by sociological theories, theories that fail to take into account that ordinary production of the technology involves actors who, in their work, distinguish the social and the technical. The focus on the social construction of technology can merely add another cryptic layer to the description of the technical artifacts, so much so that the social forces become the object of analysis and the technology merely the platform from which to view the social negotiations and conflict, the associative and disassociative forces at work (Button 1993, 24). As such, over emphasis on the social construction of technology can hide or confuse the extent to which the reality of the technological is itself accounted for, articulated, and testified to in the course of participants' activities (Button 1993, 11). Button (1993) explains:

> The common recognisability in our culture of the phenomenon of science or the phenomenon of technology is lost to the relativist position; just what is involved in doing scientific work and just what goes into the production of a piece of technology is certainly blurred in their accounts, and thus the ordinary distinctions that exist in our society are disregarded in the name of a sociological theory of reality. People are being asked to give up established distinctions without it being clearly understood what they involve, on the basis of a sociological theory, which has only the most ambiguous relationship to the meaning of their activities. Consequently, the methods through which phenomena are distinctly produced and recognised are missing from these accounts. '*What*' it is to be doing science or technology, the interactional specifics of the work of (the) science and of (the) technology are ignored, and hence the science and the technology vanish from view. (20)

Woolgar does not address the actor-network position of Latour (1987, 1988), Callon (1986), and Law (1987), but Button does find important potential in the position.

> [I]n the actor-network approach, with its emphasis upon the *association* of elements, it might be possible to find the specifics of the interactional work involved in the production of technological artifacts. In emphasizing association the actor-network proponents might actually direct attention to the work involved in the production of technology as opposed to becoming entangled in debating reality with societal members. (23)

A number of more recent approaches loosely associated with the actor-network school have made concerted efforts to describe technology in the terms given in the production of technology by participants engaged in the processes. Such approaches explicitly strive to *avoid* reducing the technical to sociological terms (see for example de Laet and Mol 2000, Akrich 1992). What I take to be important here is the attention and emphasis on participants' understandings of technical actions and interactions that are recognizable as being part of their role in producing technologies.

Moreover, Button's position is important to note because it demonstrates that key researchers in the field of HCI also engage theoretic STS, sociological, and similar research involving description of technology development. Further, that Button has such a position demonstrates a minor corollary implicit in his position: Developers, like Button and the HCI research teams in which he is involved, frequently engage the same kinds of understandings (social theory) that sociologists invoke in their descriptions, so it can be misleading to describe actors as if they are always totally naïve about the social processes (described by the observant and objective sociologist) that may describe, drive, or explain a particular sphere of their actions. It has been argued above that people in their ordinary work and interactions can treat the "technical" aspects of their work differently than the "social," and, as such, their distinct "technical" activities and how they understand these practices can have ramifications to their work. Similarly, the "social" aspects of their work, as they construe them, can also have relevance *to their technical work* (developing technologies) as well as to their social, economic, and political interactions.

For example, computer programmers write code and design interfaces. In doing so, they act in ways that explicitly challenge their own understandings of the entities of computer programs, for example, computer networks, components, and widgets. They acknowledge and interact with their economic motivations, social group dynamics, situational and cultural constraints, and so on. Moreover, they reflect on their own work, learning, and procedures in order to find alternative ways and means to do their work, for example to consider the relationships among technical entities, networks, and understandings.

Participant Observation

As a participant observer, I described actors in their work places. I tried to assume a role or viewpoint that recognized that actors have understandings of and beliefs that affected their work. I had personal understanding of and experience with descriptions and explanations of science and technology that influenced how I interpreted actors' descriptions of their work, but I also appreciated that these were often different from the actors' interpretations.

Here lies a source of tension and ambivalence. The participant/actors and their common sense ways of speaking may have reflected common nuances and particular ways of communicating and understanding concepts that had social and technical meanings and relevance. The distinction that I, the observer, took with respect to the social and the technical was problematic. Latour and Woolgar (1986) discussed this in detail (see p.23-27) that I will not reproduce here; however, the stance they took is worth restating:

> We want to pay attention to "technical" issues in the sense that the use by scientists of "technical" and "intellectual" terminology is clearly an important feature of their activity. But we regard the use of such concepts as the phenomenon to be explained. More significantly, we view it as important that our explanation of scientific activity should not depend in any significant way on the uncritical use of the very concepts and terminology which feature as part of that activity. (p. 27)

A Note on Reflexivity

There is not a simple and obvious way to address concerns about the participants' distinctions of social and technical aspects of their work. There are several reasons for this. First, participants are not normally engaged in high-level sociological analysis when they describe their technical work. As such, they use common ways of talking about their work, and these common ways often reflect inherently whiggish, internalistic positions and viewpoints that are often highly susceptible to philosophical scrutiny and criticism. Scholars in SCOT have critically addressed such issues. Second, social groups (of participants) do not all have the same viewpoints, understandings, backgrounds, and beliefs. Some study STS, sociology, and history of technology, and as a result they bring this background to their descriptions of their work. Thus, participants collaborating in the same work may have very different ideas about what they are doing, what it means, and how to describe it. Third, the participants may describe their work in different ways to different observers or in different contexts. For example, in casual conversation, one can be very candid and self-deprecating about one's own work; while in another, one can describe the same work in a very serious and technical manner. Experience with the observer, his or her purposes in eliciting the description, the context of the conversation, and the political relation between participant and observer all factor into the resulting description as well as its credibility to a certain extent. Nevertheless, the actors' viewpoints and dispositions have ramifications for their work, and it is important to acknowledge and identify these.

There is still another issue, reflexivity. Latour and Woolgar (1986) define reflexivity for their purposes: "By reflexivity we mean to refer to the realisation that observers of scientific activity are engaged in methods which are essentially similar to those of the practitioners which they study" (p. 30). To explain the issue, the observer brings her or his own categories and beliefs to the process of representing participants. This means that there may be significant tension between the observer's goal to strive to remain analytically ambivalent with respect to the actors' categories and beliefs and the production of those categories and beliefs with which the observer operates in describing and explaining. A "reflexive" account is one that acknowledges and explores both of these aspects of the production of the account. Fuhrman and Oehler (1986) discuss and explain.

> A reflexive sociological study of science (and social life) depends on exploring the limits of the sociologists' self-understanding of the sociological project. A reflexive sociological study of science must simultaneously reach a self-understanding of how sociologists qua researchers arrive at the beliefs they do *as well as* focusing on scientists' beliefs. Reflexivity in science studies must pay attention to the social structures and processes under which knowledge is produced and legitimated (p. 304).

For technology studies, reflexivity would seem to be less of a problem since claims about knowledge production need not apply, but technologists do provide accounts of production, that is they make claims about what is real, significant, causal, and so on. Thus, while the methods of technology studies might appear to be very different from those used by technologists and engineers, the accounting for technological change and development may not be that very different and in fact, I argue, they may in some instances be very similar and even identical.

In the present work, reflexivity was particularly problematic. The goals of action research and the goals of description and explanation created tension. My active role in the research, my conversations and opinions on relevant matters with participants, managers, and technical developers, and my interventions into the processes, all flavored, to certain extents, the outcomes and information that I collected. Thus, in attempting to be reflexive, I was compelled to arrive at and convey some self-understanding of how I as a researcher arrived at the beliefs I did *as well as* focus on the participants' (teachers', researchers', managers', and developers') beliefs. This was a difficult task in itself, but add to that the goal of also describing and explaining my account of the processes themselves, and it seemed a daunting task. To this end, I provided a comparative account of the perspectives involved in each chapter of this work. My hope was that it was relatively clear that there was some tension in the various accounts including those of the participants and my own. Moreover, to some extent my own understanding was, naturally and purposefully, influenced by my interactions with participants, and the accounts given by participants were also influenced my their interactions with me.

Questions

In the body of this work, I focused on three main topics: The technology development, the political and social background of the LiNC project, and the execution and implementation of the project goals mainly in the classrooms. The guiding goal of the present work was to provide an account of the main social processes of the LiNC project and related technology development. To varying degrees, I attempted to address and answer the following questions:

- How did social and technical infrastructure shape the production and work in the LiNC project for the researchers, developers, and teachers?
- What were the political and social forces and contexts that led to and shaped the development of the LiNC project, its technology, and related grants?
- What were the major innovations? What was the infrastructure involved in the LiNC project technology, and how was the infrastructure shaped socially and technically?
- What impacts did the development, design, and implementation of collaborative technologies for use in classrooms have on teaching practices and culture?
- How did teaching and classroom culture and practices affect the research and technology development in the LiNC project?
- What were the major obstacles and problems that teachers faced when introducing collaborative technology to their classrooms, and what kinds of changes did they experience?
- What were the main issues involved in engaging teachers in participatory design of collaborative computer technology?

Setting and Limitations

This study directly involved four Montgomery County Public School science teachers in Southwest Virginia, their classrooms, and their students. It directly involved about ten or more administrators and staff members from Montgomery County Public Schools including science and technology supervisors, technical and computer specialists, principals, superintendents, and other staff. It directly involved at least five professors from Virginia Tech, and it directly involved over thirty post doctorate, graduate, and undergraduate researchers. It also involved program directors and administrators at NSF and other institutions that have funded the work being studied. Including school student participants, teachers, administrators, and university project members, the LiNC project involved hundreds of people over five or more years of work.

I had direct experience, through meeting and talking, with a large number of these participants, well over half of them, and I had indirect contact through email and phone conversations with many others. I directly conducted over twenty-five formal personal and group interviews involving around seventy-five people. I have been directly involved in another thirty to fifty informal interviews and instances of contextual questioning before, after, and during the project activities. I have been involved with hundreds of additional interactions with researchers, developers, students, teachers, and administrators in working with efforts related to the LiNC project. While all of these interactions informed the present work, it would be implausible to document most of them.

I have attempted to include the major players of the project in this study; however, participation of humans in such a university-sanctioned study requires informed consent. I have attempted to obtain informed consent from any persons that I felt should be directly questioned and whose views I felt should be represented; however, not everyone to whom I have made the request has agreed to participate. While most have consented, including all of the four main teachers involved, at least two important participants have declined, so I feel ethically and legally obligated to ignore and exclude certain information and interpretations pertaining to them. Moreover, I have chosen to identify by real name most participants, and have indicated so on respective informed consent forms, but I have chosen *not* to name the teachers in this work. Their identity is public information and is no secret, but I felt that their interpretations and views were more sensitive than those of other participants. I felt that the benefit of identifying them individually was not critical, and the cost of treating them anonymously was not exceedingly detrimental to the study. I have not included real names of school students or identifying materials since they were not of legal age, and so they must be held to a higher threshold for consent. While I did not feel that they needed to be identified, their views were included anonymously and implicitly. I believe it was well within ethical and legal bounds to consider the views of students since they *did* consent to be part of the LiNC study, and, moreover, I did not include sensitive, compromising, or identifying material.

Nevertheless, these factors all entail limitations to the study. I have not provided in depth analysis of the teachers' personalities, styles, opinions, and views since that may, in my mind, compromise their reputation at some point. I have not been able to include valuable viewpoints, quotes, and interpretations from some critical members of the project since they declined my request to participate. I have not been able to get in touch with one or two members because they have moved away and cannot be located. I have only been able to communicate indirectly or asynchronously with some participants because of typical work and geographic constraints.

In addition, in the flux of personnel and resources over the course of time, materials and documentation of the project have been scattered, lost, and discarded. Memories have faded, and impressions have been muted or altered as other events have mitigated. This was an inevitable result of a long-term project, and these circumstances exemplify the partiality and temporality of such research. I can only reiterate that this represents but one of many plausible accounts of the LiNC project, one that is recollected and told by me over a particular span of time, for a particular audience, and in the course of particular work goals and organizational affiliations. Nevertheless, I have strived to present viewpoints and events accurately and as I understand them.

Significance

This study is important on a number of levels. The Virtual School software represents an innovation in classroom technology supporting collaboration. The study has the potential to inform researchers about the potentials and pitfalls of introducing collaborative technology to science classrooms and about innovative methods for gathering data from such activities. Specifically, I described (a) methods for collecting and organizing field observation and computer generated data from participants located in remote collaborative school settings, (b) some of the major problems encountered by participants involved in computer-mediated collaboration in the LiNC project, and (c) related the problems and successes described in the LiNC project to concepts from various disciplines including, but not limited to, prominent theories from Education, STS, and Computer Supported Collaborative Learning (CSCL). In doing this, I intended to advocate ways of thinking about the roles of collaborative computer technology in science classrooms (Roschelle, 1995; Means & Olson, 1995).

Outline of Dissertation

What follows this introductory chapter organizes the study around central themes that allow the telling of various aspects of the story of the LiNC project. While this organization scheme may seem somewhat arbitrary and achronological, it is part of my attempt to avoid falling into a linear or progressivistic history of the technology.

Chapter 2, which begins the story, tells the end of the story, so to speak. It describes the product of the LiNC project today as a tentative end-point artifact of the project. This is considered an “end-point” purely for the sake of telling the story. The product, so to speak, was the technology that was developed *and* the context of its use and design. This too, was not a simple and singular “thing” though it may appear so to users and others. Rather, there were strands of software and hardware that have complex social implications and roots. The software included two basic ancestors that consisted of suites of collaborative network tools: These are known as The Virtual School and MOOsburg.

These software tools were not only interrelated in terms of programming development, but their infrastructure, design goals, uses, and trajectories were inextricably intertwined. In the main body of this chapter, I described these design goals, the context of use, for example, what the school students did with the tools, and what is being done with the tools today. In doing so, I described some of the infrastructure and architecture of the tools that enabled the technology. This included an innovation of Virginia Tech developers known as the Collaborative Object Replication Kit (CORK) that enabled efficient collaborative use of familiar and innovative computer applications. My description of these tools required that I describe the transfer of technology to and from the project. Key individuals and circumstances came together to form this nexus of infrastructure that radically changed the technological products we see today. Moreover, we can trace some of the transfer of this technical knowledge outside and beyond the project to other corporate and institutional development projects. In explaining these technology transfers, I attempted to describe how the artifact, that is, the technology, was significantly transformed as the context, use, and personnel associated with it changed and mutated. Once I described the product or end-point of the LiNC project, I retraced the political and social context that seeded and enabled the beginning of the LiNC project and its supporting grant.

In Chapter 3, I described the political context of the late 1980's and early 1990's that produced the fertile ground for justifying the giving of the largest education grant in Virginia Tech history to a Computer Science department rather than a College of Education. In order to explain this political climate, I described the national policy crisis rhetoric of the 1980's that was aimed at public fears that the U.S. was losing its international competitive edge with respect to education measures and productivity. The program goals of the National Science Foundation (NSF) reflected these concerns, and began to concentrate more and more on developing a technological infrastructure that would support school reform. I described this result in terms of "big science" (Price 1963, Galison 1992) or more properly, I framed the discussion in terms of "big education" or "big technology for education."

After setting up the larger political climate, national reports, and crisis rhetoric, I described the particular NSF program that seeded the LiNC grant, the National Information Infrastructure (NII) program. This spawned a more focused program that directly funded LiNC, the Networking Infrastructure for Education (NIE). These programs, and their political and social context set the stage for the thinking, writing, and acceptance of the LiNC proposal. I interpreted this grant with the help of the views of the principal investigator in charge of the project, John Carroll, his rationale, goals, and resources, namely the beginning of the Center for HCI. This led me to the details of the history of the execution of the LiNC project.

In chapter 4, I provided a narrative that attempts to distinguish several major phases of the five years of the project. The main focus of this chapter is on describing interactions of the many researchers and the four main teachers responsible for carrying out the project goals. One important aspect of the resulting interactions among participants was the ways in which the goals of participation were enacted. There were multiple dimensions to the social processes surrounding the participation of teachers, and they were dynamic, in that they changed significantly over time. For example, investigators anticipated working with teachers, but they were naïve about and unprepared to deal with the culture of teaching. They did not anticipate many social issues involved in collaborating with teachers over participatory design and technology in classrooms. While teacher participants remained relatively constant throughout the project, the periodic change in researchers significantly altered the character of the phases of the project. This had ramifications for the participatory process, and many of the resulting problems reflected typical challenges that the teachers encountered in having to collaborate in new ways with each other. For example, investigators had different backgrounds, agendas, and beliefs about evaluating the project. Teachers also had different beliefs about pedagogy and classroom research. These differences provided opportunities for conflict, negotiation, collaboration, and learning.

In chapter 5, I addressed the main goals of the LiNC project and drew conclusions about each area of focus. I described infrastructure that shaped the technology and development process especially with regard to the social, political, and technological outcomes and contexts that situated and enabled the work. One important set of conditions that shaped the work repeatedly involved interactions of teachers and researchers, and the related negotiations regarding collaborations among teachers and among students in participatory design of collaborative computer technologies. I situated the conclusions among challenges waged by studies of technological change, those of social construction of technology and SSK described above. I described difficulties and offered examples of methodological concerns. In the final section, I suggested that there are a number of opportunities for further kinds of research related to the present work, some of which are being pursued and others which have promise for the various fields addressed in the present work.

Chapter 2: The Technology

"Don't worry about what anybody else is going to do… The best way to predict the future is to invent it. Really smart people with reasonable funding can do just about anything that doesn't violate too many of Newton's Laws!" [1]

"Is the Best Way to Predict the Future to Invent It? Or to Prevent It?" [2]

Introduction

The LiNC project directly and indirectly supported the development of a wide variety of complex computer network tools and systems. The assumption that there exists "*a* technology" produced by the project is misleading since it implies that the project culminated with a finished and ultimate product. The assumption fails to acknowledge the many dead ends, detours, and off shoots that constitute the achievements and failures influencing the technical objects in use today. The social and political infrastructure related to the technology is described in Chapter 3, but in this chapter, I describe "the technology," that is, the technical objects used, developed, and the history shaping those technologies that enabled users and developers. While I describe the political context in one chapter and the technical context in another, I do not intend to demarcate fundamental elements of social and technical description. I have discussed these issues in the introductory chapter.

In this chapter, I also described some key illustrations of the transfer of technology to and from the LiNC project. In doing so, I have attempted to avoid the temptation to portray the social and technical events in a deterministic fashion; for example, I avoided the assumptions that social situations occurred in isolation of technical developments or vise versa, or that technological constraints led to inevitable advances in technical knowledge. The boundaries of the social and the technical were fuzzy and dynamic. They were tangled and enmeshed to the participants involved in the production, and they changed according to the perspective from which they are viewed. While I was bound by my own understanding of the events, I have attempted to describe the actors' understanding of the socio-technical context, the tools, and how they impinged on their work practices.

The entirety of the technological infrastructure and its history was of course impossible to detail here, but there were several key aspects or dimensions of the technical objects worth describing. The Internet, telnet, Java and CORK represented important elements in

---

[1] "The origin of the quote came from an early meeting in 1971 of PARC, Palo Alto Research Center, folks and the Xerox planners. In a fit of passion I uttered the quote!" — Alan Kay, in an email on Sept 17, 1998 to Peter W. Lount (see http://www.smalltalk.org/alankay.html). Kay also explained, "I said that to the Xerox planners back in 1971. They were worrying about what the rest of the world was going to do and the statement was made to get them to understand that as long as we had some top technologists, we didn't have to worry about what anybody else was going to do -- we could just do it ourselves. And we did" (see http://www.convergemag.com/Publications/CNVGSept99/IN%20CLOSE/INCLOSE/InClose.shtm).

[2] Title of Alan Kay's Keynote Address for CHI 98: April 18-23, 1998, Los Angeles, CA USA.

this story since they functioned as "obligatory passage points" (Callon 1986). The two major suites of software, called The Virtual School and MOOsburg, were not inevitable outcomes of the development process or a final result. Rather, they were temporary and highly visible benchmarks in the complex web of technical and social relations of their production and use. The histories of these artifacts, their different contexts of use, design goals, developers, and users were neither anticipated nor linear stepping-stones to the present tools. The paths to these technical objects took many unexpected twists and turns.

For example, technology, which involved a conglomerate of know-how, people, software code, and hardware, was transferred from development of the Virtual School to a "new" iteration of MOOsburg. This *third* iteration of MOOsburg in effect absorbed the Virtual School technology and personnel. This was more than a mere technical matter. The technology was transformed in the process, and consequences reverberated in the political funding processes, social relations, and know-how that constitute the production of the technical entities. The boundaries of the technology and its related transfer were also not clearly delineated. Pieces of the technology directly related to artifacts were transferred to and from the LiNC project. Moreover, these objects were not the anticipated outcomes of the funding of the LiNC project in form or substance. Technological changes and social forces intermingled in the development of the project and radically altered the trajectory and goals articulated in the early visions. Changes in technological infrastructure account for many of these twists and turns in development.

Technological Infrastructure: Definitions

Philosophers of technology have challenged traditional conceptions that narrowly equate technology with "tool-as-mechanical-mechanism." In broadening the definition of technology, they include not only physical but social mechanisms that can be used to achieve a goal, such as bureaucracies, funding agencies, laboratories and so on. "Technology is now to be conceived as a complicated process of humanity at work in which knowledge gained by prior action is reconsidered in the light of new knowledge and new actions attempted by way of focusing on achieving specific goals. The process involves assessment and feedback, action, and analysis" (Pitt 2000, 23). Defining technology as "humanity at work" captures many of the complex social and technical aspects crucial to describing the development of collaborative computer network tools of today.

"Technology" represents the physical and social tools, artifacts, and know-how in which people engage. "Humanity at work" captures both tools and tool use important to providing an appropriate understanding of technology since the concept implicates both human know-how and work involving tools and tool use, that is, it implicates both social and technical aspects technology. Strictly demarcating the social and the technical dimensions of tools in doing history and social study of technology arbitrarily separates the tools from the tool users and makers. Technology represents knowledge and objects but also complex social activities and their artifacts. Knowledge is tool-like. It embodies capacities to do and assist in doing work. As such, it gets carried around, materialized, and codified by people.

One important feature of the LiNC project is the way that participants regard the technological infrastructure as fundamental to their own ability to develop state-of-the-art technology. Philosophers of technology have even turned to requiring an account of technological infrastructure as "*the mechanism* that makes the discoveries of science possible" (Pitt 2000, 132). It is a weaker and even somewhat analytic claim to require an account of the technological infrastructure as the mechanism that makes technological discoveries possible, but such a claim should not be regarded as an internalist view of technology development. The infrastructure does not determine the inevitability of one particular kind of innovation. Rather, it provides a socio-technical structure and context for innovation. Infrastructure involves historical processes for technological innovations rather than an a priori lineage. Accordingly, it is useful to think of *technological infrastructure* as "an historically determined set of mutually supporting artifacts and structures that enable human activity and provide the means for its development" (Pitt 2000, 129).

With regard to the present study, technological infrastructure is, on the one hand, the Internet, Java and related programming languages, and the particular code of the software at hand, but there is much more that enables and provides for the development of the technology, for example, the Center for Human-Computer Interaction at Virginia Tech and the personnel that constitute that center. It is a political and social infrastructure that makes the work possible, and it is itself an artifact of that work. This chapter will describe the first part of that infrastructure, and Chapter 3 will describe the latter part.

Social Construction of LiNC Technology

The presumed boundary between social and technical determined the ways that technology was represented. The transfer of tools and know-how among people implicated it. Actors in the LiNC project included software developers, investigators, schoolteachers, other individuals, and their tools. The roles of these actors often blurred in activities involved in developing and using the technology. Teachers explicitly participated in development. Investigators purposefully participated in enacting curricula, and so forth. In addition, people joined and left the project, and with them, know-how and artifacts came and went. Developers brought their knowledge of programming languages and systems learned in their education and work, and they took technical objects away to be subsequently represented in their teaching and work in industry. Thus, a multitude of interpretations became relevant in describing the technical objects and infrastructure if one attended to the range of perspectives available.

First, there was the hindsight afforded by the product, the technical object that emerged in the process of development. The historian of technology can consider the form and function of the artifact to be the ultimate "thing" that needs to be explained. This position evokes explanations that are "internal" to the technology. As such, functional requirements of engineers and developers and material constraints are invoked to explain why the technology came to be what it is today. Historians, philosophers, and sociologists of technology who, for example, criticize it for focusing too narrowly on the "winner" in the development process have enumerated problems with this "internalist" approach discussed in the previous chapter. Other details about the development process can reveal the numerous dead-ends and unforeseen detours that demonstrate the lack of inevitability in the trajectory of the development process. Technical development is not a simple linear accumulation or growth. Likewise, engineers do not operate independently of the economic, educational, political, or the social contexts, of their work. Thus, description of the growth of technologies needs to account for more than is captured by the "internal" constitution of the final products of development. This position is summed up with the adage, "technical artifacts are social constructs." More importantly, the artifacts and their social and technical boundaries are not absolute. Rather, they are "fluid," that is, "the *boundaries* are vague and moving, rather than being clear or fixed" (de Laet and Mol 2000).

The second sources of interpretations important to describing technical objects are those owned by the actors themselves involved in the process of technical development. Since they engage in the process, they hold insights about the details of the technical development that can be hidden to the retrospective account. Moreover, they hold insights about their own understandings related to the work process, their role in the production of the technical objects, and even understandings about their own social context. Thus, when the historian and sociologist choose a technical object to study, along with it comes a social complex and infrastructure, not just the material that is immediate or internal to the object. "Technical objects define actants and the relationships between actants," and "technical objects distribute causes" (Akrich 1992, 207). The traditional and common sense boundary between the technical and the social is challenged by these viewpoints.

I have elaborated the tension or ambivalence in descriptions of "technical" and "social" objects above. Actors' descriptions and common sense ways of speaking about these realms have ramifications for their work and thus for "technology" as humanity at work. The social study of technology is subject to scrutiny for its ability to manage the ambivalence and tension in how to constitute technical work. Researchers must face a philosophical dilemma from the onset. Their choice of subject matter is laden with assumptions about what does and does not count as technology. Investigators of the technological infrastructure in question in the present work illustrate the point well. In this account, a critical piece of the infrastructure was the Internet.

Histories of the Internet and Historiography

Although the Internet owes its beginnings mainly to military research and development, the NSF played a large role in the spread and development of the infrastructure to non-military use. Moreover, there were crucial contributions to its development from other non-research and non-military users, many which represented groups that could be considered "counter-culture" when juxtaposed to academic and military endeavors. While the story of this early Internet development may seem a significant digression from the development of MOOsburg and the Virtual School technology, the roots and causes are not distant. Their common thread can be found in the National Information Infrastructure initiatives and programs discussed in Chapter 3. The social processes are crucial but often ignored in considering the historical development of Internet technologies. "Much of the literature on the history of computing has focused on changes in hardware, on the achievements of individual inventors, or on the strategies of commercial firms or other institutions. Relatively few authors have looked at the social shaping of computer communications" (Abbate 1999, p.4). Rogers (1996) represents one of the few to take on that challenge in his effort to describe the role of the academic sector in establishing the Internet. It is difficult to avoid describing a chronology of development of Internet technologies without falling into the common sense ways of thinking that suggest that the development was a linear succession of events driven by a formal step-by-step progress of inventions directed by clear predetermined goal and path. Despite my own tendency to think in such terms, it must be stressed that what became the Internet we experience today was *not* the result of a deterministic progression of innovations. As Rogers (1996) put it,

> The INTERNET of the 1990s is not the result of a simple linear succession of events nor the consequence of a single factor. Rather, as this study shows, the computer networks are part of a constructed environment that resulted from activities of many groups related mainly to scientific research, higher education, and government R&D. The networks were an ideal vehicle in this process not only because of the services they offered but also because of the relationships they suggested, symbolized, or made visible (4-5).

Most accounts of the history of the Internet focus narrowly on the "internal" development of the technology as if it were independent and determined by the physical function and form of the components. For example, fundamental elements of the Internet such as Internet Protocol and packet switching had political and social roots and consequences that influenced the work of developers and users. Those elements were not uniquely determined as a result of specific need for functionality of hardware and its limitations and availability. There were other viable alternative paths and trajectories that could have resulted given purely technical constraints. Particular developers, their social affiliations and interests were at best incidental to an internalistic account and often wholly ignored.

Other accounts focused almost exclusively on social and contextual factors to explain the technological developments and rise of the Internet. For example, Rogers (1996) distinguishes two perspectives of popular accounts, one focusing on "Internet community" and the other focusing on "democratic" or "anarchist" portrayal of development. The former highlighted two important stages that characterized different development communities. The history was broken up into developers of protocols up to the 1980s, and developers of applications beyond that. The latter democratic version of the "popular perspective" on Internet history centered on the unexpected and innovative ways *users* of the technology drove its development. Rogers notes that, while these histories were less deterministic about the technology development, they tended to clump together diverse groups of people with very different affiliations and goals under the heading "users." Nevertheless, these help describe the importance of the social shaping of the Internet.

In what follows, I described some of the technology used and developed in the LiNC project. The purpose here was to provide a rough chronology of a set of technologies used in the LiNC project. It was not meant as comprehensive historical account of the origins of the Internet. I dealt more with broader institutional, political, and organizational concerns in Chapter 3. Part of the intent here was to illustrate the extent to which LiNC technology was located in a rapidly changing but well-established background of technological infrastructure and dissemination. The Internet has grown exponentially over the past decades, but many so called "new" technologies have been around longer than one might expect. For example, there was an Internet around 1970, but the number of host computers was only about 10. This grew rapidly to 200 in 1980, 300,000 in 1990, and close to 10,000,000 in the year 2000 (Zakon 2000). That there was an Internet in 1970 comparable to that which we see today is both remarkable and dubious.

In fact, how we define "The Internet" in order to trace its origin and boundaries, is itself dubious. On the one hand, we can settle on identifying the Internet as the present system of interconnected heterogeneous networks. However, any network using a particular kind of digital information protocol may be considered an Internet, but such networks may not be inter-connected to other systems. Moreover, every computer using the Internet writ large is not necessarily accessible to every other such computer, and the connections change by the minute. Describing the origins of the Internet, then, is a historiographic problem since one is compelled to define the objects of historical study at some present state in order to describe its coming to that state. In this sense, some amount of Whig historiography may be inevitable. Rogers (1996), explained some issues involved in this dilemma.

> The apparent clear cut boundaries of technological objects do not provide adequate criteria for defining the object of study because the relations between people, organizations, policies, legislation, and a variety of objects, that have a part in shaping the overall process are either hidden from view by the apparent object's enclosure or are declared irrelevant by the explanations of their functions and purposes that inevitably accompany technological objects. (34)

Thus, we are left with difficulties in deciding on the boundaries of study and description. The technical objects extend ad infinitum to social, legislative, policy, and cultural entities. While these dimensions enlighten the historical context, at some point describing and tracing their roots becomes tedious and impossible to organize into a coherent story. On the other hand, the narrow focus on tangible artifacts, one that ignores the people, is similarly incomplete. Description of the interplay of technical and social can provide interest and guide the account, but accounts are partial. Some phenomena are jointly experienced as the Internet today, so the Internet is in some sense tangible. We can touch Ethernet cables and circuit boards, but it is ephemeral. We cannot point to it in space and time and capture all of what is meant when the term is used. We also use the term in different ways, to refer to the physical wires, the data being transferred, the information being interpreted, and so forth. Developers, teachers, and researchers differ in their understanding of this background. In what follows, I provide some common understanding needed to establish connections among the technical objects and the social systems that enabled them. These objects include the Internet, Java, and Telnet, and the work that was done in the LiNC project, including CORK, the Virtual School, and MOOsburg.

Another Brief History of the Internet

Before there were Internet Service Providers (ISP) and Graphical User Interface (GUI) Web browsers, many early adopters of public computer network technology dialed up remote computers directly on telephone lines in order to make information available to other users via bulletin boards and other early networking tools. While the World-Wide Web (WWW) would not emerge until the early 1990s with the systems of gateway routers, Internet Protocol (IP), and Domain Name Servers (DNS), much of the technology used to transfer information over phone lines and Ethernet was in place much earlier.

Key pieces of today's Internet were realized as early as 1960s with the development of packet switching, the labeling of packets or datagrams of electronic information according to origin and destination. Packet switching facilitated the use of phone lines for data transmission since it allowed lost or corrupt packets of information to be identified and resent. Rather than relying on constant connections or circuit switching among sender and receiver, packet switching meant that the data being transmitted could also carry information about how it was to be routed so that it would, so to speak, flip the correct switches along its path in order to find and reach its intended destination.

There was competition between three groups to implement packet switching. Each group boasted a researcher that had developed slightly different versions of packet switching and wanted to create a computer network using their version. Paul Baran at RAND was one. Roger Scantlebury led a group from Britain's National Physics Laboratory (NPL), and Donald Davies led another group from NPL. The social and political resources of the groups, and key differences in their versions of packet switching, significantly shaped the outcome. In the U.S. huge amounts of money were channeled in the Department of Defense for "basic research." Britain encouraged more short-term commercial applications and thus provided much less potential budget for NPL. Additionally, the different versions had practical implications that influenced the outcome.

> The fact that packet switching had to be integrated into local practices and concerns led to very different outcomes in the three network projects. Some visions of packet switching were easier to implement, some turned out to be a better match for evolving computer technology, and some were

> more attractive to organizations in a position to sponsor network projects. Making packet switching work was not just a matter of having the right technical idea; it also required the right environment. Only after APRANET presented a highly visible example of a successful packet switching system did it come to be seen as a self-evidently superior technique. The success of ARPANET may have depended on packet switching, but it could equally well be argued that the success of packet switching depended on the ARPANET (Abbate 1999, p. 41)

In 1968 the Advanced Research Projects Agency (ARPA) awarded a contract to build ARPANET, a network that linked computers at UCLA, SRI in Stanford, UCSB, and University of Utah. This was the first, albeit primitive, wide-area network that foreshadowed the Internet. Abbate (1999) emphasizes that "the origins of the network demonstrates that the design of both the ARPANET and the Internet favored military values, such as survivability, flexibility, and high performance, over commercial goals, such as low cost, simplicity, or consumer appeal" (p. 5). Military goals and values directed a great deal of the early development of Internet technologies. The development of packet switching at ARPANET was part of an effort to find ways to decentralize control of nuclear missiles in cases where attacks destroyed cities that contained control centers.

In the early 1970s Vinton Cerf from Stanford and Bob Kahn from Defense Advanced Research Projects Agency (DARPA, formerly ARPA) coined the term "internet" in describing their development of Transmission Control Protocol / Internet Protocol (TCP/IP). It was not until 1983 that ARPANET switched from the original host-to-host protocol, Network Control Protocol (NCP), to TCP/IP. This became the standard digital information format that allowed diverse computer networks to communicate, but this, like packet switching, was the outcome of a process of competitive struggle involving alternatives that embodied political and economic agendas (Abbate 1999 p. 147-179). In the late 1970s through 1980s, several rival groups attempted to position their networking standards for wider acceptance. For example, computer manufacturers such as IBM, Xerox, and Digital Equipment Corporation marketed their proprietary network systems. Much of the conflict, of course, arose over control of the market stemming from the control of these different standards. Earliest conflict over control of the standards was between telecommunications carriers and these computer manufacturers (Abbate 1999, p. 152). In the U.S., the American National Standards Institute (ANSI) and the National Bureau of Standards helped establish standards. Internationally, the Consultative Committee on International Telegraphy and Telephony (CCITT) of the International Telecommunications Union shared authority for networking standards with the International Organization for Standardization (ISO). In the mid 1970s, the CCITT developed the X.25 standards that some felt was intended to be in direct opposition to TCP/IP even though the two standards were not in principle incompatible (Abbate 1999, p. 155). "For those watching the development of network standards, X.25 and TCP/IP became symbols of the carriers' and the Internet community's opposing approaches to networking. Though each provided a system for networking computers, they embodied different assumptions about the technical, economic, and social environment for networking. The tension between the two visions manifested itself as a battle over standards" (Abbate 1999, p. 155). Ultimately, TCP/IP became the de facto standards in the U.S. and then internationally.

TCP/IP is critical to the workings of today's Internet because it allows standardized addresses (numbers) to be assigned to individual computers and information routed accordingly. TCP/IP was made much more practical by the DNS created at the University of Wisconsin in 1983. DNS is a decentralized system that translates domain names, like www.vt.edu, into IP address numbers assigned to particular computer servers or hosts. While the Internet was quickly becoming well established for civilian use by the mid 1980's and was well established by military use much earlier, the WWW would not appear to the public until the 1990's. Technically, WWW and the Internet are distinct, and this is perhaps more of a historical phenomenon than a practical one, as they are currently understood. Basically, the WWW represents a particular type of application of the Internet, that is, the Internet can be thought of as more general than the WWW. Specifically, the WWW allows HTTP standardized rendering of data bytes. HTML, web browsers, or web pages, are examples of an application of HTTP. The Internet consists more generally of the interconnected computer networks afforded by TCP/IP. Telnet is another example of an application that makes use of the Internet.

Telnet

The standardization of protocol affected many similar network services. Telnet is another interesting example that represents an important element in the technical infrastructure that shaped the LiNC project technology. Telnet represents two related technical objects. There is substrate that consists of the protocols for emulating a computer terminal from a distant computer over a network. Initially the protocols were standards or conventions for control codes that operated line printers, or Teletype. Line printers required command controls to designate when to execute operations like carriage return, line feed, and etc. Telnet also refers to a later instantiation of a display client that renders text on a computer screen. EWAN is or was a common Windows based telnet program. Hypertelnet has perhaps replaced EWAN as the standard interface. Prior to GUI, telnet provided the standard means of interacting with services on remote hosts. Telnet technology allows efficient rendering of text across different kinds of networked machines or platforms and terminal type control of remote computers. By sending text back and forth using telnet technology, users could remotely access and control networked computers by sending textual commands and receiving responding data. While telnet efficiently links heterogeneous computers, it is confined to the transfer of textual data. It is efficient when compared to GUI technologies because it is relatively easy to convert lines of text data to binary code since text is limited to small number of characters that appear in a series. Graphics and GUI, which require data tables and two-dimensionally oriented characters where it is crucial to maintain relative vertical and horizontal position, present special problems for telnet rendering. Some telnet systems make provisions that allow characters to line up vertically so that users could scroll and developers can create tables and related visualizations, but while textual interfaces afford luxuries in their efficient translation capabilities, they fall far short in their aesthetic and practical comparisons to graphical displays.

In the early 1970s, there were no accepted standards for Telnet commands or protocol. During that era, a major means of communicating with and querying other interested researchers about technical issues without formally publishing or directly contacting them was through Requests for Comments (RFC) that were distributed among organizations. These were often very important means of answering technical questions that were crucial to the work of developers of the network technologies. RFCs represented an important element of the culture of the Internet development in the 1970s and 1980s. In part, they have come to be replaced by web-based discussion forums and Frequently Asked Questions (FAQs) related to specific special interest groups on particular websites. One such request, labeled RFC 139, described an interesting attempt to identify the existing Telnet protocols employed in the early 1970s. I have included a large portion of the RFC below in order to help define, from a developer's standpoint in the early 1970s, what Telnet referred to and what a protocol did. The most interesting excerpt is the first paragraph that explains the failed attempt to specify an official Telnet protocol. The remainder of the portions of the document shown here include useful definitions of Telnet terminal and protocol.

Network Working Group	Jon Postel
Request for Comments: 318	UCLA-NMC
NIC: 9348	April 3, 1972
References: RFC 139, 158, and NIC 7104	

Telnet Protocol

At the October 1971 Network Working Group Meeting, I promised to promptly produce a document which clearly and succinctly specified and explained the Official Telnet Protocol. This document fails to meet any part of that promise. This document was not produced promptly. This document is neither clear nor succinct. There is NO Official Telnet Protocol.

The following pages present my understanding of the ad hoc Telnet protocol. There are some who have serious questions about this protocol. The proposed changes to the protocol are given in Section IV.

I. DEFINITION OF THE NETWORK VIRTUAL TERMINAL

The Network Virtual Terminal (NVT) is a bi-directional character device. The characters are represented by 8 bit codes. The NVT has no timing characteristics. The character codes 0 through 127 are the USASCII codes. (Note all code values are given in decimal.) The codes 128 through 255 are used for special control signals. The NVT is described as having a printer and a keyboard. The printer responds to incoming data and the keyboard produces outgoing data.

The Printer

The NVT printer has an unspecified carriage width (common values are 40, 72, 80, 120, 128, 132). The printer can produce representations of all 95 USASCII graphics (codes 32 through 126). Of the 33 USASCII control codes (0 through 31 and 127) the following 8 have specific meaning to the NVT printer.

NAME	CODE	MEANING
NULL (NUL)	0	A no operation.
BELL (BEL)	7	Produces an audible or visible signal.
Back Space (BS)	8	Backspaces the printer one character position.
Horizontal Tab (HT)	9	Moves the printer to next horizontal tab stop.
Line Feed (LF)	10	Moves the printer to next line (keeping horizontal position).
Vertical Tab (VT)	11	Moves the printer to the next vertical tab stop.
Form Feed (FF)	12	Moves the printer to the top of the next page.
Carriage Return (CR)	13	Moves the printer to the left margin of the current line.

> The remaining USASCII codes (1 through 6, 14 through 31, and 127) do not cause the NVT printer to take any action.
>
> **The Keyboard**
>
> The NVT Keyboard has keys or key combinations or key sequences for generating all of the 128 USASCII codes. Note that although there are codes which have no effect on the NVT printer, the NVT Keyboard is capable of generating these codes.
>
> **The End of the Line Convention**
>
> The end of a line of text shall be indicated by the character sequence Carriage Return Line Feed (CR, LF). This convention applies to both the sending (Keyboard) and receiving (Printer) (virtual) mechanisms.
>
> **Break and Reverse Break**
>
> The Telnet control signals provide a BREAK signal which can be used to simulate the use of the break or attention or interrupt button found on most terminals. This signal has no effect on the NVT. When the BREAK Telnet control signal is used from server to user it is sometimes called "reverse break". Such a reverse break has no effect on the NVT.
>
> **II. DEFINITION OF TELNET PROTOCOL**
>
> The purpose of Telnet Protocol is to provide a standard method of interfacing terminals devices at one site to processes at another site.
>
> The Telnet Protocol is built up from three major substructures, first the Initial Connection Protocol (ICP), second the Network Virtual Terminal (NVT), and third the Telnet control signals described herein.
>
> Telnet user and server processes follow the ICP to establish connections. The term "Logger" has been associated with the set of processes in the serving system which respond to the ICP and perform the initial interactions e.g. obtain a name and password. The ICP is defined and the initial socket number and byte size parameters are defined in "Current Network Protocols" (NIC #7104).
>
> The data transmitted between the user and server programs (and vice versa) is treated as a character stream with embedded control signals.
>
> (http://www.faqs.org/rfcs/rfc318.html)

The RFC above demonstrated that there was no obvious singular "next step" answer to developing telnet and related protocol. Rather, there were competing and "ad hoc" options and standards that became accepted through social convention and work practices. These were neither wholly social nor technical means but an example of the fluid boundaries of the social and the technical in developing the technological resources.

Telnet has a long history, and it is still used extensively today. This is also true of many network technologies. Voice conferencing and even email, like telnet, existed in the early 1970s and were widely used by a select group of military and other researchers.

While Telnet was used for a wide variety of “official” government functions, for example, the distributing National Weather service forecasts and military information, by the early 1980s, Telnet clients were employed by a wide variety of public users and developers for sharing files and games over telephone lines. Much of this public use, mainly by a small segment of technically literate early adopters of home PCs, can be considered “underground culture” because a great deal of the file sharing was technically illegal. Some of the “bulletin boards” where these files were shared by a host still exist today. The development of the technology for these devices and for “network gaming” represents a set of developments crucial to the shaping of the Internet, and I explain the direct relevance of these Telnet related developments to the LiNC project technologies below.

By the early 1990’s, the rapidly growing Internet was prepared for a computer network technology that could supply interaction and dynamic graphics, without the need for special software for each platform used. Java, the technology that would answer these needs, did not begin as a response to such needs. The original developers never anticipated its trajectory and impact on the Internet.

The Web and HTML

Much early networking leading up to the World Wide Web (WWW or the Web) was developed by NSF. In 1981, NSF created Computer Science NETwork (CSNET) to support institutions that did not have access to ARPANET. Rogers (1996) described the importance of the academic impetus and institutional context to the development of the Internet. This sector is often underrepresented because of the focus on the importance of military initiatives in creating the National Information Infrastructure.

The spread of Internet technologies beyond experts in military and research domains to the public sphere owed a great deal to the standardization of particular protocols for transferring information. TCP/IP represented one example, but one must be careful not to assume that in such standardizing, there were clear-cut, natural choices of successors. In other words, one should not take the whiggish stance and assume that the “best” technology won the day. For example, there were “good” alternatives to TCP/IP. The skills and know how of the groups of experts users and developers and their complex affiliations were crucial to the acceptance and dissemination of particular protocol. The “technology” did not persist as an artifact or object abstracted from these social contexts. The technology *is* the know-how that is traded and shared as much as the technical object that instantiate this know-how.

The processes through which standardization occurred are extremely important in explaining the proliferation of Internet/Web technologies to the public and private spheres. A key example was the development of Hyper-Text Markup Language (HTML). In 1986 the International Organization for Standardization (ISO) issued the first international standard for markup codes for text documents, that is, standard tags inserted into the content of the text to specify formatting operations on the text (ISO 8879). This Standard Generalized Markup Language (SGML) was not widely used until

Tim Berners-Lee at CERN developed a proposal for a hypertext document system in 1990 and developed the first Web package to serve text documents on the NeXT computer. This was later to be called the World Wide Web. CERN's text-mode browser was released to the public in 1992, and around that same time Dan Connolly developed the specifications for the first version of HTML. In 1993 the National Center for Supercomputing Applications (NCSA) released the Internet browser software called Mosaic (for X) developed by Marc Andreessen. Mosaic, a direct ancestor of Netscape, was the first graphics-mode browser and used the first HTML standard.

Graphics Web browsers unleashed a tremendous surge of growth for the Internet. This same year, the NSF created InterNIC to provide a variety of important services including Network Solutions Inc. where domain names are registered. Also, 1993 saw the Whitehouse and United Nations go online. Finally in 1995, companies like Compuserve, America Online, and Prodigy entered into the growth as dial-up Internet Service Providers. Netscape also went public in 1995, and domain registration ceased to be a free service.

Java and Applets

Java takes advantage of "Plugins" in order to make Web browsers move and interact. It represents a complex set of technical developments in networked computing. It is considered a programming language, a platform for creating networked computer applications, and a computer control system infrastructure. The key innovation that Java brings to network computing lies in its ability to traverse different computer platforms or architectures. In order for a program to run on a particular computer, the computer must translate the program into the specific language used by the operating system of the machine. Programs are normally written in a language appropriate to a particular platform. Java mitigates the translation process by using an intermediate language that can be more efficiently interpreted by different computers. Java was not the first instance of the use of similar intermediate programs. Berkeley P-code interpreter at University of California Berkeley is another prominent example about twenty years earlier. P-code compiler compiled Pascal code into an intermediate "P-code" that was transferred to another virtual machine to be executed as a Pascal program. One type or set of Java-based intermediate programs is referred to as Java applets. In short, they allow, for example, animations or other programs to run on various computers on the network. When a particular animation or interactive program is requested, the computer calls up or downloads the applet needed to run the program.

Java did not begin as an Internet application. It represents another unanticipated case of technology transfer that led to implementation in Web browsers. Developed at Sun Microsystems in the early 1990s, the technology was initially intended as a hand-held home entertainment microsystem controller for TV and cable applications. The original instantiation of the technology, called *7, used a language called "Oak" to run a purely graphical display that controlled a wide range of appliances. Oak was the processor-independent language created for *7 by a group at Sun called the Green Team. James

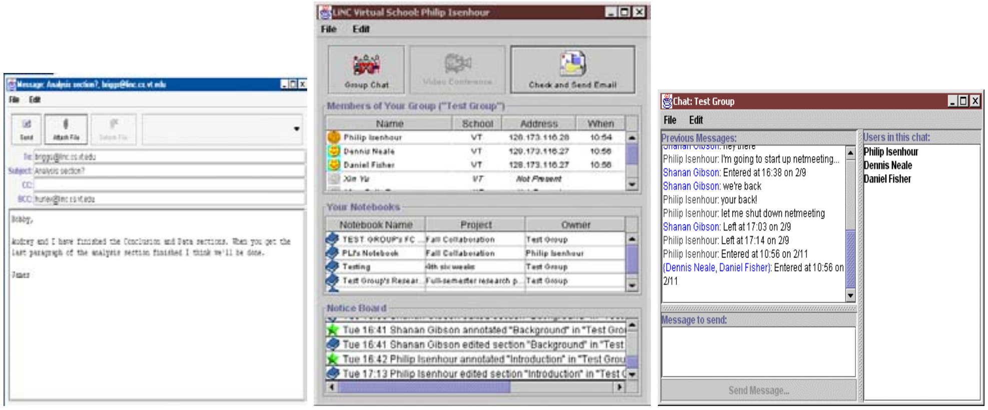
Gosling was a member of that team and became chief engineer of the Java technology. He claimed that the transfer of the technology to the Internet was an accident.

> Even though the Web had been around for 20 years or so, with FTP and telnet, it was difficult to use. Then Mosaic came out in 1993 as an easy-to-use front end to the Web, and that revolutionized people's perceptions. The Internet was being transformed into exactly the network that we had been trying to convince cable companies they ought to be building. All the stuff we had wanted to do, in generalities, fit perfectly with the way applications were written, delivered, and used on the Internet. It was just an incredible accident. And it was patently obvious that the Internet and Java were a match made in heaven. (Byous 1998)

Java applets differ from most applications because they are placed on the network server rather than on individual client computers. They are downloaded to dispersed clients when they are requested.

The Virtual School

The Virtual School (VS) software took advantage of Java's unique capabilities. VS consists of a variety of familiar desktop applications that are combined and networked together to support collaborative group work (Isenhour, Carroll, Neale, Rosson, and Dunlap 2000). There are two main parts to the VS, client-side applications and server software that coordinates the client applications. Operating the software as intended requires individual PCs and software for each client and a central networked server machine with the server side software installed and configured.



To: briggs@linc.cs.vt.edu
Subject: Analysis section?
CC:
BCC: hunter@linc.cs.vt.edu

Bobby,

Audrey and I have finished the Conclusion and Data sections. When you get the last paragraph of the analysis section finished I think we'll be done.

James

Name	School	Address	When
Philip Isenhour	VT	128.173.116.28	10:54
Dennis Neale	VT	128.173.116.27	10:56
Daniel Fisher	VT	128.173.116.27	10:56
Xin Yu	VT	Not Present	

Notebook Name	Project	Owner
TEST GROUP's FC ...	Fall Collaboration	Test Group
PLI's Notebook	Fall Collaboration	Philip Isenhour
Testing	4th six weeks	Test Group
Test Group's Resear...	Full-semester research p...	Test Group

Tue 16:41 Shanan Gibson annotated "Background" in "Test Gro
Tue 16:41 Shanan Gibson edited section "Background" in "Test
Tue 16:42 Philip Isenhour annotated "Introduction" in "Test Grou
Tue 17:13 Philip Isenhour edited section "Introduction" in "Test G

Philip Isenhour: I'm going to start up netmeeting...
Shanan Gibson: Entered at 16:38 on 2/9
Shanan Gibson: we're back
Philip Isenhour: your back!
Philip Isenhour: let me shut down netmeeting
Shanan Gibson: Left at 17:03 on 2/9
Philip Isenhour: Left at 17:14 on 2/9
Philip Isenhour: Entered at 10:56 on 2/11
{Dennis Neale, Daniel Fisher}: Entered at 10:56 on 2/11

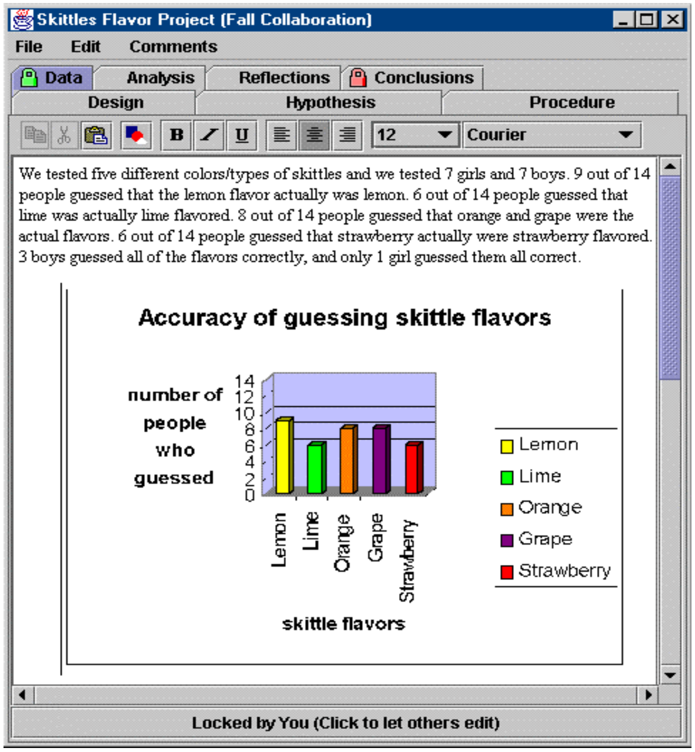
Philip Isenhour
Dennis Neale
Daniel Fisher

Figure 2.1. Key Virtual School components are shown: Email Client (left), Main Window (center), and Chat Client (right).

The client-applications consist of a main window along with several typical web-based desktop applications such as chat, video-conferencing, email, and some innovations of typical applications including a shared writing tool and shared whiteboard. The main window of the VS integrates the various components and coordinates the remote groups.

To use the VS, a user (student) or a small group of users clicks on an icon on the computer desktop. After a small wait of a minute or so, a login window appears that prompts for username, password, and (checkbox) whether it is a group or individual logging on. Once the user clicks on the "OK" button, the program loads the main window. Figure 2.1 above shows the main window, chat client and email client for the Virtual School.

This main window displays a list of all "members of your group" (and your group name). Members that are logged on are represented with colored icons while grayed-out icons represent members not presently logged on. Below that is a list of all of "your notebooks," and below that is a list of notices of recent changes to notebooks and emails sent. At the top of the main window is a set of buttons for "group chat," "video conference," and "check and send email." In order to begin a group session with remote members, users first clicked any icon/name of remote members that were logged on, and then click a button to initiate chat or videoconference. The email client functions regardless of whether remote members are logged on.



We tested five different colors/types of skittles and we tested 7 girls and 7 boys. 9 out of 14 people guessed that the lemon flavor actually was lemon. 6 out of 14 people guessed that lime was actually lime flavored. 8 out of 14 people guessed that orange and grape were the actual flavors. 6 out of 14 people guessed that strawberry actually were strawberry flavored. 3 boys guessed all of the flavors correctly, and only 1 girl guessed them all correct.

Figure 2.2. The Virtual School collaborative notebook is shown.

Figure 2.2 shows the heart of the VS, the collaborative notebook, which, beneath the surface, is a HTML text editor, disguised as a normal Windows-based text editor. It is much like typical word processors or text editors except without many of the advanced functions. The key difference is that the collaborative notebook allows users in different locations, that is, using different clients on different PCs, to edit the same document without downloading and uploading document files. Users did not ever interact with the

HTML source code, but they could add text and graphics similar to HTML web pages. Thus, the collaborative notebook functioned as a shared workspace with a shared product dispersed across common groups.

Like the collaborative notebook, the chat and email clients were developed within the project from existing Java components and tools, but the video-conferencing client relies on Microsoft Netmeeting to perform its function. The VS simply allows users to identify remote users for video-conferencing and initiate the application with one or two mouse clicks and without entering any Internet Protocol (IP) settings for the machines being used.

While video-conferencing was a major source of motivation and intrigue for the students to use the technology, as well as a major conduit for synchronous social interaction and situational awareness as discussed below, it was the greatest source of technical instability and complication for developers and users. Video transmission via Netmeeting requires particular point-to-point IP protocol and significantly more network bandwidth than text communication. Thus, it faced greater technical problems with firewalls, network traffic, and processor load than chat and email communication; however, it cames standard with licensed Windows software packages and required relatively little development to integrate. The use of video-conferencing within the VS was a tradeoff, one that has not survived the transition to MOOsburg.

Context of Use of the Virtual School

Over the five-year period of the LiNC project, teachers and researchers engaged in a range of activities related to the grant. In addition to student online collaborative projects and activities to investigate the goals of the grant, teachers and researchers discussed, gathered, and developed needs requirements, scenarios, evaluation plans, student project ideas, and prototypes for tools. A more detailed unfolding of these events and projects is described in Chapter Four.

The fourth and fifth year of the project focused on the use of the Virtual School. It was used mainly to support cooperative learning group activities. The fourth-year projects were of two basic types. Short-term activities were generally types of lab activities that asked students to design and carry out an experiment as a group. The long-term activities were more involved projects that typically asked students to choose a topic to research as a group and to produce a report about the history and scientific principles involved in the topic. For example, some students who chose aerodynamics studied kites. Other students studied bridges and created models of a bridge out of toothpicks. Long-term projects were relatively open-ended compared to the shorter-term experiments. These often had a mentoring component that used professors to help students with the projects. The fifth-year long-term or “year-long” projects employed Lego® Dacta™ materials. These included a set of structured materials including directions for building machines and mechanisms with Lego® and structured questions to guide students through the learning activities. These were also explicitly set up as a mentoring relationship among the remote groups with older students “helping out” the younger ones.

The software supported a variety of functions for the projects. First, it was a means of assigning and organizing the students into groups that crossed classrooms. In many cases, students had never physically met some of the members of their group since they were located in different classrooms across the district. Once teachers and investigators had formed groups, these groups were entered into VS according to location so that when a student logged-in to the VS as a group, the VS was able to recognize other members that were on-line and display their presence accordingly. After they were logged-on, the group was able to initiate on-line communication (chat, email, and video-conferencing) with each other. They could also edit the collaborative notebook after logging-on. For the Lego® projects we further adapted the collaborative notebook so that they contained structured questions provided with the Lego® instructional materials. The students then used the notebooks to type in answers to be shared with and assessed by remote team members. The notebooks also contained scanned images of pictorial diagrams provided with the Lego® instructional materials that helped describe how to construct the Lego® machines.

With only about five computers in each of classrooms, groups often had to trade-off. Sometimes this meant that teachers had to assign other activities for those not using the computers. In most cases, students were formed into collocated student groups (groups of two to four students in the same classroom) that were joined with groups from other remote classrooms. This meant that the total number of students working on a single project might be as many as seven or eight. This created a number of challenges for the participants and software that are discussed in detail in Chapter Four.

MOOsburg

MOOsburg evolved through three distinct iterations of technical development. It was originally suggested by Carroll around the Fall of 1995 as a course project for a group headed by John Kies, an Industrial and Systems Engineering (Human Factors) graduate student at Virginia Tech (Kies, et al. 1996, Carroll et al 2001, also see Carroll, Rosson, Isenhour, Ganoe, Dunlap, Fogarty, Schafer, and Van Metre 2000 for a summary of the early vision and development). The first iteration was based on telnet technology prominent in the early 1990's. Telnet provided an efficient and standardized means of transferring information and interacting using simple text. Because it allowed users to send text commands to remote networked computers, telnet technology became useful for library catalog lookups and similar systems that queried databases and information systems. Because telnet allowed multiple users to query, send commands to, and respond to computer systems, it became useful to developers and users of network games and interactive tools that could be based on textual commands and responses.

By the early 1990s, Multi-User Dungeons/Domains/Dimensions (MUDs) became popular for a relatively small group of network computer users interested in designing interactive virtual communities and playing games using telnet technologies. These were used often in role-playing games (RPG) such as the popular computer versions of Dungeons and Dragons. This development sphere arose out of single user video games on computers that placed "gamers" in fictitious "roles" within virtual environments and allowed them to move about in the environment using textual commands. For example, the program might begin by providing you with a statement like "You are standing on a street corner in a small city. You see a door in front of you and a piece of paper on the ground. You can go left, right, or forward." The user then typed some specific command in order to proceed, such as "Pick up the piece of paper," "Go right," or "Open the door." Then the program responded with either something like "I don't understand that command," where the syntax was incorrect, or with a response that "moved" the user to another virtual location or described an interaction with that environment like "The piece of paper you picked up is a map of the city" and so on. Programmers adapted these games for use with other remotely located users on networked computers using telnet technology in order that the program could be run by multiple users in ways that allowed others to interact with users and "objects" within the virtual environments or MUDs. Programmers developed games and spaces that allowed objects in the MUDs to be modified and virtual spaces added by users. Over time, MUDs that allowed such user interaction, authoring, and manipulation of objects became known as MOOs (MUD Object Oriented). Pavel Curtis at Xerox PARC (Palo Alto Research Center) (http://www.parc.xerox.com/parc-go.html) created the first MOO, LambdaMOO (lambda.moo.mud.org:8888) in 1991. There have been hundreds of MOOs created since then, and many are still in operation today. See Rachel Rein's web page at http://cinemaspace.berkeley.edu/~rachel/moo.html for links to comprehensive lists, explanation, bibliography, and vocabulary associated with MOOs.

The first and second iteration of MOOsburg relied on traditional text based MOO server software (Jay's House MOO; http://jhm.moo.mud.org:7043). Initially, MOOsburg was purely text based and supported hundreds of users. Unlike most MOOs that were designed to connect users from very distant locations, MOOsburg was targeted at users within the local town of Blacksburg Virginia. It was based on real locations and community groups within the town, but it also served as a means for keeping former and distant residents in touch. While many MOOs reserved certain access privileges to MOO "wizards," such as the ability to create new objects and places, MOOsburg programmers intended to blur this line between users and creators of the MOO. Thus, many programming abilities were made available to ordinary users. It had no central organizational initiative, but development progressed through locally distributed groups such as the members of the Science Fiction and Fantasy club and local residents of Blacksburg.

In the mid 1990s on to the present, some MOOs remained tied to telnet text commands, but with advances in web and html technologies, many MOOs went beyond simple telnet text by supplementing and enhancing cumbersome text messages with graphics. These hybrid MOOs are sometimes referred to as Sprawls (see http://erp.fis.utoronto.ca/~easun/infomoo/figment/search.htm). In 1997, another Computer Science graduate student at Virginia Tech, Craig Struble, introduced the sprawl version of MOOsburg by adding a supplementary web-based interface to the text MOO (http://moosburg.cs.vt.edu/). This development followed other MOOs like BioMOO (http://bioinformatices.weizmann.ac.il/BioMOO/) and Diversity University (http://www.du.org/) that had shown success in educational domains. This second iteration of MOOsburg maintained the telnet text basis, but it also made use of Java technology, specifically the CupOmud Java client (http://www.du.org/java/CupOmud), to support a Web-based user interface to advance the textual MOO. The graphic Java-based interface allowed users to access Web pages corresponding to text-based MOO locations. Soon after this new interface was added, Cara Struble, wife of Craig Struble, developed a map of the town that allowed users to navigate to the virtual space associated with those locations. These spots were basically point-and-click hyperlinks to associated MOO locations and corresponding Web pages. Thus, images became directly associated with MOO locations, so, for example, pictures of Main Street accompanied text commands to move down the street.

Other important MOOs or Sprawls retain this dual character of textual MOO enhanced with graphics. Lingua MOO (http://lingua.utdallas.edu/) focuses on supporting teachers and researchers in virtual communities. It is hosted by the University of Texas at Dallas and is typical of textual MOOs supplemented with some graphics for navigation and description. The text and images are well integrated in one main browser window with two halves, text on left and images on right. Tapped-In (http://www.tappedin.org) represented perhaps the most prominent MOO of this type and also focused on the educational community. When users entered the Tapped-In environment, an image provided a map of a virtual building in a window on the left of the users' screen, and on the right was a list of available objects or items that were hypertext. The whiteboard, for example, was a bulletin board list of text items available for other users to see. Another example of an object is a “recording vendor,” a vending machine full of tape recorders that served as lists of web sites, transcripts, or other textual items for distribution to others. When a user clicked on an object to create it, the object was put in the user's “pocket” to carry around. Most items simply consisted of containers for text. Other items included containers for audio clips and survey tools. Recently, Tapped-In has been transitioning to a new Java-based interface that consists of a single window that combines the clickable graphics navigation area with the chat.

Some MOOs have left the text interface completely and so retain the title “MOO” in name only. Like MOOsburg, it the historical continuity of identity within technical development through which they correspond to MOOs. For example, Amy Bruckman began MOOSE Crossing at MIT as text-based programmable MUD for children. This inspired the development of Pet Park (http://el.www.media.mit.edu/projects/petpark/), a graphical “MOO” built with YoYo, a Java-based programming language designed for specifically for children. Pet Park uses cartoon like graphics and allows children to define behaviors for avatars and create interactive simulations, animated stories, and video games (Bruckman 1998, Bruckman and Resnick 1995). While MOOs like Pet Park are considered “graphical MOOs,” they are technically very different than telnet based textual MOOs. They are not text based MOOs at all. They are, nevertheless, shared virtual environments or collaborative systems but with purely graphical-based interfaces rather than textual commands-based interfaces.

Many so-called graphical MOOs are not MOOs at all in the technical or traditional sense. Traditionally MOOs are text-based virtual environments with telnet interfaces, but many graphical MOOs today make no use of text-based telnet interfaces. They are, nevertheless, interactive virtual environments but with graphical http interfaces. Infomoo (http://erp.fis.utoronto.ca/~easun/infomoo/figment/search.htm) provides an overview and assessment of graphical MOO types including sprawls. Many graphical MUDs still continue in the tradition of interactive role-playing games (RPGs; for a listing, see http://www.mudconnector.com/mud_graphical.html); however, Visual Chat represents another type of interactive virtual environment that has risen to a popularity that far exceeds RPGs or MOOs. Visual Chat grew out of much of the same desire for social interaction as seen in the early development of MOOs. Many people logged on to MOOs for general social interaction rather than as a way to play games.

Visual chat utilizes much of the same features as standard chat tools like AOL instant messenger (AIM). When users enter or logon, they chose or are assigned a username with a password. In AIM, users send text messages to other users that they find or already know. In most visual chats, users are assigned a default avatar, choose from a collection, or download their own graphical representation as their avatar. Username usually appears attached beneath the avatar. When users log on, they go to or "join" virtual environments or rooms where they can see the avatars of others and chat using text. Sometimes the chat appears in a "bubble" by the users' avatar to indicate its source. Visual chats often place the avatars among background images in order to provide the feel of being in a place with others. Many use standard software like ThePalace (http://www.thepalace.com) to create the visual chat environments (see http://www.west.net/~starfire/palace.htm and http://www.reality-online.com/). These employ two-dimensional graphics that often simulate three dimensions using perspective. Perhaps the most popular is On Chat (http://www.onchat.com/) with hundreds and sometimes thousands of users at any given time. Other visual chat environments like Visual Chat (http://www.geocities.com/SiliconValley/Program/3996/chat/chat.html) provide a more three-dimensional representation of the rooms. Visual chats are almost exclusively for social interaction and are often associated with "cyber-sex," interaction focusing on sexual fantasy and role-playing. The latest iteration of MOOsburg borrowed features from graphical MOOs and visual chats. Among these is the use of movable avatars to represent a user in the space, the use of bubble chat to indicate when a particular person is typing, the use of background graphics and pictures to represent the space, and the use of variable size of avatars depending on placement on the background to simulate 3-d perspective in the virtual space.

Putting in the CORK

From 1997 through early 1999, MOOsburg entered a relatively dormant period with respect to development and use. Email and chat had become the prominent means of Internet communication, and MOOs had lost much of the appeal they once held. However, web technologies were rapidly advancing. Computer processing power and Internet quality, traffic and speed were increasing dramatically. By spring 1999, Philip Isenhour, chief developer for the Center for HCI and a former Computer Science graduate student, had completed a masters' thesis aimed at implementing an innovative infrastructure for efficient server-based replication of Java objects. The technology became the Collaborative Object Replication Kit (CORK; Isenhour, Rosson, Carroll 2000).

The innovation of CORK lay in the ability to capture and distribute changes made to client side objects. An object represents any of a number of client side applications that require input from users and provide some output to users. A Java-based text editor is a typical object under the CORK scheme. With CORK, objects that typically require input from a single user can be made collaborative through an efficient means of capturing and coordinating changes made to each clients version of the object. Collaborative tools often require that the document or object being manipulated by multiple users be completely transferred each time it is edited. In simple terms, CORK allows a way to transfer *just* the changes. The server stores the core of the object. The object is replicated for each networked client requesting use of the object. If any client makes a change, the server receives the change, changes the core object, and then distributes those changes to each relevant client side object. Each client object has the ability to assimilate the changes in the correct way since each change sent to the server comes packaged with pertinent information about where and when it was generated and which object it corresponds to. By encoding each change to an object located at the server in this way, multiple synchronized copies of objects are possible without cumbersome downloading of entire files or copies each time there is a modification.

The initial implementation of CORK was in the creation of the Virtual School application. By summer 1999 the third iteration of MOOsburg was implemented using the CORK infrastructure. This version updated the MOO with room views rendered as html and a graphical gif version of the map that allowed point-and-click navigation to the different virtual spaces in the MOO. This version required users to download a program that was run each time the user chose to enter MOOsburg.

In Spring 2000 a new user interface was implemented in MOOsburg. This iteration used Java 1.2 exclusively, so it did not require any special download of software other than the Java applets associated with the application. None of the rendering was done with HTML. The program was for the first time available via a standard Java equipped Web browser. This accompanied a flurry of new development and activity around the application. Isenhour began incorporating many of the tools of the Virtual School into MOOsburg, and Carroll began a series of grant writing to support development and extension of the application to old and new areas of interest. Rosson also reintroduced development of tools for the application in her graduate Computer Supported Collaborative Work (CSCW) class in spring of 2001. In these grants and development efforts, the line between the Virtual School and MOOsburg began to blur considerably. Part of this was on purpose, in order to avoid confusing reviewers while leveraging prior development work and publications; however the blurring was partly an historical artifact of the technical development that was not foreseen by anyone.

Technology Transfer [3]

The transfer of technology to and from the LiNC project is also complex and hard to pinpoint. There were many programmers involved with the development of the technology in various ways, but there was a central person and a technical object that stands out as crucial to the development of the Virtual School (VS) and beyond: Isenhour and CORK. CORK was the technical infrastructure that enabled VS and the third iteration of MOOsburg developed mainly by Isenhour, which was based largely on earlier systems developed by Isenhour and Begole. However, they did not set out in the beginning to develop CORK. Rather, they "backed in" to it through a series of circumstances that were not anticipated in the development of another tool they called Sieve. In the course of developing the software, they explicitly challenged their own understandings and training. They realized in the process of their work that their training in programming had implications to some of the issues that they were attempting to re-think and ameliorate. Isenhour explained the roots and implications of the processes in the technical development of CORK in great detail:

> There are basically two related issues:
>
> The first is the issue of how to make components collaborative. The mechanism used by other toolkits was to provide collaboration-aware replacements for standard components like buttons and text fields. Instead of using or subclassing (inheriting from) the standard TextField class, you would instead use or subclass something like a toolkit-provided "CollaborativeTextField" class, which worked just like the standard TextField but added collaborative functionality.
>
> This approach works great if you are writing a new application from scratch, but you quickly run into problems if you are trying to convert an existing single-user application for collaborative use. If you don't have the source code, you're out of luck. If you do have the source code but don't have the resources to do the conversion manually, you're also in trouble. Finally, if the application didn't use the standard classes that the toolkit provides replacements for, then the toolkit doesn't help you. (e.g., if the original designer didn't like the standard Java TextField class and decided to write his own.)
>
> [Java Applets Made Multiuser] JAMM [see below], among other things, provided a very clever solution to the first two problems (no source code or no developer resources). Like the other toolkits, JAMM provided a set of collaborative equivalents for standard components. The difference was that the standard components could be automatically replaced by collaborative equivalents at runtime (rather than in the source code), so you didn't need the source code and didn't have to do anything manually.

---

[3] For most of the technical descriptions contained here, I am deeply indebted to Philip Isenhour (cited as Isenhour 2001, Isenhour 2002, and numerous informal and casual communications with Isenhour throughout the years of 2000 and 2001 that are not cited).

Inheritance, however, caused problems. Because of the inheritance-based nature of Java, JAMM could only replace standard components that hadn't been subclassed. So, for example, if I used a standard TextField in an application, JAMM would find it and replace it with something collaborative. If, on the other hand, I had subclassed TextField in the original application to make a NumericTextField (which, e.g., only let the user type numbers), JAMM wouldn't help.

Sieve (and eventually CORK) got around this general inheritance problem by using composition rather than inheritance: Rather than implementing a replacement for TextField, we implemented a “listener” that could be attached to the text field and would then detect changes and propagate them to the other replicas. The implication of this was that you didn't have to use a different set of widgets -- the standard ones could be used “as-is”. You still generally had to write code to attach the appropriate listeners, though a JAMM-style mechanism for automating that attachment is certainly plausible (and, in fact, proposed in Bo's [Begole] ToCHI paper [Begole, Rosson, and Shaffer 1999] before we'd really thought this through for CORK). Finally, (continuing the example from before) it didn't matter if the listeners were attached to an instance of TextField or a custom subclass like NumericTextField.

This sounds nicely planned and analyzed, but of course it wasn't. This gets to the second issue, the “backing into it” part.

The idea of doing collaboration support with composition (attaching listeners) was prompted primarily by the introduction into Java of the “JavaBeans” architecture, and in particular of a feature of JavaBeans called “introspection”. Introspection was a means for getting and setting atomic “properties” of arbitrary objects at runtime, without any a priori knowledge of the objects. So, for example, a java object could get and set the contents, font, and color of a TextField without knowing exactly what kind of object it was acting on. Furthermore, such an object could listen for changes to these properties, again without any specific knowledge of exactly what kind of object it was listening to.

This functionality was conceived by Sun as a mechanism for use by software development tools, but somewhat accidentally provided a means for writing a single implementation of a generic listener that could detect and replicate property changes for “lots” of kinds of objects. Replication by listener attachment would have been possible without this kind of generality, but one would had to have written a specific listener implementation for each kind of object that you needed to listen to. This was potentially a much more daunting task than just writing a collaborative implementation of a TextField or other widget.

Once we had a generic way of replicating arbitrary property changes on arbitrary objects we designed the communication mechanism for passing this information around. Basically this consisted of a means for passing messages containing the (object-identifier, property-name, new-value) triples among the clients. When a

> property change on a given object was detected, one of these messages was created and broadcast. When received, the appropriate object was found and introspection used to set the named property to its new value.
>
> Of course, once we had this working we began seeing lots of things that the generic atomic-property-based mechanism could not handle easily. List manipulation, for example: operations like adding, removing, and modifying objects in a list cannot be efficiently modeled as changes to an atomic property. Basically you need to send a message with something like (object-identifier, list-item-identifier, add-or-remove-or-modify, value), where "value" is only appropriate for add or modify.
>
> This realization resulted in a significant change. Since different kinds of messages now described changes that had to be applied in different ways, we moved the logic for actually applying the change into the messages themselves. This is the "smart messaging" part -- messages were no longer wrappers around three pieces of data that Sieve pulled out and acted on, but were instead "black boxes" that Sieve could just point at the appropriate object and have them make whatever modification they knew how to make.
>
> Unfortunately we also made what in hindsight was a significant design blunder. Much of the underlying Sieve communication mechanisms had been written with the original kind of messaging in mind, so we implemented new kinds of messages as refinements to the original kind. This was equivalent to saying "a train engine is a truck that is fueled by coal, has steel wheels, and runs on tracks". It's not wholly inaccurate, but a little bit of abstraction (e.g., the notion of "vehicle") would allow a more elegant representation. This was really clear only in hindsight, so I downplayed this in the thesis and fixed it in CORK. (Isenhour 2002)

Isenhour's description revealed the fluidity of the social and technical boundaries of artifacts in a number of ways. First, the presumably technical constraints were not purely technical. The need to convert existing single-user applications for collaborative use comes from a desire to leverage previously made widgets and applications, that is, to avoid the need to write new collaborative components to replace the single-user components. This was made possible by designing the "listener" mechanism that was relatively generic to Java objects. The way this was achieved as a "composition" move rather than a "subclassing" move was constrained by the "inheritance-based nature of Java" which had important roots related to how programming was taught and learned in U.S. versus European programming cultures described below. Second, Isenhour's vividly described the twists, turns, and "design blunders" that reveal the important differences in the design and planning in the development processes and the hindsight afforded by the outcomes of the design and production. This hindsight had ramifications to other modes of description of the work, and in its analysis it made clear the non-linearity of the production processes. Further explanation should make this more apparent.

Sieve

As mentioned above, some of the early ideas that lay the basis of CORK were developed in a technology called Sieve which stands for Collaborative Interactive Visualization, a phoneme for the acronym CIV (Isenhour, Begole, Heagy, and Shaffer 1997). This was a class project done by Begole, Isenhour, and Heagy for Rosson's CSCW course. Basically, Sieve was a prototype Java-based collaborative desktop computer workspace where users could configure components representing data-flow for visualization purposes. It allowed a shared view and collaborative manipulation of the workspace and components. The architecture of Sieve made use of JavaBeans functionality to allow collaboration and collaborative awareness by replicating and distributing instances of the workspace for real-time and dynamic collaborative editing. Sieve took advantage of the property change mechanisms (e.g. position or color of a component) in JavaBeans. It was this idea of efficiently replicating various distributed instances of the application using JavaBeans, without reproducing the whole application, which set in motion many of the ideas for the development of CORK and thus the architecture of the Virtual School and MOOsburg III.

However, as Isenhour explained above, it was not a case of a traditional linear "stepping stone" model of development. Rather, the developers later realized Sieve to be a specific case of a more general type of object-change replacement. First, they did not begin with the overall goal of creating a generic way to efficiently replicating Java objects. Second, they did not begin with the most general case and work toward more specific and particular cases. Using JavaBeans functionality became a special case of the notion of having "smart messages," messages that "knew" (i.e., carried contextual information and behavior) about how to efficiently reproduce changes to distributed object replicas (Isenhour, Begole, Heagy, and Shaffer 1997). Interestingly, this process of "backing into" the more general case used by CORK was downplayed in Isenhour's Master's thesis (Isenhour 1998) precisely because it did not fit the standard model of development and, as Isenhour explained above, was only apparent in hindsight. Isenhour approached the description of the system from a end-result system perspective rather than from a perspective that detailed the history of the development process.

This standard model is exemplified in the notion of "inheritance," a feature of object oriented software design that relies on hierarchies of classes of software entities with behaviors specific to those classes. Understanding JavaBeans as a special case of "smart messages" represents a counter-instance of standard models of technical development. Another important example of the process of discovering the limitations of the standard model of development concerns a related technology developed by Begole with help from Struble. The application, described by Isenhour above, was called Java Applets Made Multiuser (JAMM). Both exemplify differences in the ways that object oriented programming is taught and developed in the U.S. as opposed to Europe.

Carroll also described the development process as haphazard and counter to traditional linear accumulation models of technical progress. In describing the development of MOOsburg, Carroll explains,

> We kind of backed into it. We had MOOsburg, but we had the wrong implementation and kind of just stole the foundation from LiNC [the VS] and remade MOOsburg as a spawned-ant from LiNC. And now it kind of encompasses LiNC, but I think that was the right way to go. I think that the way we were going with the web-based MOO there is no future really for that. There is simply an inherent architectural limitation of MOOs; namely, they're basically mainframe dialup services, and they produce a kind of a stream of text… and that's just not the paradigm for network communication anymore. It doesn't work like that. Nobody expects that. You can't do enough with that, and I think it's been verified…I think it is the right thing to replace MOOs. (Carroll 2001c)

JAMM, Culture, and Subclassing

JAMM was an ambitious project that focused on a general problem of allowing collaboration or "sharing" using Java components. JAMM was a result of work that was being done at Sun by Randy Smith. Several applications directed by Smith helped demonstrate the feasibility and functionality of using Java to support collaborative work (Rosson 2001). For example, Smith's Alternative Reality Kit, Radar Panes, and especially Kansas paved the way for Begole and Struble's work with JAMM. The work and mentoring from Smith was part of a co-op experience for Begole and Struble at Sun's JavaSoft division during the fall semester of 1996.

Systems are referred to as "application sharing" when they allow two or more users on different computers to access and edit applications. They are "transparent" when the mechanisms that enable such sharing are not seen or known by the user. JAMM was an alternative approach to collaboration transparency, one that provides a more flexible and practical system for sharing Java-based applications (Begole, Rosson and Shaffer 1999).

Previous conventional application sharing systems have several limitations that JAMM attempted to address. One key feature that was retained in CORK was the ability to provide individual views of the workspace for the distributed users. Collaborative systems commonly provide only one view of the workspace for all collaborators. That means every distributed collaborator sees the same view. This is referred to as strict What-You-See-Is-What-I-See (WYSIWIS). Such systems usually share a pointer such that others must trade control of the space among collaborators. JAMM not only allowed a relaxed form of WYSIWIS, but also provided group awareness, information about what other distributed collaborators were doing in the workspace.

Begole, Rosson and Shaffer 1999 described key limitations of JAMM that served as an important lesson in the development of CORK. The general strategy that allows objects to be updated or replaced according to distributed changes does not allow subclasses of replaceable classes to be replaced. To avoid this general problem, CORK relies on a method of sharing that uses composing rather than subclassing. As the term implies, composition relies on combining objects in such a way as to extend their behavior or make objects aware of each other rather than sub-classing them.

The different method reflects a cultural difference in the way object oriented programming is taught on different sides of the Atlantic. In the U.S., object oriented design focuses on inheritance or subclassing, whereas in Europe the focus is much more on composition. This means that there is greater emphasis on designing classes with "hinges" such that parts of their behavior can be plugged interchangeably into others. In Europe, Simula is the main object oriented programming language taught. In the U.S., C++, the object-oriented form of the language C, is taught.

Object-oriented programming began in Europe in the early 1960s with systems such as B1000 and Sketchpad. Nygaad and Dahl developed Simula at the Norwegian Computing Center in the mid 1960s, and a later version, Simula 67, became the first language with "objects" and "classes" around 1970. Alan Kay with the help of others at Xerox PARC developed Smalltalk throughout the 1970s and introduced a completely object-oriented language, Smalltalk 76; in the early 1980s, Smalltalk 80 became commercially available. Kay learned to program in Simula and to use Sketchpad while at the University of Utah. Incidentally, Kay is also credited with helping to conceive the lap top computer and GUI windows. The development work with Smalltalk provided a basic foundation for later object-oriented languages like C++ and Java. Moreover, Smalltalk is not incidental to the LiNC project. Carroll and Rosson became involved in research with Smalltalk in the early 1990s just prior to their arrival at Virginia Tech. With them, they brought interest and knowledge of object-oriented programming that deeply influenced the LiNC technology development (e.g. see Rosson and Carroll 1996).

The reliance on the C++ programming language in object oriented software design is one of the main reasons that inheritance hierarchies are so important. Objects in programming can be specified so as to conform to hierarchies of classes of objects, where each subclass carries the characteristics of its parent class (as with the hierarchy of vehicle – car – sedan). C++ allows numerous ways for creating object subclasses. For example in GUI libraries, a hierarchy might consist of component – container – widget. A container is a type of component that can contain things, and widgets (buttons and things) are a subclass (retains all of the characteristics) of containers. This suggests a model for designing software: Specify component, then specify containers, then specify widgets as types of containers.

As Isenhour alluded to above, there were two basic approaches or alternatives to designing a collaborative component, for example, a text field. The first approach was employed by JAMM. It relied on attaching collaborative behaviors lower in the hierarchy, for example writing a collaboratively aware or shared text field and using that component instead of the text-field component normally employed in the application. CORK took a different path. It attached collaborative behavior more globally by employing the "listener" used to detect changes made to components and invoke methods to update replicas from remote changes. These methods could apply to components regardless of their level in the hierarchy of classes, hence the advantage in this context of composition over replacing or subclassing. This had the advantage of allowing for the creation of components above or below the collaborative fields, as in JAMM, without worrying about their position in the hierarchy.

Isenhour described CORK as an example of replicating that was not dependant on class hierarchy. Rather than starting from the top of the class hierarchy and working down, they "backed into it." Rosson described it as a "bottom-up" approach to programming. As Rosson put it, methodologies teach "top-down," but if the domain is unfamiliar, it is hard to innovate using established methods. So you often begin with specific cases, and then generalize from them (Rosson 2001). Accordingly, Isenhour claimed that the next step would be to try to use these run-time replacement mechanisms of JAMM, "attaching" collaboration behavior to objects using CORK in a "composition" fashion rather than a replacement or subclassing fashion.

PEPPER, CORK, and Sun

Prior to the implementation in MOOsburg and prior to receiving its name, CORK was used for less serious ventures than the VS. Frustrated with the limitations of the AOL Instant Messaging (AIM) system, Isenhour and Begole used CORK to create their own instant messaging (IM) system. PEPPER was used to keep their circle of friends updated on social gatherings, general communication, and other social events. When Begole left Virginia Tech and moved to Sun Microsystems, he took with him ideas that were fundamental to CORK in the form of PEPPER. At Sun, he worked in a development team where they extended PEPPER to create a research prototype IM system for the workplace called ConNexus (Tang, Yankelvich, and Begole 2000). ConNexus features a variety of mechanisms unavailable in AIM, including awareness information about availability to chat and calendar appointments, and integration with other communication resources such as phone, email, and conferencing.

Summary

I began this chapter by exploring ways of understanding "technologies" in terms of the work done in their production and use. I followed many others in suggesting that internalist approaches to technology studies tend to focus too narrowly on technical innovation at the expense of describing contextual and social factors critical to technical production and use. On the other hand, externalist approaches err on the other side and, as such, miss many critical concerns that directly relate to the technical work done in the production processes. In an attempt to maintain a healthy balance, I situated the work of developers in the larger technical infrastructure that participants take to be critical to their work. I described various ways that the infrastructure on which the LiNC technology was built involved social constituents as well as technical objects and practices.

The Internet and related technologies were, obviously, crucial to the development of the technical objects produced in the LiNC project, but the respective development of these technologies was not linear, simple, or anticipated. The diagram below (Figure 2.3) representing the heredity of the technical objects produced in LiNC project is misleading. While it illustrates some of the numerous dead-ends and offshoots, it suggests a finished history. Developments currently taking place and those to come might render this mapping obsolete. In fact, even today the technologies are being reconfigured for different purposes and uses even in similar contexts, for example, teaching, education, and local school classrooms. Thus, even MOOsburg III was a contingent and temporary ending point. The new developments will entail a reconfiguring of the timeline below. Some of the elements, like Telnet, will become even more peripheral and historic while others, like Java and HTML, will become more central.

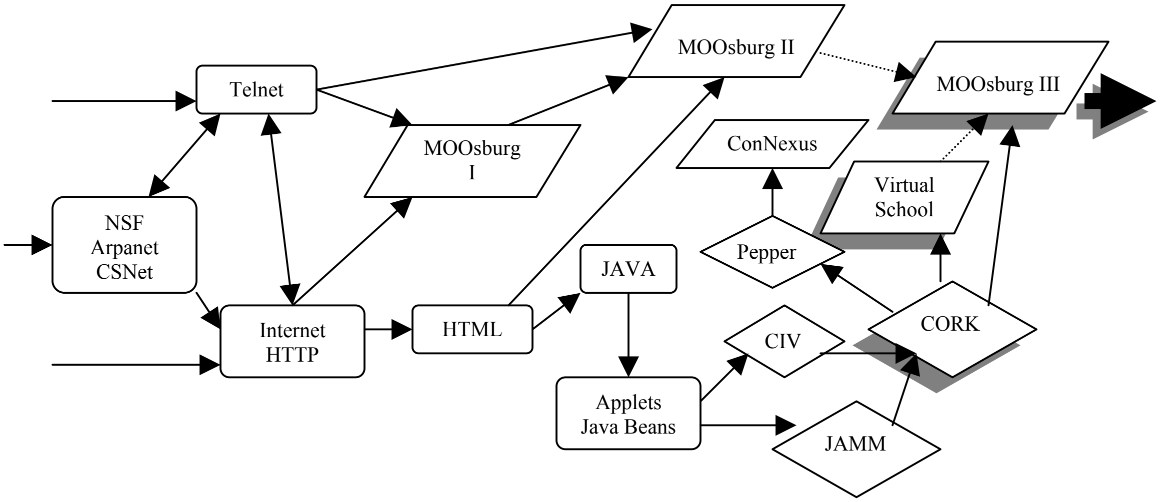


Figure 2.3: A diagrammatic non-linear time-line of the technical associations of elements in the development of the major components of LiNC technology, CORK, the Virtual School, and MOOsburg III.

Moreover, different groups viewed these developments as instrumental in different ways. For Carroll and Rosson, the transfer of technology from corporations and industry was vital to maintaining a legitimate research program for the Center for HCI; however, they are quick to distinguish university research and development and technology development in business and industry. Academic research is “by nature exploratory and ad-hoc.” It is “creative” and “opportunistic” (Rosson 2001). A critical judge of good technology development was how well it advanced a research program, how well it fit into other contemporary research, and how well it generated successful publications and grants.

For Isenhour, the development process was much more intrinsically motivating. For example, Pepper was conceived and developed for “fun.” It was not strictly part of any academic or work venture. Rather, it was a way to facilitate and organize the social events of the group of friends. I seriously doubt that Isenhour would have done this work unless he found it personally exciting and rewarding to develop interesting applications. Of course, that perception should not be taken to exclude the view of Carroll and Rosson because part of the judgment of the development was how well it was received by others, including Carroll, fellow developers, investigators, journal reviewers, grant reviewers, and teachers.

For the teachers, the technology was viewed in different kinds of instrumental terms. They had little awareness of or interest in the inside of the "black box" that was the hardware, CORK, and the related source code or technical development. They were mainly concerned with what it allowed students to do particularly that was motivating and educational for them. This was difficult to ascertain, but a key part of that was how well it was received by the students, how much they enjoyed the activities, and how much it encouraged the students to engage learning goals. Again, this should not be seen as wholly independent of the other instrumental concerns mentioned above. The kinds of things that excited and motivated students were situated in a social context of computer technology use. For example, what excited these students, video conferencing, chat, and so on, will most likely appear mundane and boring to students in the future. The boundaries and interactions of these groups was fluid in the sense that the categories and contexts that emerged were part of a larger cultural context of computers and development that emerged in the 1990s out of a complex set of technical and social developments, but these boundaries and interactions were also a function of shifting and changing knowledge and experiences of individuals that comprised the different groups.

In this chapter, I described how network technologies developed in social and technical circumstances. The development of Telnet technologies enabled the earliest iteration of MOOsburg and initiated much of the focus of the later developers on object-oriented programming and networked computer collaborations. I described some of the roles of political and economic interests in establishing protocols and programming languages that became crucial to the working and development of Internet technologies, including TCP/IP, Telnet, HTTP, HTML, and Java. In doing this, I showed how different groups provided alternatives and interacted to shape the technical production in LiNC project. I described the importance of the role that the transfer of technology in among developers and researchers influenced the design and architecture of the LiNC project technologies through the education and work of various developers and directors. The focus in this chapter was on the development of the technical objects produced in the LiNC project, the infrastructure in which they occurred, and the twisted and shifting paths that shaped their heritage. In the next chapter, I focus more on the political and social context out of which the LiNC project grew.

Chapter 3: The Policy and Funding

"[T]he technologies which give form to political principles are themselves shaped by the exercise of political choice and the struggle of competing political interests. The kinds of technology we have, and therefore the kinds of values and principles which can be articulated, are products of a political process, whether in their theory, their design, their implementation or their regulation." (Street 1992, p. 197)

Introduction

In the previous chapter, I describe the technical objects produced in the LiNC project and the infrastructure that enabled their development. That description focused on computer network technologies produced in a wide range of contexts and organizations including military, academic, as well as less organized and more dispersed commercial groups and individual programmers. Development of this socio-technical infrastructure was largely supported by national initiatives that funded large grants aimed at supporting diverse computer networking and information technology projects. These same national initiatives funded programs focused on applied research and development, many which were targeted toward education programs. The National Information Infrastructure (NII) initiative spawned and nourished many NSF programs, investing millions of dollars targeted at developing technology for the "information age." Among them was a key program focused on directly on technology for education called the National Infrastructure for Education (NIE). This was the primary source of funds for the LiNC project.

I describe the broader political context of the late 1980s and early 1990s that surrounded the NII, NIE, and ultimately the LiNC grant. The national crisis rhetoric aimed at education reform in the U.S. represented a climate of public fear that embraced hope that information technologies could ameliorate U.S. educational deficiencies and make U.S. students more internationally competitive and economically productive. Developing Internet technologies and infrastructure was central to that vision, so millions of dollars were dumped into programs promising to produce these technologies for educational purposes. At the same time, Human-Computer Interaction (HCI) had emerged as a field in its own right from sub disciplines of Human Factors engineering, computer science, and behavioral sciences. The field drew from a wide range of experts in psychology, social sciences as well as computer science and engineering. Universities like Virginia Tech supported new leaders in social science and computing who aimed to establish programs and centers that would expand the new field. This chapter describes the political context of the LiNC grant and project, focusing on the intersection of political forces, especially the NSF, NIE, and the Center for HCI at Virginia Tech.

1980s Crisis of Education: "A Nation At Risk"

The epitome and climax of national education crisis rhetoric came in the early 1980s with the publication of a congressional report named "A Nation at Risk." This report outlined the need for extensive reform of U.S. education in order to meet international competition for the emerging workforce (U.S. Senate 1983). The report does not mince words. It invokes strong rhetoric that has become a mainstay for educational policy. Among such polemic, it warns that “history is not kind to idlers,” and “the world is indeed one global village.” The alleged “risk” reported by the authors is a particular new kind of productivity that is at stake, productivity slightly different and more recent than that of the industrial revolution. According to the report, the new productivity requires training the future workforce in computer and information technology so as to enable the U.S. to compete better with foreign powers in “knowledge” production. It urges the federal government to take steps to insure that the U.S. lead the world in technology development for the impending “information age,” computers and their related infrastructure.

> The risk is not only that the Japanese make automobiles more efficiently than Americans and have government subsidies for development and export. It is not just that the South Koreans recently built the world's most efficient steel mill, or that American machine tools, once the pride of the world, are being displaced by German products. It is also that these developments signify a redistribution of trained capability throughout the globe. Knowledge, learning, information, and skilled intelligence are the new raw materials of international commerce and are today spreading throughout the world as vigorously as miracle drugs, synthetic fertilizers, and blue jeans did earlier. If only to keep and improve on the slim competitive edge we still retain in world markets, we must dedicate ourselves to the reform of our educational system for the benefit of all--old and young alike, affluent and poor, majority and minority. Learning is the indispensable investment required for success in the "information age" we are entering.

The report points to certain indicators of deficiencies in the schooling students in information and related technologies. In this rhetoric, the production of “science” and “technology” are conflated and tied closely to education. The major assumption is that better preparation of “the average” student, not just the elite, in traditional fields of science (Biology, Chemistry, and Physics) and math along with more experience with information technology tools, will produce more competitive U.S. technology and markets.

> These deficiencies come at a time when the demand for highly skilled workers in new fields is accelerating rapidly. For example:
>
> - Computers and computer-controlled equipment are penetrating every aspect of our lives--homes, factories, and offices.
>
> - One estimate indicates that by the turn of the century millions of jobs will involve laser technology and robotics.
>
> - Technology is radically transforming a host of other occupations. They include health care, medical science, energy production, food processing, construction, and the building, repair, and maintenance of sophisticated scientific, educational, military, and industrial equipment.

Analysts examining these indicators of student performance and the demands for new skills have made some chilling observations. Educational researcher Paul Hurd concluded at the end of a thorough national survey of student achievement that within the context of the modern scientific revolution, "We are raising a new generation of Americans that is scientifically and technologically illiterate." In a similar vein, John Slaughter, a former Director of the National Science Foundation, warned of "a growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component."

The Senate report was significant for two important reasons. First, it encapsulates and vividly represents a great deal of the political rhetoric of the early 1980s targeting science and technology education reform. The policy standpoint set the stage for two important initiatives related to the LiNC project, national funding for the development of networking technology for science classrooms and the development of national and state standards that firmly established technology as a critical component of public school math and science curricula. Second, the report was (and continues to be) very influential to these policy and funding initiatives especially in NSF programs. It specifically recommended that schools initiate more rigorous and measurable standards of performance for students *and teachers*. Unfortunately, this is being realized in very counter-productive ways. Resulting standards have come to symbolize the highly pervasive and overbearing culture of standardized testing and corresponding teacher accountability threatening today's school personnel with consequences that run counter to their aims and needs. Funds and jobs serve as the "carrots" to be given and taken according to schools abilities to improve and achieve standard test scores without regard to a clear understanding of the cultural and socio-economic causes and implications of such standardized testing. More important to this story, the report recommended that the Federal Government fund this educational reform. "The Federal Government has *the primary responsibility* to identify the national interest in education. It should also help fund and support efforts to protect and promote that interest."

The crisis rhetoric continues today among politicians in works like William Bennett's article "Our Nation Is Still at Risk" (Bennett 1999) and numerous articles throughout the late 1980s and 1990s, such as "What Works in a Nation Still at Risk" (Walberg 1986), "Math and Science: A Nation Still at Risk" (Ashworth 1990), and "A Nation (Still) At Risk" (Belsky 1995).

NSF Response: NII and NIE

By the late 1980s, computer science had "succeeded in gaining recognition as a science with a legitimate basic research program" and a major contributor to economic competitiveness (Rogers 1996, 50). The establishment of the National Research and Education Network (NREN) program within the High Performance Computing and Communications (HPCC) initiative at NSF signified a shift in emphasis from high performance super computing to network computing. The addition of the educational component to the National Research Network (NRN) thus changing it to NREN around 1990, illustrates the paramount applied focus of the NSF's "big science" approach to networking the nation and preparing the future workforce for advanced computing. A key part of NREN was the Networking Infrastructure for Education (NIE), which began in fiscal year (FY) 1994.

NIE was a joint program of the Directorates for Education and Human Resources (EHR) and Computer and Information Sciences and Engineering (CISE). According to the solicitation for proposals from the NIE,

> The program responds to the national need to accelerate the adoption of advanced technologies in support of science and mathematics education to: better prepare all citizens for participation in our society; attract groups currently underrepresented in science and technology fields and careers; and better prepare future scientists, engineers, and technologists.

According to the NIE program director Nora Sabelli,

> NIE was specifically set up to fund simultaneously people and wires, which had been funded independently by two programs. The more general relations between education and technology were funded under an older program, AAT (Applications of Advanced Technologies) that coexisted with NIE, and by a program called CRLT (Collaborative Research in Learning Technologies) that was more computer science oriented. All of this preceded the awareness and emphasis on IT workforce, and came after there was a well established computer science community (Sabelli 2001).

This perspective illustrates how, in the minds of the directorates at NSF, the NIE program signified a joining of two formerly separate issues; one dealing more directly with technological infrastructure, that is "wires," and the other dealing with social and specifically educational support, "people." This combination of machines and people in the funding initiative provided an ideal opportunity and setting for researchers in the interdisciplinary field of HCI.

Around August of 1995, there was a round of discussions between Sabelli at NIE and perspective directors of the LiNC grant. While the grant had not been "officially" accepted, it was clearly being pursued by NIE. The main concerns that Sabelli felt needed to be addressed revolved around the nature and focus on research versus development. Clearly, Sabelli and NSF reviewers of the proposal were suggesting that the project focus much more on answering "education research" questions rather than software or hardware (infrastructure) development. Part of the reason for that was that there was an already established substantial infrastructure surrounding MCPS and the Blacksburg Electronic Village (BEV) that was potentially being leveraged by the project, and, as such, the project appeared to be in a good position, according to Sabelli, to define a strong research agenda. Infrastructure building to the NIE was equated continued use, sustainability, and scalability, rather than hardware.

Funding LiNC

The NIE program funded two Virginia Tech grants around the mid 1990s. The first was a Planning Grant for about $100,000 called "Planning for Virtual Schools in Electronic Villages." This was a one-year grant with five principle investigators: The grant generated a series of training sessions for MCPS teachers and report to the 1995 HCIC conference (Ehrich 1995), but it was generally aimed at generating a second grant proposal to be submitted to the NIE program at NSF. The HCIC report (Ehrich 1995) provides a generally optimistic view of the BEV and hope for a very comprehensive educational network for local teachers, but the report is also somewhat critical and highlights some of the problems that obstruct efforts at creating a truly democratic computer network and technological reform in schools. For example, it suggests that many citizens are resistant and skeptical about the utility of the internet, teachers need time to learn and to use computer resources, computers suffer from poor human-factors with regard to teaching practices, and meaningful educational change requires a concerted community effort.

Before the LiNC Grant: BEV and "The Planning Grant"

In the fall of 1993, the Blacksburg Electronic Village (BEV) was established. At the time, BEV was an innovative community network that offered the public free Internet services and connection (Cohill and Kavanaugh 2000). From the onset, a chief goal was to engage the local schools in providing resources for education (Ehrich and Kavanaugh 2000). This included connecting all Montgomery County Public schools to Internet and providing them with BEV software. Problems and hopes led to the hiring of a full-time BEV staff member for school related liaison, a supervisor of technology for MCPS, and the drafting of a technology plan for MCPS by a committee of teachers, administrators, and citizens.

In the fall of 1994, NSF awarded a one-year planning grant to Virginia Tech for the purpose of developing an alliance among the MCPS, BEV, the Town of Blacksburg, and Bell Atlantic-Virginia. The abstract from the proposal describes the plan.

> The primary goal of the planning period is to lay the groundwork for developing and documenting a virtual school, an unbounded educational environment with no walls, no halls, no bells, where (virtual) collaborative classrooms encompass the entire community and exploit connections among diverse educational resources - schools, libraries, homes, businesses, local and global networks. This virtual school, to be implemented and evaluated over a three-year development period following the planning grant, is enabled by the Blacksburg Electronic Village which, by providing high-speed full connectivity throughout the entire town of Blacksburg, offers a unique opportunity for us to create a virtual school. In the one-year planning period, we will undertake a series of planning meetings, workshops, and preliminary evaluations of basic equipment, network links, and network services for an emergent virtual school comprised of teachers and classes in one elementary school, one middle school, and one high school in Montgomery County, Virginia…The primary output of this

> planning period will be a proposal to be submitted to NSF for a three-year development effort to create and evaluate a virtual school. (Kavanaugh, et al.)

The investigators named on the proposal were Norman Dodl from Education at Virginia Tech, Andrea L Kavanaugh from BEV, and Deborah Hix and Roger Ehrich from Computer Science at Virginia Tech. The $100,000 award, titled *Planning for Virtual Schools in Electronic Villages*, was from NSF's Networking Infrastructure for Education program. Ehrich and Kavanaugh (2000) describe many of the activities and outcomes that resulted from the planning grant including the participant meetings, the computer equipment provided, and the documents generated. They claim the grant had extensive effects on public interest in computers, technical infrastructure, and political ramifications for MCPS.

> [The NSF planning grant] probably had a greater effect on public education in Montgomery County than any other single event in the county's history. It came as a *deus ex machina*, a rather unexpected event that galvanized interest and concern for public education throughout the community. It was accompanied by much publicity, discussion, experimentation, demonstration, and learning. Its effects penetrated the political arena as well – the county held its first school board elections, changing the board significantly in the process. Previously, members of the school board had been appointed by the County Board of Supervisors. Although a number of circumstances magnified the effect of the NSF grant, the process arguably was fueled by the accessibility afforded by the BEV in Montgomery County as well as the astonishing growth of electronic communication and networked resources including e-mail and the World Wide Web. Managing the evolution of a virtual school is a brand new experience requiring network connections, education reform, networked information competence, leadership, and financial backup.
>
> Dramatic as those events have been, the schools and their university counterparts had much to learn about each other and the business of networking and education reform. Firsthand experience with managing networked education taught them more than anything else. They learned by doing and from mistakes each step of the way. Technology, new roles, budget, and scheduling presented new challenges. For example, the few yards separating Riner Elementary School from its T1 connection turned out to require a ditch. That had to be bid, whereupon the selected contractor declared bankruptcy. Almost everything was over-budget. (Ehrich and Kavanaugh 2000, 153-154)

The most important outcome with regard to the present work concerns the connections to the LiNC grant proposal. The concept of a "virtual school" long preceded the LiNC grant and technology development. In the early 1990s, a "virtual school" was a vision of much more than simple and singular technical artifact. As suggested above, it was a technical infrastructure, an embodiment of education reform, and part of a wave of political and public interest. The LiNC grant exemplifies just a relatively small piece of the overall momentum and prospect of the early 1990s; however, the direct contribution of the planning grant to the development of the Virtual School in the LiNC grant is debatable.

According to Carroll, there was only a very loose connection between the planning grant and the LiNC grant. While Kavanaugh agrees that there was no direct link, she acknowledges the social and political milieu that carried over. There were trust relationships that were cultivated in meetings prior to and during the planning grant, important relationships among members of the different organizations involved: MCPS teachers and supervisors, BEV, CS and College of Education at Virginia Tech. These included relationships that developed among MCPS administrators such as supervisors like Larry Arrington and Melissa Matusevich and researchers at Virginia Tech, especially Carroll (Kavanaugh, personal interview 5/30/01). The LiNC grant proposal also sought to leverage much of the technical infrastructure initiated by the planning grant that was represented by BEV, T1 connections, and machines provided to classrooms from a variety of sources. These various factors helped justify the understanding at NSF's NIE program that the LiNC grant "builds upon an ongoing NIE Planning Grant" (Carroll et al. 1996).

Nevertheless, Carroll's observation that there was little relation among the grants is understandable since, interestingly, there were no investigators common to the two grants. When Carroll arrived at Virginia Tech, the Planning Grant was already underway. He joined meetings with the participants but made no direct contribution to the grant. One external outcome is that this cultivation of social relations allowed a perception of cooperation and common goals to be portrayed to NSF. Another more internal outcome is that social networks were developed and identified to various members, so the members of the various organizations began to anticipate ways to capitalize on the collaboration of the different organizations, that is, individually the members advanced their role in the developing social networks. Carroll reflects on the meetings during that period as a time of appealing to future collaborators. "I was trying to build a core group of colleagues to work on an interdisciplinary analysis of the BEV -- ultimately this was funded in the epic grant (Carroll and Rosson 2000)…This started in 1995-1996 at about the time that Carmen Sears did her thesis and MOOsburg was first started" (Carroll, 9/18/2001).

PCs for Families Grant

One of many important sideline examples of the momentum captured during this era was a grant that was proposed and awarded to Virginia Tech by the U.S. Department of Education. The 3-year grant, "Testing a Network-based Approach to Home-School Coupling in Elementary Education," was subtitled and became known as "PCs for Families" and began in fall of 1996 (see http://pixel.cs.vt.edu/edu/fis/). It was directed by Roger Ehrich of CS at Virginia Tech, one of the principle investigators on the planning grant and also involved Melissa Matusevich, MCPS Social Studies supervisor, and Keith

Rowland, MCPS school principal, as principle investigators. The goals are described by the project proposal:

> The PCs for Families Program is an innovative program at Riner Elementary School in Montgomery County, Virginia whose goal is to bring new and dramatically different educational opportunities to rural students and their families. In this pilot program, a computer is to be purchased for each student in a 5th grade class and configured with a networking suite and camera. When plugged in at home, these computers will connect the students with each other, with the schools and teachers, with the community, and with the worldwide information resources of the Internet.
>
> In a careful study we will track the effects of this resource on student achievement for a period of up to five years. We will determine whether we can make substantial improvements in the social relationships important to the educational process and give the students a new perspective on their citizenship in a world information society. (Ehrich 1996)

This proposal also cites the planning grant. In short, the investigators wanted to create one ideal constructivist classroom fully equipped with latest technology not only inside schools but also in the homes of the students. The proposal describes the equipment:

> The 5th grade classroom of Susan Hood at Riner Elementary School will be renovated and connected to the school's T1 communication line. The classroom will be provided with 12 networked Macintosh 7500 multimedia computers, one for each two students. Ms. Hood will have a Macintosh 8500 configured with laser printer, LCD projection panel, digital camera, and scanner for multimedia publishing and presentation. Each of the 24 student families will receive a networked Macintosh 7200 computer with printer.

The project had some ambitious and problematic goals and assumptions that might explain the perception of limited success of the program, but I will not attempt a critique here. In short, they were trying to change the learning culture inherent in a single classroom and in the families of these children. They invoked constructivist pedagogy as a means for bringing about adoption of the technology. Susan Hood's 5th grade classroom at Riner Elementary was chosen to fulfill these goals.

This project had indirect ramifications for the LiNC project. First, administrators and teachers tended to clump together Virginia Tech efforts, especially those common to particular departments with similar goals and resources. The PC's for Families project and the LiNC project both put computers in classrooms for the purpose of experimenting with networks. Both were Computer Science guided efforts. As such, blame for problems or conflicts occurring in one of the projects can understandably be attributed to the other. There were some conflicts over ownership of the computers. This resulted in concerns for both projects and is now an issue in any grant being coordinated with Virginia Tech and MCPS. Other issues concern less tangible results that have to do with trust and uncertainty in dealing with such projects. These are difficult and controversial to describe, but they are important to establishing and maintaining social relationships among the organizations.

The LiNC Project

The second grant became known as "The LiNC Grant." Titled "Leveraging Networks for Collaborative Education in the Blacksburg Electronic Village," it was a three-year grant that intended to carry out the work planned as an outcome of the planning grant. The actual arrival of the money in 1996 did not correspond directly to academic calendar school years, so the grant periods are somewhat fuzzy. Moreover, the overlap with other grant funds taken in during that period gave the illusion that there was no definite beginning and end to the three-year grant period. There was a supplement requested that allowed some leeway in the end. There was another grant awarded by the Hitachi Foundation to the Center for HCI in 1998 in the amount of about $100,000 for the purpose of extending and facilitating similar work in the schools and community. All of these initiatives and awards get amalgamated as part of descriptions of "the LiNC Project," that technically includes as a subset the work related the three-year NSF grant. Boundaries related to the personnel, funding, and technical infrastructure get drawn differently depending on the contexts. Funds for equipment and personnel get used in a variety of work that gets co-leveraged in the numerous goals and awards that sustain the Center for HCI. In addition, there is departmental Graduate Research Assistantship (GRA) funding, Navy grants, and NSF Graduate Research Traineeships that contribute to the various overlapping goals of different initiatives. This all represents the socio-technical infrastructure that is instrumental to ongoing grant awards, publications, and other recognition that contributes to more powerful networks, more funding, and more publicity and publication abilities. This infrastructure as it is conceived and realized is instrumental to the ability to get work done and to convey that perception.

The LiNC Grant

Three of the four principle investigators of the three-year NSF grant that became known at "The LiNC Grant" were from the Department of Computer Science (John Carroll, Mary Beth Rosson, and Clifford Shaffer) and one was from Education (John Burton). This grant was budgeted for $1,117,128 and also received a supplemental year of funding.

The NIE solicitation specified several goals crucial to the formulation and award of the LiNC grants:

- establish testbeds, implementation models and prototypes that explore the role of electronic networks in support of reformed education;
- support the R&D needed for large-scale, cost-effective implementation of educational networking, including infrastructure, organization, tools, materials, and mechanisms for technology transfer;
- strengthen collaborations between groups that are developing services and technical assistance for network users, and large

> education stakeholders, such as states and school districts; and,
> • supplement existing CISE and EHR infrastructure and/or systemic educational reform awards that are consistent with NIE's cross-directorate goals.

The first, third, and fourth items relate directly to the grant. In accordance with the first statement, the proposal summary clearly identifies the common goals of establishing testbeds and prototypes that explore education reform, particularly the use of technology to promote active learning models: "Our prototype testbed will address physical science middle and high school students. The project represents a rational melding of existing technologies in new ways that we believe will do as much for active learning as the advent of World-Wide Web browsers such as Mosaic has done for passive browsing of information." The summary also clearly espouses the goal of strengthening relationships among "people and wires" alluded to in the third and fourth item:

> Key elements of our proposal are: a participatory design approach involving teachers and students as design team members (in contrast to externally-imposed educational technology solutions)… continuous on-site teacher support to help in selection and composition of project-oriented curriculum elements, community involvement in experimental projects, and evaluation of technology change, attitudes, and outcomes. This project seeks to leverage the technological and cultural opportunities of the Blacksburg Electronic Village (BEV), a densely interconnected community in rural Southwestern Virginia.

The participatory design process mentioned here, is important not only in demonstrating the intent to breakdown traditional distinctions among "people and wires" in the design process, but also in defining the roles of the teachers and researchers in the unfolding of the work plan described in the next chapter.

Particularly important to the intent of the LiNC grant was fostering partnerships among schools, research universities, and business/industry. The solicitation states that:

> NIE will promote the development of new alliances and partnerships including two- and four-year degree-granting academic institutions, school districts, professional societies, state agencies, and others concerned with educational reform. Business and industry participation, with cost-sharing consistent with their role, will be required for demonstration and model sites, and for infrastructure and testbeds, and strongly encouraged for policy studies and R&D projects.

The grant proposal aims at supporting deeper collaborations among university researchers and local educators, and clearly it aims to establish new kinds of relationships among developers of technology and teachers. Teachers are expected to take on new and instrumental roles in the actual development of the technology, rather than simply acting as consumers and testers of it; however, the later final report of the grant illustrates an underlying perception that the quality educational innovation and research tends to come from outside of education.

> From our perception, the NIE program (under which we were funded) seems different than other REC [Division of Research, Evaluation and Communication] programs in weighing innovation and potential for impact on society more highly. We have become somewhat discouraged in dealing with REC panel reviews that seem consistently to encourage us to be less ambitious, and to address narrower and smaller-scale problems. Also unlike the NIE program, the regular REC panels tend to weigh academic affiliation with education departments as a sort of critical credential, ignoring the fact that in the past and currently most transformative education innovations have come from outside the educational establishment, or at least through interdisciplinary work that included psychologists, anthropologists, technologists, and others. EHR does not do a good job in managing these parochial tendencies.

Item two in the solicitation makes it clear that the NIE program envisions a big science approach to creating and utilizing the computer networks for education reform.

Big Technology: NSFs Big Science Approach to Networks for Education

Hevly (1992) characterized "big science" according to several important features, and these features also characterized NSFs approach to creating a networking infrastructure for education. Big science, according to Hevly, represents more than just an increase in the size and scale of research expenditures. It also represents an increasing effort to coordinate collaborations among specialized workers, managers, and business leaders. More importantly, big science "depends on the attachment of social and political significance to scientific projects, whether for their contribution to national health, military power, industrial potential, or prestige" (Hevly 1992, 357).

In national policy initiatives, the support of building big technology networks was attached to two dominant and related objectives, information access to the public and education. Since the inception of the NSF amid cold war rhetoric warning of declining U.S. technological supremacy, K-12 education reform has been a major focus of NSF initiatives, and this focus has been directed chiefly at improving science and math education for the better production of engineers and science researchers. The mid-1980's science and math education crisis rhetoric refocused these reform efforts on computer technologies. This has resulted in new phenomena of big education, that of big technology for education; however, the big education and big technology of the NSF bear a marked contrast to Galison and Hevly's (1992) big science in an important way. One key feature with which Hevly (1992) characterizes big science concerns the concentration of its resources. "Big science has come about through not just an increasing concentration of resources devoted to scientific research, but also through the increasing concentration of resources into a decreasing number of research centers, and the dedication of these special facilities to specific goals" (356).

Government policy on computer research and development shifted in the 1980s away from super-computers and toward efforts to build and populate large-scale computer networks especially for education (details in Rogers 1996). These networks were intended to connect researchers, educators, and students so as to bring about collaboration and the transfer of technology and knowledge among dispersed sources and locations. This shift in emphasis is linked to the big science of large-scale particle physics experiments, and, perhaps, marks a new era of big science or even its partial demise. The paradigm of centralized super-computing began to be replaced with visions of a de-centralized infrastructure involving dispersed but readily retrievable information, that is, the idea of super-networks replaced super-computers partly because "high performance" computing became a much more common and accessible commodity to individuals and universities. Thus, in keeping with the vision of the NII, the investments into infrastructure naturally took on more dispersed and de-centralized forms considered beneficial to strengthening the network as a whole. NREN was key to governmental efforts aimed at accomplish this.

Big Education[4]: The NREN

What is NREN? Like the Internet, NREN is difficult to define. It is an acronym that refers to a variety of objects and initiatives. It has been described as proposed successor to The Internet (Branscomb 1992), a federal initiative that was an outcome of the High Performance Computing Act of 1991, "an internetwork of autonomous logical networks – not a single centrally managed network" (Kahin 1992, 6), "a collection of significant, confused and sometimes conflicting interests" (Cook 1992), "both the end-to-end gigabit connections…and a set of issues about who can connect, at what price, and who foots the bill" (Kahin 1992, 8), and it has even been referred to as "a state of mind." In what follows, I will use NREN to refer to a related set of policy and funding initiatives of the federal government, but bare in mind that within these policies the name NREN is also used to refer to a set of technical objects and a networking infrastructure.

The focus on education networking infrastructure was pervasive in public policy by the early 1990s. The assimilation of technology in schools was a major priority of the Clinton-Gore administration, spawning and expanding a number of programs with related goals. In addition to NSF related initiatives, there were a number of other expensive federal programs specifically concerned with networking for K-12 education in the early 1990s, for example, in the Department of Education, Department of Energy, Department of Commerce, NASA, Department of Agriculture, and the National Endowment of the Humanities. Important examples of such federal policy initiatives related to using the NII for educational goals include the Information Infrastructure Task Force (IITF), the Goals 2000: Educate America Act, the National Science and Technology Council's Committee on Education and Training (NSTC/CET), the Nation Telecommunications and Information Administration (NTIA), and the National Information Infrastructure Advisory Council (NIIAC), all circa 1994 (see Vedantham and Breeden 1995).

---

[4] I am indebted to Barbara Reeves for conversations and coursework wherein she suggested that I compare the notion of "big science" to education history and policy, giving rise to the idea of "big education."

NREN epitomizes “big education” (that is, big technology for education reform), but it does so in a way that directly contrasts with the centralizing tendencies of the big science experiments in particle physics described by Galison and Hevly (1992). While funding and policy initiatives concentrate on a particularly narrow area (computer networking), the nature of networking suggests that development gets distributed or de-centralized; however, de-centralization was not an inevitable outcome of the shift in focus toward super networks. For example, some had envisioned a network infrastructure that was much more centralized with large nodes and supercomputers coordinating higher levels of activity, but as described in chapter 2, early military concerns, namely the threat of the destruction of entire cities and thus entire portions of the network, favored a decentralized network that would survive the loss of any lone part.

Aside from the tendency to be de-centralized, NREN reflects much of what is captured in Galison and Hevly’s characterization of big-science, that is, large-scale, concentrated funding of research in a specific area with clearly attached social and political significance related directly to industrial potential, namely, the crisis of economic competitiveness in the form of declining status of science and math education. The NIE program typifies NRENs social and political significance.

The NIE program is important to this story for two reasons: First and foremost, it funded the LiNC project, and second it was specifically intended to cross human science research with technical development in computer networking for education. The specific attempt to cross traditional disciplinary domains with research and development (people and wires) by NSFs NIE program required the concentration of resources in groups with expertise in hard-wiring and programming computers for networking, and it also required groups with expertise in educational technology and/or learning, behavioral, and cognitive sciences. There were a variety of disciplines that exhibited expertise in some of these areas, for example educational and instructional technologies departments in education colleges, but few that explicitly cross-cut all of the technical, cognitive, and social dimensions of computer science research and development. One of the key groups that made explicit attempt to cross these disciplines was contained in the newly emerging field of Human-Computer Interaction (HCI).

Interestingly, according to Sabelli NIE did not actively seek expertise in HCI.

> There was no thought of HCI expertise, nor was much funded, if I recall. The program focused on groups networking experts and user support and education staff, based. Software was developed in cases where it was demonstrable needed, but that was not the major goal of the program. Prior work in interacting with education (for networking groups) and with networks (for education groups) was important. (Sabelli 2001)

Given this, it is interesting to ask if the LiNC project *was* focused on HCI research. Insofar as it was, how and why did this happen? Carroll was the director and person most responsible for the growth of the Center for Human-Computer Interaction at Virginia Tech. He was becoming established as a leader in the field of HCI, so much, if not all, of his research at that point and onward to today focused on HCI issues. HCI was and is a broad enough umbrella to encompass the diverse interests of Carroll, and the Center for HCI was and is a fitting vehicle for this. Moreover, other researchers who might have moved the project in alternative directions, for example into more mainstream educational or software engineering kinds of research, fell out of the project for various reasons (discussed in the next chapter). Outcomes of the project were reported in HCI conferences and journals, and funding from the project was directed toward students and researchers most directly associated with the Center for HCI. Likewise, the development of the technology focused on many HCI concerns such as usability and awareness over more educational and traditional software engineering concerns such as learning outcome measurement and programming logic. This, of course, was a result of social situations and contingencies that drove the management of the project and not of any kind of linear logical process of technology development. The process could have gone any number of directions depending on who took charge and their interests and expertise. The foray into HCI was but one of many possible trajectories, one that was opportune given the context and energy provided by the emerging field of HCI and the Center for HCI at Virginia Tech.

The Field of HCI: People and Wires

There have been a number of attempts to describe the history of the field and discipline of Human-Computer Interaction (HCI), but most of these are internalist histories of technology. As such, they focus narrowly on details associated with technology, requirements, and innovations that have been developed over the past decades arising out of various related fields such as Human Factors, Industrial engineering, and supplemented with cognitive and social sciences. These histories of HCI reveal very little about the political and cultural contexts that have contributed to the massive growth of the academic and business industries that have solidified HCI as a field and a "science" in its own right.

Brad Myers' (1998) paper titled "A Brief History of Human Computer Interaction Technology" represents a typical history of HCI. Not surprisingly, it reflects a well agreed upon timeline of innovations that delineate the development of HCI as a discipline and field of research. HCI is commonly described as a field that arose out of the intertwining of a number of disciplines dealing with problems related to the design and understanding of the interfaces between computers and human "users." The fields of Human Factors and ergonomics engineering represent major contributors that, for example, arose out of the study of aircraft flight displays and controls and studies of technologically mediated work, but these early studies tended to focus on sensory and motor skills rather than cognitive dimensions. Early HCI researchers identified needs for cognitive and social psychological studies involving authentic work contexts. Advances in computer displays and the wide acceptance of personal computers contributed to the focus on graphics and graphical interfaces as a major catalyst for the growth of the emerging field.

Myers (1998), like many others, traces the origin of the field to Ivan Sutherland's 1963 Massachusetts Institute of Technology (MIT) PhD thesis known as Sketchpad

(Sutherland 1963). Sketchpad was acclaimed for two major reasons. First, it introduced a graphical input mechanism, the light pen, which served as an efficient alternative to the keyboard. Second, it introduced a number of graphical objects and structures such as icons and their manipulation (grabbing, moving, and changing size). The development of the mouse at Stanford Research Institute in 1965 was another example of an innovative input device and an inexpensive replacement for the light pen that contributed to the emergence of HCI. Xerox PARC made this into a practical input device in the 1970's and introduced it commercially in 1981 as part of Xerox Star along, and Apple computers soon followed. Other advances associated with the origins of HCI include tiled Windows in 1968, drawing programs in the 1970s, the personal computer in the 1970s, text editing applications in the 1960s and 1970s, spreadsheets in late 1970s, HyperText in late 1970s and 1980s, Computer Aided Design (CAD) and video games in the 1960s.

By the mid 1980s, HCI researchers had begun to campaign for the acceptance of the field as a legitimate science complete with a research agenda and distinct methods and goals. One key indication of this was the plenary address (Newell 1985) of the major HCI conference hosted by the Association for Computing Machinery, *CHI '85 Conference on Human Factors in Computing Systems* (Carroll 2002). Alan Newell's work continues to draw acclaim for establishing the science of HCI. His HCI model, Goals, Operators, Methods, and Selection (GOMS), reflected and extended cognitive psychology orientations to research on human-machine interactions. While addressing mental models and similar perspectives, it also attempted to move beyond the tradition of cognitive science to introduce alternative paradigms.

Interestingly, CHI '85 also included some important voices from STS that represented influences on HCI from interdisciplinary fields including social psychology, anthropology, and sociology. For example, speaking about the context of equipment used in particle physics research, Sharon Traweek discussed "how scientific machines shape scientific practice, and how scientists regard the machines that they build" (Traweek 1985). Michael Lynch discussed the studying of scientists' work, particularly the organization of laboratories, through the construction of graphical displays used in their work (Lynch 1985). These works suggest an orientation of HCI that is sensitive to an understanding of technology as it is situated in the organization of social activities rather than abstracted from the organized communities in which it is used.

While these works mark the influence of sociological approaches to studies in HCI, there are questions about the longevity and pervasiveness of that influence. The training of much of the HCI community in engineering and experimental approaches to psychology has had a far greater impact on HCI research, reflecting excessively rigorous quantitative analyses of behavior, a "scientization" of HCI, rather than providing critical analyses of methodologies and organizational contexts of research suggested by STS and related analyses. At a recent Human-Computer Interaction Consortium conference involving many of the founders of and leaders in the HCI community, there were explicit demands for more controlled and quantitative analyses in HCI that would "tell us facts" about HCI phenomena. It was striking to me how little of an attempt was made by many of these researchers to account for the complexities of contextual factors and contingencies associated with their research interests. On the other hand, I am encouraged by some leaders in the field, (for example Graham Button, Jack Carroll, Mary Beth Rosson, Colin Ware, Andrew Monk, Peter Pirolli, Robert Kraut, Alan Dix, and Scott MacKenzie at a workshop at Virginia Tech for a textbook on HCI theory, models, and frameworks in October 2000, see Carroll 2002), who appear very willing to debate and describe criticisms of methodology and theory in HCI research at a very deep level and with sympathy to understandings in STS.

The field of HCI has expanded and matured a great deal in its research agendas and focus. The classic example of a "scientific law" of HCI and a benchmark for the field of HCI is Fitt's Law (Fitts 1954, McKenzie 1992). This research epitomizes the beginnings HCI because of the focus on sensory-motor operations describing interactions of people and computers such as hand movement and similar physical behaviors. Fitt's law was developed in the early 1950s in the field of experimental Psychology. It is a general model of psychomotor behavior that predicts how fast or accurate a human can aim and move an appendage (like a hand) in a line from rest to a specified target some distance away. Fitt's found that movement time (MT) was a logarithmic function of distance (A) for a given target size or width (W) and, similarly, movement time was a logarithmic function of target size for a given distance. The law is given by the equation below:

$\mathbf{MT} = \boldsymbol{a} + \boldsymbol{b} \ \mathbf{log\ 2\ (2}\ A/\boldsymbol{W}\mathbf{)}$, where a and b are regression coefficients.

By the late 1970s, early HCI researchers were applying Fitt's law to model human interactions with input mechanisms. The study of Card, English, and Burr (1978) represents one of the earliest attempts to utilize the law to describe and compare how well subjects could use input devices for a computer, for example joystick and mouse, to select text on a Cathode Ray Tube (CRT) display. MacKenzie (1992) discussed the history of the use of the law in HCI, human factors, and kinematics in great detail and described many of the problems of across-study comparisons stemming from inconsistencies in performance measures and sources of experimental variation.

Such early research focusing on physiological measures like the Model Human Processor, Fitt's Law, and GOMS, while they allow quantitative measures for comparison, lack what has become a rally cry in HCI; focus on "the context of use." Influences partly from social science research, like anthropology and work-studies, have refocused HCI research on questions related to how the usage of technologies fit into existing social practices. For example, Grudin (1995) discusses a shift in HCI research focus from single-user studies to studies of users in group contexts.

HCI typifies an interdisciplinary, or multi-disciplinary, field in many respects. First there is debate about its origin, most important subject matter, and it's standing as a science with distinct goals, theories, and methods. Second, and similarly, it draws researchers and interests from a wide range of more traditional disciplines or fields. It reflects engineering approaches to research that involve strict and controlled quantitative study of very specific domains in HCI. It also reflects a wide variety of methodological approaches from social sciences and anthropology that are important not only to the academic side of HCI, but also industrial and business research and development. A key example is Xerox PARC, which has a long history with extensive experience and reputation for producing quality HCI research. PARC has for a long time been responsible for crucial innovations related to HCI, and for example, they employ anthropologists that utilize ethnomethodology to study the organization of work, research that is applied directly to the design of their products. Much like the field of STS, the confluence of these diverse perspectives, while fueling debate and diverse methodological perspectives, does not necessarily create a synthesis of ideas that results in a distinct set of methods and theories of HCI. Rather, it produces a heterogeneous collection of methods, approaches, theories, and even a-theoretical perspectives on research.

The Center for HCI at Virginia Tech: Disciplines and Dollars

In academic fields, the multidisciplarity of HCI is more amenable to the establishment of centers of research rather than traditional academic departments. While they are often closely associated with Computer Science departments like at Virginia Tech, some other universities attach HCI programs to engineering, psychology, and related departments. At Virginia Tech, the department of Computer Science currently coordinates HCI, but it is affiliated with faculty and students from Industrial Systems Engineering (ISE), STS, Psychology, Education, and Accounting Information Systems. The center boasts 35 faculty members and 13 other departments in the university that participate in various ways with the center including Accounting and Information Systems, Civil Engineering, Center for Interdisciplinary Studies, Communications Studies, Engineering Science and Mechanics, Information Systems, Media Services, Newman Library, Interior Design, Philosophy, Sociology, Teaching and Learning, and Veterinary Medicine.

While their has been faculty at Virginia Tech interested in and doing HCI research and instruction since 1979, the Center was not established until 1995, and it was the LiNC project that enabled and shaped the formation of the Center. Despite recent efforts by Carroll to establish an official HCI curricular tract, no program currently names an "HCI" major, minor, or concentration; however, there is an interdisciplinary emphasis in HCI within the CS major and CS courses in HCI. The Center for HCI at Virginia Tech was a direct outcome of the LiNC grant.

According to Carroll, establishing the Center took some learning on his part about how administration responds to proposals and university initiatives. The initial Center proposal was presented to James Wolfe, Virginia Tech Associate Provost, around 1994. The intent of Carroll and other CS faculty was to fund half of the salary for a faculty member who was various jobs for other faculty, but was not being appropriately compensated. Despite the fact that many members of the administration appreciated the idea of Center for HCI, this initial proposal was never funded. The problem, as Carroll puts it, was that the Provost and other members of the administration 'looked at this and they saw through it, because, of course I'm more sophisticated now than I was then, there wasn't much in the way of an agenda. It was really just hands out. We didn't say what we'd do. We didn't say how we'd bring more resources in. Now I know that's what you have to say. You can’t just go and say, ‘here’s a good idea. Give us half a salary’” (Carroll 2001c).

Despite the lack of funding, this initial proposal was not without consequence. The idea was set in motion.

> They liked the idea of HCI, but they didn’t do anything for us. But the idea was floated, and that was the key thing because after that point it was kind of on the table. And it kept coming up, at least in my mind, and when we got the LiNC grant… I reminded the administration, I reminded [the Vice Provost and Dean of the Graduate School at that time] in particular, that we now were succeeding, that HCI was coming through. So that’s the sense in which I know those things got linked. It was me that linked them, and I saw that what we had to do was show that HCI not only sounded good and was worthy but could produce something. (Carroll 2001c)

Most interestingly here is the layers and sophistication of Carroll’s interpretation of the events and his understanding of the administration’s thinking that led up to the establishment of the Center. First, he reflects on his own learning in the process of dealing with proposals to the administration. In this regard, he explicitly invokes actor-network theory of Latour to explain *why* things happened as they did.

> Part of this was also my education because what I might have done is gone through some of these formal steps earlier, and then gone to the provost; taking a tip from Bruno Latour, get your allies lined up. I could have gone to the commission on research, proposed the center, got their support, then went to the provost and said, ah shucks we’d love to do, they want us to do this, but we need half of Debbie’s salary, but I didn’t know that at the time. I didn’t realize that was the order to do it in, because the commission on research is not a funding body. They’re an authorizing body of their peers. It’s part of faculty governance. The provost has money…It had little to do with the CS department, but I do believe that through this whole process, I was aided by being department head…Administratively, you have more credibility. (Carroll 2001c)

Second, Carroll identifies a crucial reason that the Center proposal gained recognition to the administration, namely the LiNC grant was big enough (just over one million dollars) to get the attention of administrators.

> The reason [the LiNC grant] stands out is, at Virginia Tech, there is a discrete difference in interpretation when a grant is over a million dollars, at least then. Maybe it’s two million now, but at least then they used to, in the annual report, have a list of million dollar grants, so the poor shmuck who got 999, he’s just sitting there invisible, anonymous. Ours was just a million point one, but that put us into this gilded category. (Carroll 2001c)

For Carroll, the grant has obvious and crucial ramifications to the development of technical objects, but here he is invoking a social description of the processes to explain major aspects of the social infrastructure that enabled such technical development. This is not at all surprising, but one may wonder how Latour might handle an actor invoking "Latour" and "actor-networks" as an explanation for his own actions, an explanation that has meaning to the production of technical objects and socio-technical infrastructure. Here we have a very neat actor-network description of the processes. First, the idea of the Center for HCI was seeded in the mind of the administration and allies were formed. Then a million dollar grant became associated with the Center and crucial nodes or actors in the social network materialized the network that enabled production. Carroll describes this interpretation of events. "I ran into [an administrator] at the Atlanta airport, and he asked me 'how is the Center grant going,' and that was the first time. It was the LiNC grant, which he called the Center grant, and the reason was that it was enabling the Center. So at that point the discussion kind of shifted from just propose a Center" (Carroll 2001c). Once the actors and nodes of the network were in place and allies were form, the Center was only an administrative step away from coming into being. What, then, is the Center?

In the beginning, it was just purely a funding entity since it had no real "place." The personnel were initially just those named in LiNC grant with Carroll and Rosson as the directors. One important thing that it represented was a way to obtain and channel grant funds. As semi-autonomous university entity, it carried the clout associated with a research university without all of the trappings of an academic department. As such, it represented a research group to funding agencies, in this case, mainly NSF. Thus, it was a way to hire full-time research and development staff without the usual worries of academic departmental commitments. It was also a source of funds to the university since nearly 45% of grant money goes directly to the university. Partly as a result of continued recognition and support, the Center is now housed in the new Togersen Hall, a very expensive building designed to support a variety of high-tech initiatives associated mainly with computer-based research and teaching. In retrospect, the Center appears to be a crucial piece to the development of the technology; however it was not in the forethought of the LiNC project. Carroll, again, invokes Latour to explain the retrospective view of the events associated with the development of the technology. "A lot of these things (LiNC, MOOsburg, the Center for HCI) are semi-independent threads that got woven tighter together with time, which is not at all inconsistent with Latour and other people who say that things get constructed as we go along or re-constructed as we go along" (Carroll 2001c).

In elaborating on the technical elements related to the merging of LiNC (the Virtual School) and MOOsburg technologies, Carroll moves directly from technical matters, described in the previous chapter, to organizational concerns.

> There is simply an inherent architectural limitation of MOOs, namely they're basically mainframe dialup services and they produce kind of a stream of text… and that's just not the paradigm for network communication anymore. It doesn't work like that. Nobody expects that.

> You can't do enough with that, and I think it's been verified…I think it (MOOsburg III) is the right thing to replace MOOs, and also it would have been impossible to continue LiNC and MOOsburg separately. I don't even know how I would have managed that because the resources are a bottleneck, and by bringing it together, we leveraged those interests instead of diluting them. (Carroll 2001c)

While at some level Carroll understands the social and the technical lineage of the two technologies as inextricable, he articulates a distinction relative to the social resources in the development process and the requirements and constraints imposed by technical matters. This is, of course, no surprise since it is consistent with ordinary ways of speaking about such affairs.

Summary

The period leading to the funding of the LiNC grant represented a dynamic era where there were shifting emphases and uncertainties about the direction of technological development and the prospect of computer technology for general public and educational applications. The nation was responding to an onslaught of rhetoric and signs that indicated that U.S. schools were becoming less internationally competitive, and this response was given in terms of an impending crisis of national productivity especially with regard to information technology and general technological superiority.

The NII initiatives represented on aspect of the shift in national priorities from super-computing to super-networking with the prospect of personal computers inter-connected across the nation to provide schools with access to the new era of information exchange. The "information age" was seriously impacting the national and local attention to and funding of education infrastructure building. "Big technology for education," which epitomized by the NREN, provided the context for NSF's NIE program, and the focus of technology for schools also fed the notoriety of the local infrastructure of BEV. All of these initiatives and related attention, which was materialized in both social and technical networks, provided fertile ground for the LiNC grant.

The dual requirement for research with "people and wires" in the context of education situated Carroll and his interests in HCI research with the right qualifications and ideas that made the project viable to NIE. The resulting grant added to Carroll's prominence in the eyes of Virginia Tech administration, and the social and technical capital that surrounded the grant helped seed and establish the Center for HCI. This provided a rich social and technical infrastructure for the development of the LiNC project and related work. The Center for HCI enabled the development of a number of technical objects, most importantly the Virtual School and MOOsburg, which later would merge and propagate even further infrastructure development and grants.

For Carroll, as well as all of the other people in the present account, there was a difference in the kinds of resources or instrumentality that technologies embody and the kinds resources that people and organizations embody. This distinction not only occurred in ordinary language, but it also represented a philosophical distinction. Technical objects were different kinds of "actors" than were people and organizations. People act on intentions and politics. Technologies may embody the intentions and politics of the producers and users, but they do not, as yet, properly demonstrate intention and politics. At least, that was how participants understood and acted in this project, and that was how people commonly thought of these things. MOOsburg, the Virtual School, CORK, etc. do not literally take action or have intent. The fundamental difference was that found between the tool-user and the tools. The technologies were used and acted on with intentions from people that had "expectations" about their functionality. While there may be a sense in which people can be used as tools, that is, other people can utilize them to accomplish work, the reverse does not hold in ordinary language use. Tools do not use people except in a metaphoric, anthropomorphic, or euphemistic sense. For example, computer technologies, even the most sophisticated artificial intelligence systems to date, are not thought of in the same way as social systems, and this crucial distinction was important to understanding how participants thought of the work done in the LiNC project, specifically to the production and use of the technical objects, CORK, Virtual School, and MOOsburg.

For Carroll and Isenhour, the technical objects (CORK, VS, and MOOsburg) were social productions. The objects reflected values and intentions, but they did not "have" them. The infrastructure embodied by the Internet, Java, and related technologies represented socially situated opportunities and challenges. For Isenhour and other developers, they created a context for development, but this context was more than just that given by the strict technical functionality of the technology. The interest in developing collaborative technologies was a product of the interactions of popular topics in computer science and HCI, the interactions and transfers from corporations, and the common interests of the groups of friends, acquaintances, and colleagues that emerged from the academic cultures of Virginia Tech computer science.

For Carroll, the technology developments were instrumental in a variety of ways that went well beyond their functionality but that relied in various ways *on* their functionality. The technologies allowed arguments to be forwarded in order to establish research in the Center for HCI as legitimate and reputable research. Technology allowed for the acquisition of funds from various sources; however, this required, at some points, that the functionality be demonstrated or somehow be verifiable. In many cases, this only required convincing a peer group that the technical description had merit and was viable. In other cases, it required opening the black box that was the technology. This often meant making the source code available and explaining, for example, the inner working of CORK.

There is an important sense in which technical functionality should be seen as the "outcome" of the development process rather than the "arbiter" similar to the sense in which Latour (1987) notes that "nature" or scientific "truth" is the outcome of experiments rather than that which decides them. For Carroll, human requirements were the hardest part of the development process. Software, according to Carroll, is infinitely flexible. Work is very specific and often relatively inflexible while software is relatively malleable. But computer technology is highly constrained by what can be input, output, processed, and transferred. Moreover, human work and intelligence is highly adaptive to tools and their constraints. Thus, what gets designed and developed is largely the functionality that emerges in the processes of gathering requirements, analyzing usability experiment, writing programming code, and adapting the tools to work practices. The constraint is not just what can be done with computers, but also what humans do, that is, what functions they perform, with computers.

For Sabelli, other NSF "big education" program directors, and similarly for local directors of the community networks, for example, Kavanaugh with the BEV, the technology research and development had yet another form of instrumentality. Technology served political ends in a very direct sense. It contributed to the goals of government programs as seen by NSF and BEV leaders if it was disseminated broadly by being widely published and adopted. Sabelli made it clear that it was not enough for the NIE directorate awards to develop innovative technologies, that is to fund "wires." They needed to be used in authentic social or "people" settings such as genuine public school classrooms.

Teachers saw the instrumentality of the technology and the project in yet another way. To them, it was useful, as discussed in the previous chapter, if it did a variety of things for their students including motivating, engaging, as well as connecting them with chat and other shared authoring and communication tools. The LiNC project was instrumental to their work for a variety reasons including providing them with computers, stipend, time, technical support, and increasing visibility to and recognition with colleagues and administration. Certainly all that was provided was not positive. For example, one teacher did not want the free period at the expense of losing a class. There were also numerous disappointments and hours lost to meetings and dead ends as discussed in the next chapter.

For some of the LiNC investigators, the classroom environment was like field experiment setting. Thus, they wished to manipulate certain variables and observe the effects. For educational researchers like Burton, this was not likely to be feasible, and, when the manipulation could be correlated to things like learning outcomes, it was likely to yield null or insignificant results. In this view, the classroom was more like a place of end deployment rather than an experimental setting.

The technologies were productions embedded in an infrastructure that implicated social and historical processes; however, in describing the social processes, the technical work was in danger of escaping my description of the work. Contextual factors, social, economic, and political concerns could have easily become the subject of the description of the development processes, and the technical production could have easily been moved aside as secondary to or contained by these "external" forces. On the other hand, the technology and respective innovations that contributed to it could have become the sole focus of the description. Either approach would have been less than ideal since they both would have ignored critical interactions, negotiations, and transfers among the presumed boundaries of the technical work, understandings of technical functionality by participants, perceptions of the infrastructure development, economic, and political contexts.

The LiNC project itself was a complex entity, and its surrounding social and technical infrastructure only added to the complexity. The events that constitute the LiNC project are not easily described or well-defined, but in the next chapter, I have attempted to provide some details describing how the project unfolded and was carried out, paying particular attention to the engagement of the project research and development with teachers in their classrooms.

Chapter 4: The Teachers: Technology In the Classrooms

"Those who have tried to convince teachers to adopt technological innovations over the last century have discovered the durability of classroom pedagogy. Those fervent advocates who see the computer as the way to increase classroom productivity also will need to reckon with the enduring processes of constancy and change in public schools." (Cuban 1986)

The LiNC Project and the LiNC Grant

As suggested in Chapter Two, the boundaries between what became known as the "LiNC grant," the "LiNC project," and other initiatives of the Center for HCI are fuzzy. There are few clear starting and ending points, and the funding channels, personnel duties, and work products often overlap and coincide. There are a number of reasons this is so. First, there were, at times, explicit efforts to leverage other projects so as not to duplicate work and capitalize on existing infrastructure and efforts. This included explicit efforts in writing grants and papers to avoid confusing readers needlessly with historical and technical distinctions that might be less meaningful to future or proposed efforts. The clearest example of this is the distinction between the Virtual School and MOOsburg. Early proposals invoking the concept of a Virtual School, such as the LiNC grant, sought to investigate MOOs for their educational potential, but the technical and developmental paths of the artifacts diverged significantly early on in the process. What became the Virtual School was very different from a MOO and thus very different from what was then MOOsburg; however, the implementation of CORK as the architectural basis for the Virtual School eventually was co-opted for a newer iteration of MOOsburg. This had social and technical ramifications and causes. Such is the technical history, but the story is confusing and the distinction between the two technical artifacts became more and more an historical relic. Whether one was abandoned for the other, one was subsumed by the other, or they were synthesized into a new artifact is largely a matter of rhetorical strategy. Similarly, who was studying and writing about one or the other piece of software, who was funded on which grant, what was being touted in publications and grant proposals, all was complex and generally merely technical, since work and money was often shifted and used where there was a declared need to move the joint efforts forward to strengthen the technical, social, and network infrastructure that would be capable reproducing and multiplying itself.

Chapter Two focused on the technological aspects of the infrastructure and its impact and relation to the development of the Virtual School. In this chapter, I focus on the social aspects and work done that constituted the activities of the LiNC project more generally, especially those located in the classrooms. The project included a large assortment of academic work, such as dissertations, various grants, especially the LiNC grant, and professional work of software developers and teachers. As with the descriptions in Chapter Two, the beginning and end was somewhat arbitrary, and there was much that was left out for reasons already mentioned. Nevertheless, I note some key figures and influences that shaped the LiNC project as I have come to know it.

Timeline

In this chapter, I focus on mainly on a five-year period, though events extend beyond that on both ends. A five-year period may seem to be an odd choice to describe a three-year grant, but for reasons discussed above and below, the grant is a piece of a larger project with causes and extensions that go reach well beyond the three-years specified in the NSF grant. There was dissertation work by Stuart Laughton that was instrumental in introducing the setting and opportunity for the grant proposal. There was the planning grant and BEV that provided foundation for the proposal. There was the writing of the NSF proposal. There was work directed by George Chin that began without help of the grant award money since the money did not arrive at Virginia Tech in time to hire personnel at the beginning of the academic year. There were the three official years of the grant, which began just after the 1995-1996 school year began. Then there was the Hitachi grant that continued much of the work of the LiNC project beyond the grant period.

I have chosen to divide the work into segments since that roughly corresponds to the grant periods and the academic years. First I describe work done prior to the first year of the grant. In the main body of the chapter, I consider periods that run from one September or October to the following one, starting in 1995 and running through 2000. Below I include a timeline to help the reader get a rough chronology of the major events and personnel discussed in the chapter.

YEAR	MONTHS	PERIOD	TEACHER ACTIVITIES, MEETINGS, AND INTERPRETATONS	TOOLS	STUDENT ACTIVITIES
1995	Jan - Mar				
	Apr - Jun				
	Jul - Sep				
	Oct - Dec	1st			**George Chin's work**
1996	Jan - Mar		**Teachers Meet** Arrington introduces project		
	Apr - Jun		**1st Summer Workshop:** Team building, defining roles, capabilities, participation		
	Jul - Sep		**Brainstorming**: Initial design, setting, expected results (2 weeks)		**Collaborative Activities,** e.g. melting/freezing point w/ chat, audio and video conference
	Oct - Dec	2nd	**Try Scenarios** (e.g. Block and plane. Material worked but results were not as expected	**Macs:** Email, Video conference, Computer simulations	
1997	Jan - Mar		**Appraisal of activities:** Cosidered results generally "less than rosey" Paper Protyping sessions		**Physics labs** w/ data shared by email
	Apr		**Teacher Revolt** Ask for project-based Virtual School; throw out "one scenario-at-a-time-approach for big projects; redirection of approach		
	May				
	Jun				
	July		**2nd Summer Workshop:** Teachers give specs/ mock-up for Virtual School and decide to do Long Term instead of isolated projects		
	Aug		**Eisenhower workshop;** revised approach is worked into classes, software is not ready but new platforms more reliable		
	Sept		**First indication** that Virtual School would not be delivered on time		

Figure 4.1. Basic timeline of LiNC Project activities.

1997	**Oct - Dec**	**3rd**	**Testing** of features and trials in classroom activities	**Toolbar; PCs** purchased Deployed Fall 97	**Long-Term** Virtual School Projects: Robotics, optics, amusement parks using Netmeeting and Toolbar
1998	**Jan - Mar**		**Realized** Virtual School would not ebe completed as promised		
	Apr - Jun		**Continue Projects:** Involve community mentors	**Virtual School** Developed	
	Jul - Sep		**Teachers give specs** for Fall Virtual School projects	**Virtual School Projects**	**Short-Term** Virtual School projects
	Oct - Dec	**4th**			**Long-Term** Vitual School Projects
1999	**Jan - Mar**				
	Apr - Jun				
	Jul - Sep				**Short Term** Virtual School Projects
	Oct - Dec	**5th**			**LEGO** Virtual School Projects
2000	**Jan - Mar**				
	Apr - Jun				
	Jul - Sep				
	Oct - Dec				

Figure 4.1 (continued). Basic timeline of LiNC Project activities.

The Years Before: Early work by Laughton

In the years preceding the LiNC grant, Stuart Laughton was preparing a dissertation for Computer Science about designing computer-mediated communication (CMC) systems in education (Laughton 1996). He successfully defended this dissertation in 1996 with Jack Carroll as his advisor. Gary Downey from STS and Andrew Cohill from BEV were also included on his committee. This work contained the early seeds of the LiNC proposal and the Virtual School.

"Stuart's [Laughton] work was underway when the planning grant was written. It helped him because it provided a few computers for teachers…(those) computer(s) facilitated the classroom technology that Stuart (Laughton) was supporting and observing" (Carroll 9/18/2001). Laughton's wife, Wendy, was a teacher in MCPS at the time, and his dissertation focused on four case studies in the use of the CMC (specifically, Internet-mediated communication) in education. Two of these case studies described activities in MCPS and the other two described activities in college courses at Virginia Tech. This provided an opening, rich context and opportunity to seed Carroll's research interests in using the local public schools as a setting to study educational technology.

Laughton's work had two main roles developing the vision and substance of the LiNC proposal. First, it established a presence and precedent for the work of Virginia Tech computer scientists interested in CMC in MCPS classrooms. Two teachers were given computers for use in their classrooms, and Laughton engaged them as participants in his research and design. Second, it established a foundation including literature review and prior research for demonstrating and arguing for the use of participatory design, scenario-based design, and CMC with school, especially MCPS physics and middle school, classrooms and teachers. The work was influential for the LiNC proposal in three areas. It established positive social relationships and social networks among Virginia Tech researchers and MCPS personnel. It generated and elaborated a participatory and scenario-based computer science design approach, and it began the process of introducing the local culture of teaching, in the context activities concerning, CMC directly to Laughton and indirectly to Carroll by engaging them and teachers in discussions. The results were twofold. First and foremost, the knowledge and experience strengthened the LiNC proposal. Second, it made MCPS an ally.

The LiNC Grant Proposal

Like the Virtual School technology that was finally developed and deployed in the fourth year of the project, the LiNC proposal embodied, represented, and reified the history and contexts of development. This history and context included important social networks, technical knowledge, expertise in several academic disciplines, political interests, and power. In addition to the attention and clout garnered by the BEV around this time along with Carroll's synergy and knowledge, several other centers of activity contributed to the writing of the proposal including, for example, the planning grant described in Chapter Three.

Design goals in LiNC

Software designers, especially in the field of Human-Computer Interaction, have criticized traditional approaches to systems development. The most significant criticism concerns the exclusive focus on functionality over usability. Systems designers have traditionally been programmers trained to gather functional requirements, that is, specifications of what operations a software package should be able to execute. The steps and interfaces that a user must perform in operating the software result from considerations secondary to the internal functioning of the program. This is considered a very linear model of design. First one specifies the desired functions or gathers requirements. Then one breaks down those functions into chunks that correspond to sub-systems that can be programmed. Then one designs an interface that allows a user to input and output the specified functions. The main problem with this approach concerns the discrepancy between how a system is designed and how a user actually uses it. In many cases, designers cannot anticipate the contingent needs of users in genuine work settings, so the functional design does not closely match the way users apply the program. These are called usability problems, and recently usability engineering has become a major field and business related to software engineering and HCI.

More recently, techniques that focus on user-centered design have emerged as a way to address problems with the linear model of functional specification design. A number of approaches have been advanced to account better for user-centered design. Among these, and very close to the LiNC project, are scenario based design (Carroll 1995, 2001) and participatory design (Carroll 2000).

In scenario-based design, designers consider the context of use in developing requirements for the design process, rather than focusing exclusively on functional outcomes of software and specifying those functions purely beforehand. Scenarios or situations in which users apply the software elaborate the context of use. One particular scenario guided the vision of the grant and development of the Virtual School. This was called the Marissa scenario (Carroll et al. 2000).

- Marissa, a 10th-grade physics student, is studying gravity and its role in planetary motion. She goes to the virtual science lab and navigates to the gravity room.

- In the gravity room she discovers two other students, Randy and David, already working with the Alternate Reality Kit, which allows students to alter various physical parameters (such as the universal gravitational constant) and then observe effects in a simulation world.

- The three students, each of whom is from a different school in the county, discuss possible experiments by typing messages from their respective personal computers. Together they build and analyze several solar systems, eventually focusing on the question of how comets can disrupt otherwise stable systems.

- They capture data from their experiments and display it with several visualization tools, then write a brief report of their experiments, sending it for comments to Don, another student in Marissa's class, and Ms. Gould, Randy's physics teacher.

The scenario contains several important and telling features. First, it describes an instance of student-directed use of the technology as opposed to teacher-directed instruction. Second, it suggests that students from different classrooms use the technology to work together toward common goals. It also defines a grade level (10th) and a subject (physics). Finally, it suggests that the technology serve several roles in the process: a tool for introducing dispersed students, a tool for organizing the collaboration, and a tool for providing instructional content such as simulation and modeling. Perhaps even more importantly, the Marissa scenario continues to act as an example of a powerful description in providing a vision for software development in the acquisition of grants. There has even been a visual representation created to elaborate the scenario. This is shown in Figure 4.2 below.

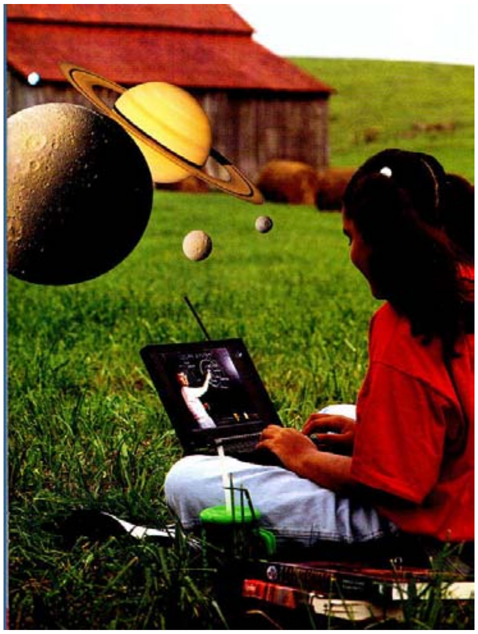


Figure 4.2. A visual image meant to elaborate the Marissa Scenario.

Since software designers are often alienated from the ways in which users end up adapting software and features for particular uses, they have turned to techniques that bring users into the design process as participants. Participatory design was a major focus of the design goals of the LiNC project. The motivation for participatory design was explicitly directed in the overview of the grant proposal:

> **1. Abstract**…
> Key elements of our proposal are:
> A participatory design approach involving teachers and students as design team members (in contrast to externally-imposed educational technology solutions)…Continuous on-site teacher support to help in selection and composition of project-oriented curriculum elements, community

> involvement in experimental projects, and evaluation of technology change, attitudes, and outcomes….
> **3a. What is/are your primary research methods?**
> We use ethnographic description, participatory analysis and design, and a wide variety of logging, quasi-experimental, and anthropological measures.

Carroll, Rosson, Chin, and Koenemann (1998) distinguish participatory design from the traditional "waterfall" model that treats requirements gathering as a single initial step in creating software, rather than an iterative "developmental" process in which different views of the requirements emerge through different design activities. "Participatory design contemplates a more substantial *process* of users and designers working together during an extended period of engagement to exchange perspectives, to learn about each other's skills and values, and to jointly identify an appropriate set of requirements" (1156).

Carroll, Chin, Rosson, and Neale (2000) suggest that the roles of the teachers in the LiNC project developed in stages throughout the long-term relationships established over the course of the project. They describe three stages of cooperative engagement through which the teachers moved. Initially they acted as practitioner-informants, then they became more actively involved in the process as analysts, and finally they assumed the role of designers.

Participatory and scenario-based design represented Carroll's team's expertise in computer science, especially HCI, but an important area where Carroll admittedly lacked significant experience was in the field of education, especially as related to public schools. His interest and experience in learning theory in the context of object-oriented programming was enough to provoke his interest in Laughton's work in public schools, but he felt the need and was encouraged to seek an established educational researcher who would lend support to the project.

Educational Expertise: John Burton

Carroll realized early on in the visioning process, and later in communication with Sabelli at NIE about the proposed outcomes of the project, that he needed expertise in educational research. For this he turned to John Burton from the College of Education at Virginia Tech. Burton's background was in psychology of learning with some interest in instructional design. He described his preparation as a "straight up learning theorist" with emphasis on behaviorism, saying that he "backed into technology." Burton was asked by Carroll to join the group as the expert in education in charge of evaluating the project.

He first saw his role as team member in charge of program evaluation. He helped write a portion of the proposal dealing with evaluation relevant to the educational or classroom interventions of the project. He initially felt that his role should one of evaluating the program against its own goals. As the meetings and interactions progressed, his concerns were directed more toward issues about the educational research questions involved, specifically looking at how the technology might impact student achievement. Burton claimed that these kinds of questions were misdirected, and suggested that these types of data could be not be used to the advantage of the research. First, he believed that these teachers were already doing an exemplary job in the teaching; so trying to improve their instruction with technology was not likely to yield significant results. Even if a difference between mediated and unmediated instruction was demonstrated, it was unlikely to represent a meaningful comparison, in Burton's view. It was "apples and oranges." To explain, Burton viewed the technology as a type of "media." Thus, such comparison would amount to what the literature deems media comparison study. Burton suggested that there were good reasons that media comparison studies were problematic and had been abandoned several decades ago. He offered a paper (Clark 1983) as evidence of his position around the summer of 1996. In short, he opposed efforts to collect baseline data on how students achieve, because he believed that it was not meaningful to try to demonstrate the potential *added value* of the technology as instructional media for increasing student achievement.

Year 1 of LiNC (1995-1996)

In the first report on the grant to NSF Carroll and other investigators described a number of problems getting the project started.

> Moneys arrived too late in 1995 for us to hire personnel. Thus, during the Fall of 1995, we focused on working with the Montgomery County School System, through co-PI1 Dr. Larry Arrington, to identify and recruit teachers for the project staff…
>
> We have suffered some personnel set-backs. Dr. Stuart Laughton, whose Ph.D. project was the original inspiration for our project and who had planned to serve as Technical Coordinator, was hired away by industry. Professor John Burton withdrew from the project in August when he was appointed Director of the Teaching and Learning Program. [Another investigator] withdrew as of the Fall semester 1996 due to maternity.
>
> We also have experienced a major modulation in our staffing resulting from a developing relationship with JavaSoft: they have hired two of our graduate student assistants (James Begole and Craig Struble) as research interns for the Fall semester of 1996.

Burton left the project after he was appointed temporary head of the Division of Education in the College of Human Resources and Education. At that time, he was coping with the dissolution of the College of Education and merger with the College of Human Resources at Virginia Tech in the fall of 1996. As such, he became inundated with serious departmental administration issues that required attention to staff in his own area. Since then, he has worked with Carroll on other projects and maintains a healthy working relation with and respect for the work directed by Carroll, but his contribution to the LiNC grant was limited to this beginning phase of writing the proposal and initiating the first year of the grant. He was uninvolved in the actual deployment and data gathering with the Virtual School technology.

Each of the five LiNC grant periods ran from one October to the next October, thus they generally corresponded to the beginning of a school year plus summer. The MCPS school year typically begins around the end of August. While technically the first period of the LiNC grant began in October of 1995, some work had begun in anticipation prior to October 1995 since NSF already had notified the team of the award of the grant and there was preparation and other projects that related to the first phase of the project.

Despite the skepticism voiced by Burton, baseline data pertaining to student achievement was collected in the first year of the project. While they did collect grades and achievement data as baseline measures of "typical" students, they also initially collected a variety of other measures about students and teachers (see http://simon.cs.vt.edu/nie/evaluation/baseline.index.html for more details). Basically, these measures included survey instruments such as the Vocational Learning Styles Inventory (Hendrix-Frye 1991), Norwicki-Strickland Personal Reaction Survey (Norwicki-Strickland 1973), the Computer Control Survey (Cook 1986), and The Stages of Concern Questionnaire (Hall, Wallace, and Dossett 1973). The Learning Styles Inventory is an instrument that was designed to assess a students' preferred learning styles and preferences for working conditions and focuses on five domains: physical, social, environmental, mode of expression, and work characteristic. The Personal Reaction Survey was designed to measure generalized locus of control in students, that is whether students feel that they have control over certain events or that they are externally controlled. Scores on this test have been related to achievement. The Computer Control Survey was meant to determine a student's feeling of control when using a computer. Teachers were given the Stages of Concern survey as a way to measure their attitudes toward using the Internet. By the third year of the grant, investigators were no longer collecting data or looking closely at student achievement. The struggle at that point was deciding on what, then, evaluation should focus.

George Chin's work

In addition to the various surveys, there were a variety of data-collecting activities directed mainly by George Chin. These included videotaped activities in the four classrooms, interviews with about twenty students that focused generally on learning styles, and open-ended interviews with five teachers that focused on teaching styles, teaching philosophies, walkthroughs of typical lessons, and other related topics. The interviews and videotapes were used in "ethnographic" analysis where Chin looked for and documented certain categories, patterns, and themes. Chin developed taxonomies from the analysis that were presented to teachers for discussion and confirmation. Edited extracts of the videotape were presented to the teachers in the summer of 1996.

During the summer of '96, Chin and other investigators engaged the teachers in a number of activities. These included participatory analyses of the classroom videotape segments (see Chin, Rosson, and Carroll 1997) and scenario development of new computer-enhanced lessons based on findings from participatory analysis.

There were twelve scenarios that came out of the summer work, six dealing with middle school physical science and six dealing with high school physics. The following (Figure 4.3) is a typical example of a high school based scenario.

From our summer workshop:

Scenarios from a High School Physics Inelastic Collision Lab

Context

The scenarios presented here have be extracted from actual observations taken from a physics class at a high school. The observations are on a lab on inelastic collisions.

The physics class consisted of twenty-seven students - fourteen males and thirteen females. Of the students, two are Asian-American females, two are African-American females, and one is a African-American male. The class has no Hispanic nor Native American students.

The basic layout of the class is shown in the diagram at right. Normally, students would sit in student desks during lectures and at the student workbenches during experiments.

Scenario #1 - Overview of the Lesson (A Sticky Issue)

The teacher introduces the inelastic collision experiment to the class. Features of the experiment are elaborated.

[1] The objective of the lesson is to teach high school students about inelastic collisions. The lesson consists of a number of activities and is covered over four school days. Three days are devoted to the lab and one day is reserved for a lab quiz.

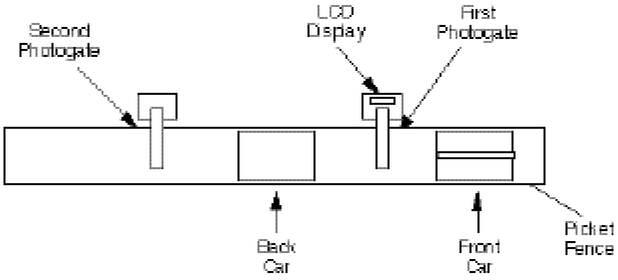
[2] At the beginning of class during the first day of the lesson, Mr. Neidermeyer passes out a data worksheet to each student. On a desk near the front of the classroom, Mr. Neidermeyer then demonstrates the step-by-step procedures for assembling the equipment.

[3] The experiment involves two metal cars, a metal rail, and two photogates. The two cars ride on top of the metal rail. The front car has a notch on top in which a "picket fence" is placed. A picket fence is a glass plate with visible markings along its flat surface. Both cars have velcro on one end such that when the cars collide, the two cars attach. The photogates are connected by a wire and are placed alongside the rail. At the base of one photogate stand is a LCD display. Each photogate has two sensors. The sensors of a photogate hang over the rail such that when the front metal car slides along the rail, the attached glass plate moves cleanly between the two photogate sensors.

[4] The photogate may be set via the LCD display to take different types of time measurements across the photogates. For the inelastic collision experiment, the photogates are set to return the time elapsed between two markings on the picket fence. A student may calculate the velocity of the glass plate (and the metal car) given the elapsed time and the distance between the two markings. The diagram to the right depicts the setup of the experiment.

[5] After demonstrating the assembly of the equipment, Mr. Neidermeyer then demonstrates the execution of one run of the experiment. To execute a run of the experiment, a student pushes the front car along the rail into the back car. When the two cars collide, they attach and energy is transferred from the first car to the connected pair of cars. The transfer of energy is observed as a decrease in velocity between the initial car and the connected pair

of cars. The first photogate is used to capture the velocity of the initial car and the second photogate is used to capture the velocity of the connected pair of cars.



[6] Alternatively, the student may calculate the final velocity of the two cars from an equation, given the masses of the two cars and the initial velocity of the front car. More specifically, they may apply the equation

$$v_f = (m_1 / (m_1 + m_2)) v_{1f}$$

where m_1 is the mass of the front car, m_2 is the mass of the back car, v_{1f} is the velocity of the initial front car prior to collision, and v_f is the velocity of the two connected cars after collision.

[7] The main steps of a particular run is to determine the final velocity of the connected pair of cars experimentally and then to compare this observed velocity with an ideal final velocity calculated from equation. The objective of the run is to experimentally obtain a final velocity which is within 3% of the ideal velocity. Students are to repeat the run until this 3% error threshold is reached.

[8] Students are to execute five different variations of the experiment where the mass of the cars are altered by adding and removing weight blocks. For each variation, the objective is to experimentally obtain a final velocity which is within 3% of the ideal velocity.

[9] The set of variations for the experiment had been written on the chalkboard at the front of the classroom by Mr. Neidermeyer. The variations are listed in table to the right.

[10] In addition to the above variation table on the chalkboard, Mr. Neidermeyer had also written the values of the settings at which the photogates are to be set for the experiment.

scenario	
I	both cars empty
II	car 1 w/ 1 block
III	car 1 w/ 2 blocks
IV	car 2 w/ 1 block
V	car 2 w/ 2 blocks

[11] Each student is to complete at least one worksheet for each variation of the experiment. The worksheet provides a chart in which the data and results of ten runs of the experiment may be stored. In cases where a group is unable to achieve less than 3% error in ten runs, the group would gather additional worksheets to the store the results of additional runs.

[12] Throughout Mr. Neidermeyer's demonstrations, students would freely interrupt Mr. Neidermeyer to ask questions regarding the experiment and to add comments. Mr. Neidermeyer gives the students some hints on how to manipulate the experiment to achieve better error values. He also discusses some safety concerns regarding the use of the equipment. Once the demonstrations were complete, Mr. Neidermeyer polls the class for any further questions. Archibald asks a question regarding the execution of the experiment. Juanita asks a question regarding the use of the photogates.

13 Once all questions have been addressed, Mr. Neidermeyer directs the class to organize into the same groups they formed during a previous experiment. Originally, these groups were allowed to form amongst themselves. Typically, a group would form among students who sat spatially close to each other. The seating assignments, however, were freely selected by the students at the beginning of the school-year. As a consequence, most students sat nearby their friends as well as formed groups with their friends.

14 Group members convene at their respective workbenches. After convening, some group members disseminate throughout the room to gather equipment for the lab while others wait at the workbench. Once all the equipment has been gathered, the group assembles the equipment. Once the equipment is properly assembled, the group performs the lab.

15 A group manipulates the error of the experimental result by changing the positions of the photogates, the positions of the cars, or the initial velocity of the front car. Throughout the lab sessions, students would execute the experiment and work on their calculations using their calculators and worksheets. By the end of each day of lab, group members would disassemble the equipment and return the parts to various areas of the room.

16 On the third day of the lab, Mr. Neidermeyer hands out lab assignment sheets. After completing the series of experiments, each student transfers the results of the group's five best runs from his/her worksheets to the lab assignment sheet. The transferred results are the best runs for each of the five variations. As directed by the assignment sheet, the student uses the experimental results to perform various energy calculations, to graphically analyze computed energies, and to answer some questions regarding the transfer of energy.

17 Students place the products of the inelastic collision experiment, which are the completed worksheets and the lab assignment, in their personal lab notebooks. Shortly after the lab sessions, the students are given a lab quiz. In the quiz, students are given a fake data table, with which students complete error and energy calculations and analysis similar to those performed during the lab.

Figure 4.3. Example classroom scenario developed in the early design process.

Another important outcome of the summer workshop was the presentation of the prototype mock-up of collaborative lab software by Marc Abrams. The chief feature of this prototype shown in Figure 4.4 below was the collaborative lab notebook that allowed students to document and collaborate on science labs using the networked computer software.

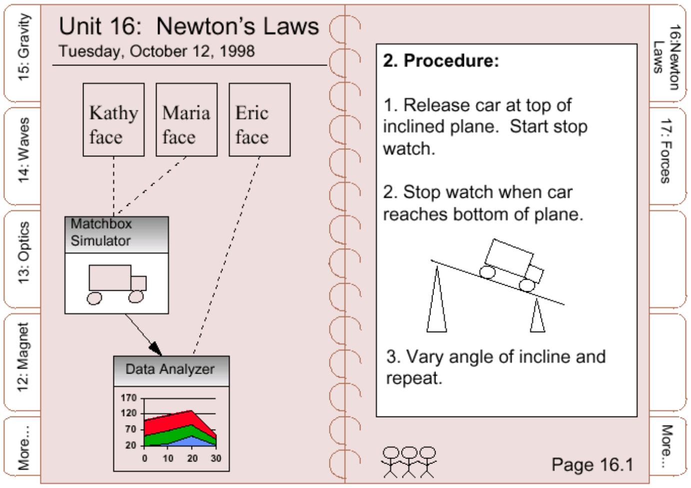


Figure 4.4. Picture of Marc Abrams' mock-up of the idea of a collaborative notebook called C'lab.

The ideas and social relationships represented by the C'lab prototype were instrumental to the development of the Virtual School software, which had a collaborative notebook as a key function for coordinating dispersed group cooperative activities among students.

Year 2 (1996-1997)

By the fall of 1996, the classrooms had been equipped with sets of Apple computers. These were Apple 8100s and PowerMac 7600 machines with Ethernet connections and software for network communication and other typical computer applications including QuickTime conferencing kits, Netscape web browser, Eudora Light email client, ClarisWorks, Fetch file transfer client, and a Telnet client. Some of the software was freeware, some was provided by the LiNC project, and some was provided by MCPS via Larry Arrington who was the science supervisor at the time and a major proponent of the project.

During the 1996-1997 school year, teachers developed and elaborated a number of different classroom scenarios. Some of these became lessons used in the classrooms. Investigators and teachers worked together in several paper prototyping sessions, and conducted more activities aimed at participatory analysis and claims analysis. Claims analysis basically resides in the process of identifying and analyzing "key features" of proposed or prototype software and inferring good and bad consequences of those features.

Starting in the fall of the 1996 school year, several of the scenarios were tried in the classrooms. These generally consisted of typical physical science labs modified so that student groups could share their data and collaborate with groups in other classrooms through email, chat, and video conferencing. Investigators observed and videotaped these activities. For example, one of the labs studied the freezing / melting point of different substances. Groups were assembled and given the task of identifying various substances by examining their freezing / melting point. Teams worked on different tasks and decided as a group on the results using computers to mediate the collaboration.

Teacher Revolt

In late spring of 1997, the teachers met among themselves as a group to discuss their plans and desires for the coming year with respect to collaborations and the LiNC project. They decided that the types of exercises that they were being asked to do were not the kinds of activities that they would prefer to be doing with their role in the LiNC project. As one teacher explained,

> We made the switch because [one of the investigators] was dictating what we were supposed to do and defining everything. So ... we just took over en masse. The other reasons were because we felt the short term things were too isolated ... no connection with anything else. In truth, they probably WERE well connected, but you couldn't tell because the technology was so awful.
>
> [The shift to long-term projects] gave us great focus. We were fabulously productive. Personally, I was renewed in my feelings for the whole grant project.

Specifically, they favored longer-term collaborative projects over the short lab-type collaborative activities in which they had been involved. Some of the investigators in the LiNC project referred to this meeting somewhat jovially as a "revolt" against the researchers, but Carroll considered it a positive move because it suggested that the teachers were exercising greater autonomy over their role in the project, that is, they were taking greater responsibility for the direction of the investigations. In July 1997, at the summer LiNC workshop, the teachers laid out their vision of the long-term projects and identified specifications for tools with which to equip a virtual school. Carroll, Chin, Rosson, and Neale (2000) described this critical episode in the LiNC project:

> In April 1997, the teachers met on their own and formulated an approach to classroom activity design that they called "projects." They had concluded that the pedagogical value of the relatively brief and technology-oriented classroom activities investigated in fall 1996 was too limited, that the overhead of initiating these activities was too high relative to their value. They urged a different approach for the 1997-1998 school year, one involving activities that extended over several weeks, even months.
>
> This episode is truly a turning point in the LiNC project. This is not because the teachers wanted to focus on long-term, rather than short-term activities; other members of the team also wanted to focus on more realistic activities, and on more ambitious activities that would drive our software ideas more vigorously. What is significant is that the teachers took the initiative to develop and articulate a central design concept to the group as a whole, and that this design concept entailed more responsibility and for work *for them*.

> There is no way to see their proposal as less than fundamental to the project's design strategy. Rather than responding to our visions, they were contributing a vision; rather than agreeing to a work plan, they were providing a strategy for the work plan. Perhaps most importantly, through this episode, the teachers embraced the virtual school as a major tool in their own pedagogical planning. This sharply contrasts with the earlier principle of cooperating as long as the project did not diminish learning opportunities for their students (p. 244).

While Carroll saw value in the ability of the teachers to initiate and articulate their desires about how to proceed with the project, he also admitted that the research team was unprepared for the culture of resistance common to teaching in public schools. This episode represented one case where teachers wanted to exercise their ability to take a stance as a group in order to control the direction of the research in their classrooms.

Teachers Understanding Their Differences

The group consensus that they achieved was not a trivial matter. The teachers realized that, while they may teach the same subject matter, their pedagogical styles differed radically. There were a number of indications of such differences, but they should be put in context. As we point out in Dunlap, Neale, and Carroll (2000), the teachers had significant differences in style, but they also shared pedagogical beliefs and practices. Teachers readily acknowledged that the most critical barriers to their collaborations centered on the stylistic and pedagogical differences between them. They expressed this sentiment in a number of ways:

> Expectations are different for what we're doing in the classroom and that's going to impact how well our different students can share stuff. We've been [talking] a little about this and we need to rethink it. I think it's a good goal and I'm not ready to abandon it.
>
> [There are] some difference in performance expectation. [The other teacher] does a lot of things rather conceptually, and I'm much more engineering oriented.
>
> Well I think the biggest [barrier to collaboration] is teacher style of teaching.
>
> Everybody will probably say I'm more conservative. You know, more the old-fashioned type teacher.
>
> So perceiving each other and understanding our teaching styles is somewhat [the biggest barrier to collaboration].
>
> The biggest obstacle for me right now is that [the other teacher] and I have a different approach to physics. He is the algebraic/trig approach where a vast amount of time is spent problem solving doing math, and I am the

> conceptual approach. Sort of the two opposite ends of Physics curriculum. I don't spend very much time doing math with the kids. I spend a lot of time talking about why things happen. Those two different approaches can cause difficulty when we try to get our kids to work together on things that are content, and we had that specific problem two years ago. Right about this time two years ago we did something on friction. It was a terrible problem because [the other teacher's] kids had a different goal than my kids. Not to say that [the other teacher is] wrong and I'm right, but we had different goals for our students. And so we're trying to get them to get different things out of the experience. And none of us are willing to sacrifice our kids to it all and just say let's do what they're doing and we just won't worry about it. I think it's more pedagogical than anything.
>
> Just like all kids have different learning styles, teachers have different teaching styles, and different philosophies and different approaches, and I think most good teachers have a blend of teaching styles.

The latter comment by a teacher represents an important insight into the way that teachers identify their instructional styles or choices. These teachers do not readily categorize themselves according to particular "fashionable" approaches. As illustrated in the passages above, the key differences they identify are those that they categorize as stylistic differences. Moreover, it is interesting to note how they distance themselves *and* the Virtual School activities from "constructivist" pedagogy. Their statements below illustrate that they consider the meanings and value of different types of learning activities. In fact, given the extent to which they express differences in their teaching styles, they appear surprisingly similar in their common emphasis on project-based and inquiry learning as well as their feeling that the Virtual School activities did not conform extensively to what they understood to be "constructivist pedagogy." There is a great deal of variation and disagreement about what "constructivist pedagogy" is. In fact, it was a subject of discussion at one point on the online CCIT discussion tool, but while we considered various dimensions and uses of the term "constructivism" including psychological and social models of learning and their implications to teaching, there was never any clear consensus about the meaning. One teacher recognized the lack of agreement over the use of the term. "We could argue the definition for days and probably find literature to support most any definition we personally favor." Nevertheless, it is interesting to note how teachers did situate the Virtual School activities with reference to constructivist and project-based teaching strategies and how they interpreted constructivism with respect to the activities. Consider the following example:

> I have never considered this project-based collaborative learning thing we are doing to be an example of a constructivist activity. This is about developing research and social skills, not the small, short-term kinds of things that are typical for constructivist activities. The very nature of this project does not lend itself to this. Constructivism is about working with a specific content or objective, making pre-assessments to gauge current

> levels of knowledge, establishing conflict, and “constructing” or “re-constructing” new knowledge on top of what was already there.

While this teacher has in mind a particular interpretation of “constructivism,” it is a version related to psychological or educational theories that suggest that learning is a process of building knowledge on existing concepts. Importantly, the teacher suggested that the Virtual School activities did not fit the mold. Another teacher took it a step further to suggest, in a banal and somewhat humorous way, that his teaching contrasts with constructivist pedagogy.

> First, my approach to what happens in the classroom is not the currently fashionable constructivist pattern. A fraction of it is skills development, almost Pavlovian conditioning. See a circle => recall A=pi(r)^2, C=pi(d)=2pi(r), tangent perpendicular to radius, inscribed angles.

Yet another teacher explains precisely how particular Virtual School activities conformed to some constructivist principles. The key to this teacher’s notion of constructivist learning rests in the degree of originality that was required of students to innovate and build through their own devices and ingenuity.

> I think students are generally allowed to have opportunities to make choices and gather information on their own at some time during a typical school year, but I don't think that is truly "constructing their own knowledge." I believe the long-term projects have constructivist aspects to them, but most fell short of true constructivist outcomes. It seems to me that the robotics group may have come closest to a constructivist project because they really did start from scratch and had to figure out all kinds of things in order to make the robot work. The bridge projects and roller coaster projects were mostly based on existing models or used contest parameters that have been tried and tested previously. The acoustics array was probably a first for those kids so maybe it had constructivist outcomes too.

One teacher recounts the origination of discussion about applying constructivist methods to Virtual School activities.

> I do not recall framing the LiNC program as an exercise in constructivist teaching/learning; certainly that was not discussed much at the beginning of the grant. I think the whole constructivist thing came about over a year ago when the four teachers talked about trying to use the VS as a means of supporting a long-term project. The design of the projects then took on a constructivist appearance because most of us felt strongly that students needed a voice in what they were going to investigate and how they might approach their project. I don't really recall any of the four of us saying lets take a constructivist approach, but I think that might be inherently a part of how we all teach at least some of the time.

As this passage points out, the shift in emphasis by the teachers to focus on longer term projects also included discussion of constructivist concerns; however, the main thrust of the discussion was on how the technology could better support project-based learning. A teacher explains the factors that precipitated this shift and its importance.

> The change in project length grew out of experience with the shorter term activities initially used. This was facilitated through a major program refinement coupled with adequate planning for the new features use. The combination was a product of a conceptual realignment and resulted in an altered view of the application of the technology. Additionally, I was pleased to bring the Virtual School to bear on projects more typical of physics class. The overhead of training students in use of the Virtual School seemed too large a proportional fraction of the instructional time when applied to short activities.

The emphasis on longer-term projects had ramifications for the design of the Virtual School, and the length and execution of the long-term projects presented a number of challenges to the activities and application. In short, groups that met over long periods of time needed more and different ways of keeping track of decisions and progress made by the group. This was especially the case for several of the long-term projects, for example the Aerodynamics project, in the 1998-1999 school year. Subtle changes in planning made big differences later in a project to the students involved, and students that were absent or involved in other tasks when key decisions were made, questions got resolved, or responsibilities got assigned or accomplished often were left out of processes, confused, or complicated matters worse by changing plans even further. Moreover, long-term projects had significant ramifications for the teachers. As one teacher said, "It required that the four teachers spend a good deal of time planning. We had to examine each others curricula fairly closely, decide on common topics/concepts we might want to develop into a project, develop a time table and think about logistics of grouping kids and matching them up in collaborative teams."

In August 1997, the teachers took part in another grant that was administered by the State Council of Higher Education in Virginia. The federal Eisenhower Teacher Development Program supported an initial workshop for a group of math and science teachers in MCPS, and the LiNC teachers took a lead role in helping other teachers gain experience with computer network tools during the workshop.

Year 3 (1997-1998)

Koenemann, one of the lead researchers on the project, left the project near the end of this second year of the grant. During the 1997-1998 school year, researchers headed mainly by Chin continued to focus on three basic activities, scenario development, paper prototyping, and claims analysis. In addition, the teachers filled out an extensive questionnaire on the participatory design process at the end of the school year. In the spring of 1998, Eales left the project. His role as evaluation coordinator was taken over by Neale marking another major shift in the LiNC project. Neale was a graduate student in Industrial Systems Engineering focusing on Human Factors Engineering.

PCs deployed

In August of 1997, twenty computers were ordered from Gateway. These were high-end machines of the day, Pentium computers with a speed of 200 MHz, including Ethernet cards, graphics cards, and typical Windows 95 software that included Netmeeting. In fall of 1997, the machines were set up in the four MCPS classrooms. Each classroom participating in the LiNC project was supplied with five computers. Each classroom had T1 Internet connections for each machine.

The number of computers was an obvious constraint on how collaborative projects could be conducted. Each one was a prized possession to the teachers. Each classroom had from 10 to 25 students who would be using the machines, so teachers and investigators decided to form groups in each class that would collaborate with similar groups in other classes. Investigators, mainly Neale and myself, decided that it would be keeping with the project goals to study cross-grade and cross-setting groups. There were basically two levels, physics and physical science, and there were two settings, Blacksburg and Riner. The original assumption was that Riner (Auburn Middle and High School) represented a rural culture and Blacksburg represented an urban culture. We knew at the time the Virtual School was deployed how problematic that assumption was, and we were able to show examples from our work that demonstrated some of the problems with that assumption.

For example, while working on one of the long-term projects, we assumed students at BHS to be “typical urbanites.” That meant that we assumed that they had significant experience with computers. It was not until one of the last days of the project that a BHS student turned to one of the researchers and said, “My mom wanted me to thank you for teaching me so much about computers because I couldn't even type well.” This was shocking to the researchers involved because we assumed that this student, like her colleagues, was well adept at computer skills. As it turned out, this student was far more “blue-collar” than she appeared, and it was only after we inquired further with other sources that that became clear. Similarly, there were several students at AHS, the “rural school,” that we assumed to be “rural” types. In fact, on investigation, these students were headed for Ivy League schools in highly technical fields and came from affluent families. Nevertheless, the distinctions among schools and grade levels gave us a way to think about combining groups for cross-collaborations.

The Long-Term Projects

Late in 1997, the teachers began to implement their visions of long-term projects. Students chose topics and were assigned to groups that crossed classrooms. The projects ran most of the second half of the school year beginning in December 1997 and lasting through March of 1998. These were group-learning projects that included a final report from each inter-classroom group. Topics included Aerodynamics, Amusement Park Physics, Robotics, and Bridge Structures. Some of these projects were more engineering oriented. Accordingly, they required the design and testing of a device that involved some principles of physics. For example, in the Robotics project, students were asked to design and build a robot that could be remotely guided to an object, sense, and indicate when it touched the object. As such, students needed to apply principles such as force, torque, and electronic motors, sensors, and controls. Other projects, like Bridge Structures, asked students to describe types of bridges, possibly provide some historical context of bridges, and design, build, and test a model of bridge that could hold a maximum amount of weight. The Amusement Parks project asked students to design and discuss principles of physics related to, for example, roller coasters. They had access to toy tracks and cars that could be used to build model roller coasters.

The collaborations were mediated using email and Netmeeting. Groups generally met once per week to work on the projects. Groups consisted of two or three members in a classroom that were combined with another similar group in another classroom. Some of these groups also had outside community mentors that assisted the groups. These were generally volunteer engineering professors from Virginia Tech who were experts in the subject area. Groups varied in their cooperative relationships. Some of these intra-classroom groups worked as level team members, each contributing according to a chosen task arrangement. Other groups took on more of a mentoring relation, especially where upper level high school students were paired with middle school students, though this was not always the case.

The projects were intended to help investigators establish requirements and provide information or "data" about problems and opportunities associated with how students can and will use networked computers to mediate project-based learning. The goals, however, were mixed. There were two basic sets of evaluation questions that roughly correlated with the two disciplines being addressed. On one level, the questions of student achievement still lingered in the minds of the investigators. Researchers continued to ask whether and what effects the computer mediation had on student learning and educational outcomes. These became less measurement-based achievement concerns and more directed at the teachers' perceptions of outcomes related to the processes. Teacher interview questions reflected these concerns. For example, teachers were asked, "What have been the educational outcomes for students who have been involved with LiNC project this year?", "What are the educational goals for your group projects?", and a number of questions about how the LiNC project has contributed to project-based learning, student learning, group projects, and student motivation.

On another level, investigators focused a great deal of attention on standard HCI kinds of issues such as usability, requirements, features, components, and participatory design of the technology. For example, there was a great deal of discussion among investigators about the use and need of video-conferencing as a feature for mediating such group activities. There was also general concern for establishing ways of facilitating and coordinating synchronous and asynchronous group activity with the tools.

The Virtual School Is Born

In summer of 1998, Isenhour began to put together the pieces of the Virtual School along with the CORK architecture driving the application. He describes this sudden spurt of development as a case of "punctuated equilibrium" (Isenhour 2001). The requirements for features had been made relatively clear by the prior year of student collaborations. The issues and limitations of the technical predecessors of the CORK architecture, JAMM and Sieve, described in Chapter 2, suggested a path for Isenhour. This path used Java to implement methods for updating server objects with changes made from remote replicas. The use of Java constrained or at least suggested default interface "looks." Thus, in a relatively short period of time, the Virtual School came into being as a particular thing. It became a piece of computer code consisting of an application and server-side client. It became an interface that functioned in specific ways. Isenhour began work on writing the Java code mid-June 1998. In August 1998, the Virtual School was born.

A log file shown in Figure 4.5 recorded the revisions made to the first instance of the Virtual School client. First the main window was created. Java versions have default border looks for their windows. This, of course, is another branch of the complex history of Java, but basically it emerged out of a collection of rejections from a design contest that Sun held in an attempt to find a look or package for their new product. Java interface windows, depending on the version of Java, look similar. The developer simply specifies the fillings in the window, which is the placement, color, size, etc. of particular buttons, borders, content, etc. The main window of the Virtual School served as the launch pad for users. This was a sophisticated version of an earlier idea of a "toolbar" that launched the communication applications (chat, email, and video-conference). Below the buttons was a crucial feature afforded by CORK that went well beyond the toolbar concept. This was a clickable list of group members assigned to the user along with their corresponding school and an indication of whether they were logged on at the time. Basically, this group list consisted of CORK objects. Below the group list was a clickable list of collaborative notebooks. Again, these were simply different kinds of CORK objects, specifically, collaborative text editor objects.

```
revision 1.1
  date: 1998/08/10 02:36:26;  author: isenhour;  state: Exp;
  first pass at the final Client implementation
revision 1.2
  date: 1998/08/14 05:38:44;  author: isenhour;  state: Exp;  lines: +12 -7
  adding code to ignore exceptions on logout
revision 1.3
  date: 1998/08/19 23:31:31;  author: isenhour;  state: Exp;  lines: +94 -16
  Revising client to use new ...linc.notebook stuff. Currently just supporting
  PlainText.
 revision 1.4
  date: 1998/08/26 02:59:54;  author: isenhour;  state: Exp;  lines: +2 -0
  Adding hack for HTML sections.
```

Figure 4.5. Log records of the first revisions of the Virtual School.

While the design of the interface might appear to be significantly open-ended, there were numerous historical and structural constraints that guided and established the interface design. This is not to take away from the craftiness and cleverness of Isenhour's work, and it is not to suggest that there were no viable alternatives. It could have been very different, but given the circumstances, at least in Isenhour's mind, there was not a great deal that needed to be determined in order to create or design the main interface or other features such as the collaborative notebook, email, or chat objects.

In October 1998 the notice board feature was added to the bottom of the main window. This was a response to several investigators and teachers' requests for a way for students and teachers to know when a user or group had done something in the Virtual School such as update a notebook or sent an email. In November 1998 an additional button at the top of the main window was added to launch Netmeeting for videoconferencing. There were a number of other features added and bugs fixed in the coming years of use of the Virtual School, but the main look and feel of the interface remained. Figure 4.6 below shows a computer screen-shot of a typical configuration of Virtual School windows during a group collaborative activity.

Name	School	Address	When
Philip Isenhour (idle 9m)	VT	128.173.116.29	10:23
Wendy Schafer (idle 4m)	VT	128.173.116.28	4:47
Dan Dunlap	VT	128.173.116.30	5:04
John Carroll	VT	Not Present	

Notebook Name	Project	Owner
Teacher's Lego	4th six weeks	Test Group
Pulleys	AMS Lego Project	Test Group
VS Paper Parts	LiNC Project Documents	IERI/LiNC People
Test Group's Resear...	Full-semester research p...	Test Group

12/3 15:04 Amy Sikes added section "Index" in "Motorizatic
12/3 15:05 Amy Sikes edited section "Index" in "Motorizatio

Wendy (17:15): what now?
Dan (17:16): now i've got to write some chat to balance it
Wendy (17:16): it sounds like horses clamping in the background
Dan (17:16): make it look like dialog
Wendy (17:16): what are we talking about?
Wendy (17:16): aeordynamics ...

```
Let's talk about aerodynamics and kites
```

This is the notebook that you will use to create the report for your collaborative project. To begin, use "New Section" in the "Edit" menu to create two new Text sections named "Background" and "Concepts". Once you have done this, the notebook will have four sections:

1) **Introduction** . This section should describe what you are going to do for your project and what you hope to accomplish. The text currently in the Introduction section (these instructions) can be removed before you submit your first draft.

2) **Background** . This section will contain background information on your topic. sdf

3) **Concepts** . This section will describe the physics concepts related to your topic.

4) **Bibliography** . When you turn in your initial draft, you should have five references in your bibliography, with notes for each. (The bibliography section allows you to enter notes when you add or edit an item in the bibliography.)

An initial draft of these four sections is due February 19, 1999.

See the "Help" menu for more information on using the notebook. Additional information about the project assignment may also appear in the Help menu.

Figure 4.6. A typical collaboration with the Virtual School involved chat (lower left), video-conferencing (upper right), and the collaborative notebook (lower right). Group members, communication features, collaborative notebooks, and notices are displayed and accessed using the main panel (upper left).

Usability concerns became more and more crucial as there became more of tangible piece of software to refine and study. A chief example of these concerns is represented by a list of Virtual School "bugs" that became much more than technical issues but also usability and human-interface issues. Here is an excerpt from that list the shows that there is attention not just to bugs and problems, but also to opportunities for better interface support and usability:

- Chat interface could support URLs (January 15, 1999 14:54:01)
- Dump full exception on InvocationTargetException (Nov. 8, 1998 14:57:32)
- Need ability to notify clients of pending shutdown (October 6, 1998 12:50:43)
- Alternative to Ctrl-click for list selection (Oct. 6, 1998 12:51:19)
- Notebook opened with locked section shows id, not name (Oct. 6, 1998 13:28:54)
- Need better support for navigating "All users" list (October 6, 1998 13:49:37)
- Need more info about state of NetMeeting confs (October 13, 1998 15:01:23)

Year 4 (1998-1999)

The Virtual School Projects

In the fall of 1998, marking the fourth year of the LiNC project, I was hired as a graduate research associate for the Center for Human-Computer Interaction. Several factors made me attractive to Carroll and Neale, who interviewed me for the position. First, I had been a teacher in MCPS in classrooms of participants of the grant. Second, I had some very limited experience with qualitative research methods and computers. Third, I expressed interest in taking on the LiNC project as a dissertation topic and planned on staying around for a significant period of time, unlike many graduate students.

My first impressions in the meetings with investigators and teachers about the upcoming year were that the Virtual School technology had been around for a while. There appeared to be clear plans about how the VS was going to be used in classrooms and projects for the school year, how the projects were going to be observed and data collected, and what was expected. I had little input into decisions about project topics and such. I had some input into observation techniques and data recording, but most of the methods seemed to be in place already by the time I began working.

Most of my interactions were directly with Neale and Isenhour. Neale directed most of my work. My office was next door to the office that was shared by Neale and Isenhour, and we interacted daily about work and personal matters. Another graduate research associate, Shanan Gibson, a master’s student in Industrial Psychology, was hired at the same time and worked closely with Jim Helms, a master’s student in Computer Science with emphasis in HCI and me. It was mainly this group that did the data collection and analysis throughout the use of the Virtual School. Initial meetings with investigators at Virginia Tech focused on how we were going to collect data from the VS projects and teachers. Meetings with teachers focused mainly on technical issues about how to assign students to groups and how to introduce them to the VS.

The Virtual School in Action

```
9/16/98 6:03:41 AM PDT; whawkins@RUBIDIUM CHANGED 904881829575-
edu.vt.cs.linc.vs.VirtualSchoolUsers; OBJECT = [whawkins on host RUBIDIUM];
CHANGE = AddUser[whawkins on host RUBIDIUM]
```

The lines of text above document the first log record of the Virtual School being used in a classroom by a student. In the 1998-1999 school year, teachers conducted two cross-classroom collaborative projects using the VS. The plan for the school year ended up including both short and long-term activities, though the focus on was on the long-term projects.

Short-term Virtual School Projects

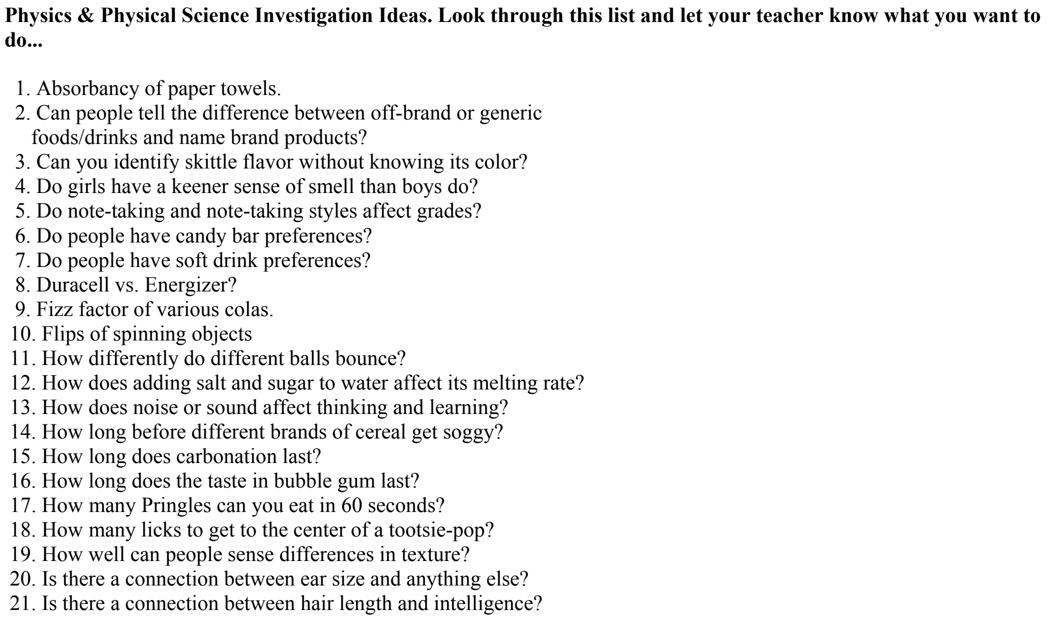
The first was a "short-term" project that began in September 1998 and lasted about one week of concurrent classes. The activity was "short-term" in the sense that it lasted only several school days in duration. It was mainly intended to introduce students to the technology and work out unexpected glitches and usability issues. The project was designed to investigate "the scientific method" of experimentation by engaging students in developing a research hypothesis, defining the variables, and collecting data to test the hypothesis in order to reach a conclusion. Many of the options given to students as topics for experiments had little to do with the subjects being taught in physics and physical science, except that they were intended to provide students with experience designing and conducting "scientific" experiments.

The goal was for the groups to negotiate and decide on a procedure for conducting an experiment, and then actually conduct it. How they went about deciding who did what was generally up to the students. In most cases, the group would decide on a shared procedure for conducting the experiment. Each co-located group would perform the experiment, and then they would share their results with the other group. Although they shared a written procedure in their collaborative notebook, when it came to carrying out the experiment, issues arose and were addressed by each side individually to such an extent that the procedures ended up varying radically. Unfortunately, the groups had little impetus or opportunity to discuss the variations even when they became aware of it. Moreover, they generally failed to criticize the very poor methodology of the experiment and the subsequent analysis of the results. For example, groups did not employ double-blind techniques or even relevant controls, and they generally did not discuss the statistical implications of their methods including the power of the results and similar concepts. Some of these issues were discussed by teachers using the CCIT, but teachers generally saw these projects as "fun" rather than valuable learning exercises, mainly because they did not teach particular content related to physics that is demanded of the curricula.

Experiments tended to be pseudo-psychological in nature dealing with whether people were able to discern differences in taste, smell, etc. of common products in the absence of certain visual or other sense clues; for example, could subjects identify generic or name-brand products while blindfolded. One or two days of class were devoted to carrying out the experiments. During that time, groups brought their testing materials and recruited classmates as subjects for their experiments. Groups generally produced some encompassing conclusion like "people were able to tell difference" or not. Data was charted or graphed and the questions given to the students were answered in the collaborative notebook.

The groups were intentionally composed of inter and intra-class makeup designated by teachers and researchers. Researchers and teachers met and decided how to makeup the groups. Generally, about three students who declared interest in a particular project choice from one classroom were paired with a group from another classroom according to the goals of the researchers and available students. For example, researchers and teachers decided it would be of interest to look at groups that crossed grade level and locality, so a group of students who declared interest in a particular topic in an eighth grade Auburn Middle School classroom might be combined with a group having similar interest in a high school physics classroom in Blacksburg. These short-term projects were intended to teach students about general experimental methodology by having them design and conduct an experiment.

The groups usually chose these experiments from a list of ideas generated by the teachers. Teachers introduced these projects in different ways, but some common information was provided. Some teachers also handed out project descriptions with grading criteria and specific directions, while other teachers simply announced general guidelines to their class orally. Figures 4.7 and 4.8 below are examples of materials given to the students to guide them in doing Virtual School projects.



Physics & Physical Science Investigation Ideas. Look through this list and let your teacher know what you want to do...

1. Absorbancy of paper towels.
2. Can people tell the difference between off-brand or generic foods/drinks and name brand products?
3. Can you identify skittle flavor without knowing its color?
4. Do girls have a keener sense of smell than boys do?
5. Do note-taking and note-taking styles affect grades?
6. Do people have candy bar preferences?
7. Do people have soft drink preferences?
8. Duracell vs. Energizer?
9. Fizz factor of various colas.
10. Flips of spinning objects
11. How differently do different balls bounce?
12. How does adding salt and sugar to water affect its melting rate?
13. How does noise or sound affect thinking and learning?
14. How long before different brands of cereal get soggy?
15. How long does carbonation last?
16. How long does the taste in bubble gum last?
17. How many Pringles can you eat in 60 seconds?
18. How many licks to get to the center of a tootsie-pop?
19. How well can people sense differences in texture?
20. Is there a connection between ear size and anything else?
21. Is there a connection between hair length and intelligence?

22. Is there a taste difference for fat free food?
23. Is there an affect of sugar on activity?
24. Object's motion in relation to the applied force
25. Vertically thrown object's motion
26. What affects the time of day that people are awake?
27. What factors affect a person's mood?
28. What is most thirst quenching?
29. What is the connection between what something costs and what people will spend?
30. What is the ideal length of a song in various categories of music?
31. What is the line between quality and cost for things like school supplies?
32. What pens write the smoothest?
33. Which brand of potato chips are the greasiest?
34. Which gender can identify flavor extracts best by smell alone?
35. Which gender can reproduce a tangram pattern the fastest?
36. Which gender is better at figuring out the magic eye pictures?
37. Which hot wheels cars travel the greatest distance down a ramp?
38. Which liquid soaps generate bubbles that last the longest?
39. Which liquid soaps generate the most bubbles?
40. Which paper airplane design is best for stunts (loops)?
41. Which paper towel brand is strongest?
42. Which type of paper is best for making airplanes that fly long distances?
43. Which type of soda pop creates the most fizz?
44. Which type of tennis ball bounces highest?
45. Which type of tennis shoe allows you to jump higher from a standing position?
46. Why do some people prefer MAC's or PC'

Figure 4.7. List of ideas provided to students by a teacher for the Virtual School short-term experimental design activity.

Fall Collaboration Write-Up **Name** ____________________ **Physics 80 pt.**

Prepare a write-up that is divided into the following parts.
This is due by Friday, October 1. You are turning in one per team.

Title Page	Research Topic, Name of Team Members
Hypothesis	State your hypothesis.
Procedures	List your procedures in a step-by-step fashion.
Data	Report your data in an appropriate table.
Analysis	Summarize your results ... find a graphical way to illustrate this also (such as with charts or graphs).
Conclusions	Discuss how your hypothesis came out in the end including a discussion of why or why not.
Reflections	What did you learn from the experience? What would you do differently if given the opportunity to do it again?
Appendices	At the end of your write-up, attach your original answers to the design questions and all original materials that you used to collect your data (such as the rough draft tables, surveys, etc). For some of you, this will be really, really big ... but we want to preserve everything so don't throw anything away!!

Remember to think quality and do your best possible work. Typing your write-up is strongly recommended so allow time to come in after school and do this if needed.

Figure 4.8: Directions for expected items to be included in the final Virtual School report short-term experimental design activity.

The outcomes of the reports generally reflected little consideration of experimental methods, problems with their experimental design, or issues about the procedural consistency across the remote sites if they pooled their data or attempted to integrate or collaborative over their findings. For example, if a group obtained a majority response from subjects, then they generally stated that their experiment demonstrated that as a result. Below is a typical example of questions provided in each group's Virtual School collaborative notebook by the teachers and answers, in italic, filled in by one group:

- **What is your research question or purpose?**

  Is it possible to determine the color of a skittle by its flavor?
- **What is your hypothesis?**

  It will be impossible to determine the color of a skittle without seeing the color or guessing at the flavor.
- **What is your independent variable?**

  Changing the colors of a the Skittles would be the variable
- **What is your dependent variable?**

  Ability to recognize skittle flavor
- **What is your control?**

  No control
- **What variables will remain constant?**

  The person we are using will remain constant as well as the different colors of the skittles

In addition, this group also provided a graph of their data with explanation in the collaborative notebook (see Figure 2.2 in Chapter 2).

Long-Term Virtual School Projects

Long-term projects were very similar in format to the extended projects of the prior year except that the Virtual School mediated these activities, rather than the typical, individual, and non-coordinated chat, email, and Netmeeting tools installed on the computers. The activities were introduced in the winter and lasted almost to the end of the school year in May or June; however, the activities were relegated to only about once per week, usually Fridays. The projects were open-ended research and development investigations focusing on a particular subject area related to physics and interesting to students, such as aerodynamics of kites, bridge structures, roller coasters, acoustics, and robotics. Students were asked to research a topic that possibly included the history and scientific principles associated with the topic, and then produce a model or experiment demonstrating some aspect of the topic.

As the year before, students generally saw their goal as two-fold: 1) to produce some kind of product, a kite, robot, bridge, or model roller coaster, and 2) to produce a report on the history and physical principles of the subject. Most groups ended up delegating distinct chunks of the project to each of the two remote sides of the group. For example, one project that focused on the aerodynamics of kites delegated the topic of the history of kites to the eighth grade classroom, and gave the physics principles of kites to the high school physics students. Figure 4.9 below is a list of projects suggested for the long-term project.

<u>Collaboration Projects</u>

Robotics: Design and construct a robot that performs a specific task or series of tasks. For example, the robot might be designed to move, locate, identify, or touch an object.

Bridge Design: Study and analyze different bridge structures and apply this knowledge to a bridge design and construction (made of balsa wood). The analysis will include making predictions about the circumstances of its structural failure.

Amusement Parks: Study and analyze the physics of amusement park rides (such as roller coasters, carousels, ferris wheels, and bumper cars). Apply this knowledge to design and construct a new ride.

Aerodynamics: Study and analyze the physics involved in aerodynamics and flight. Apply this knowledge to design and construct a kite, glider, or hot air balloon.

Creative Engineering: Study and analyze the physics of simple machines. Apply this knowledge to design and construct a creative device that performs a specific task involving the use of 3 or more simple machines.

Thermodynamics: Flow of heat, engines, thermal properties of materials

Materials Science: Properties of materials used in construction and manufacturing

Light and Sound: Photography, optics, acoustics

Electronics and Electricity: Audio technology, computer circuitry

Figure 4.9. List of suggested projects for the long-term collaborations.

In addition to the list of possible topics, teachers generally gave out a sheet with instructions and expectations for the long-term project. Figure 4.10 below is an example of instructions provided by one of the eighth grade teachers:

Teacher's instructions: Long term project

Required elements:

Notes: You are required to locate a minimum of five sources from various types of printed text such as books, magazines, encyclopedias, online internet or personal communications with a mentor. For each source you should have notes summarizing the content. These notes can be in paragraph form or as short phrases listed in a series.

Bibliography: all sources should be included as formal references using the standard format found in The Write Source.
Research Report: This portion of the project should include general background information/historical perspectives on your topic. It should also include identification and discussion of the physics principles/concepts that are related to your topic. This section should be approximately 3-5 pages in length, preferably typed, double spaced using a standard 12 point font.

Model/Experiment: This portion of the project should include a model and/or an experiment of some sort. You may design and build a model to support your research but you must keep a "log" of your design process which includes any tests, experiments, revisions or modifications to the model. Think of it as an inventor/designers record of what you are learning and doing. You may prefer to perform experiments that will generate information and data that enhance, support or further explain your research topic. Experiments may come from books or other resources or you can design your own. Remember that experiments must follow the scientific method that you used earlier in the year. Both the model and experiment options for the project require teacher/mentor approval.

Mentors/experts: An important aspect of this project is your use of a mentor or expert to help you understand the physics concepts in your project. Several mentors have been recruited who will work with you in a variety of ways. Some will simply respond to e-mail questions. Others may wish to meet you in person and others may work with you using various technologies such as videoconferencing. Remember that these people are volunteering their time to help you and as such should not be taken for granted. Their role is to support you not to do the project for you. When contacting and dealing with mentors please be polite, courteous and respectful. Don't demand, say please. Don't just take, give back. Always remember that the words please and thank you make a good impression! I will assist you in any way that I can in contacting and working with mentors. If you wish to use a mentor other than the ones I have contacted please let me know.

Timeline: As we discussed at the beginning of this project, there are two-week check off dates. Please keep those in mind as you work on the project. We will make periodic adjustments as necessary.

Figure 4.10. Instructions given by a teacher for the long-term project.

Students generally met using the Virtual School, once per week to discuss the project and/or to work on their tasks. Part of the outcomes generally included a set of collaborative text pages in their groups Virtual School notebook with some data or illustrations. In addition, most groups presented some kind of model or product such as a model bridge structure, set of kites, or robot. A typical collaborative meeting consisted of students using the Virtual School chat feature or video-conferencing to discuss what had been accomplished and what should be done. Often conversations were procedural rather than subject-content oriented. Figure 4.11 below represents a typical conversation between a group at BHS and the corresponding group at BMS.

09:50:42 BMS: Did you finish your procedure?
09:50:49 BHS: Yeah. It's finished.
09:50:55 BMS: We haven't quite finished ours yet.
09:50:58 BHS: We see that (laughing).
09:51:03 BHS: We need to figure out what products, like we need to use the same products, so cause we have different products.
09:51:03 BMS: Tell them we'll work on ours now.
09:51:11 BHS: Yeah.
09:51:15 BMS: What products do you guys want to use?
09:51:25 BHS: The ones we suggested are in our procedure. Like wait, pull up our procedure. We think vinegar is too strong, people would know it right from the beginning. So we don't want to use too obvious smells. So we didn't want to use vinegar, but the others, like peanut butter, coconut, and shampoo and strawberries are good I guess.
09:51:52 BHS: We also wanted to use one of my dirty shoes.
09:51:58 BMS: Okay, that'll be fine.
09:52:06 BHS: Actually the coconut shampoo. Where are you gonna get that? It's kinda hard to find, isn't it?
09:52:22 BMS: Yeah.
09:52:25 BHS: Ok. So this is what it is. The peanut butter, strawberries, pickles, nail polish, an old sneaker like a dirty shoe, just not the vinegar, not the shampoo, not the Febreeze I guess.
09:52:46 BMS: Yeah, say that'll be fine.
09:52:54 BMS: Uh, strawberries.
09:52:55 BHS: Ok. We need to change our procedure. Or your procedure needs to take out the vinegar and the shampoo and then we'll take out from ours the Febreeze and the Noxzema. Do you have our procedure on your screen?

Figure 4.11: Typical transcribed conversation showing time-stamp and location of the group member speaking. The names of the speakers have been removed from this excerpt.

This was from a short-term experiment design to test whether blindfolded subjects were able to identify a substance by smelling it. The excerpt is edited from an integrated script with names removed. This excerpt contains only dialog transcribed from videotape of a videoconferencing interaction. Each passage begins with a timestamp and the school of origin of the group member.

Year 5 (1999-2000)

In the following year, fall 1999, the short-term project was very similar to the year before. Figure 4.12 below is a description of the planning of the activity distributed by email to the investigators by one of the physics teachers:

> In advance of the fun, we'll discuss the whole scientific method idea with our students and assign them (or have them pick) experiments from a list we make. We're going to do our video conferencing with 3 teams in our 3rd period classes (about 20 min overlap).
>
> Here's what'll hopefully happen with these linc kids…
> Tuesday (after holiday) … they already have their topic and will spend class time thinking about what they want to do in terms of procedures and what materials they will need. They will then go into the virtual school and type this into their section of a notebook we've already created for them. No collaboration has happened up to this point.
>
> Wednesday and Thursday… Suzan and I hook our kids up in the video conferencing, they look at each others suggested procedures and materials and finally come to an agreement on the final procedure, etc. This they type into their common section of the notebook.
>
> Friday … data is collected .. no video conferencing.
>
> Monday and Tuesday .. continue collecting data, if needed, share data by placing in the appropriate section of the notebook.
>
> Wednesday, et al. … no more video conferencing or collaboration, our kids do their individual thing based on my or suzan's requirements.
>
> There you have it. We've already created a template of the notebook if you want to see it in the virtual school. It's basic but serves the purpose. This will take less structured class time than the way we did it last year … which is good.

Figure 4.12. Email sent by at teacher to the LiNC investigators describing the teachers' plan for the long-term Virtual School activity.

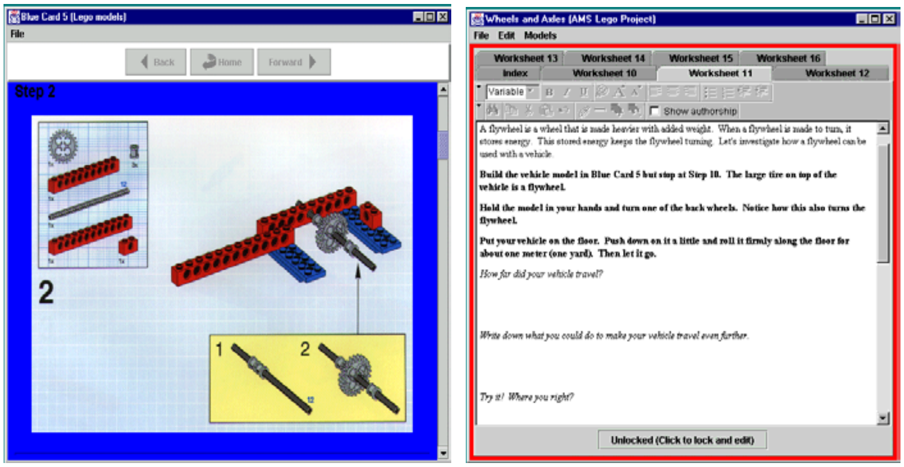
On-going Use of the Virtual School: The Lego Projects

During the official NSF funded portion of the LiNC grant, there was clear incentive and even obligation for the teachers to use the Virtual School in their classrooms. After the funding ended, the teachers were no longer paid or given time in their schedule to work with LiNC. There was a sense of collegiality that developed among investigators and teachers, and this was encouraged more with some teachers than with others. In addition, there were different degrees of initiative and opportunities taken by teachers. Some of this was circumstances including types of classes being taught and collaborative relationships among other teaching colleagues that were otherwise exploited by teachers. In a particular case, one of the middle school teachers initiated an application of the Virtual School in her classroom beyond the grant period.

By teaming with a colleague in the same school building, the teacher was able to realize a greater sense of common interests in curricular activities and teaching style that sustained and motivated the collaborations with the technology. This was partly a result of working together to add content and structure to the media, and partly because of the established social relationship between the two teachers involved. We worked together with the teachers to integrate a learning unit with materials that the teachers presented to us and convinced their principal to purchase in order to enhance their teaching and assist in their utilization of the computers and our resources. The principal openly expressed enthusiasm for supporting our project and the teachers' initiatives. This initiative by the teachers and our respective support engendered a greater sense of ownership and value of the technology by the teachers and students.

The Lego® Dacta™ materials include content that covers a range of topics dealing with mechanical systems and components. Topics begin with Simple Machines (levers, wheels and axles, pulleys) then progress to Structures and Forces (rigid structures etc.) then move on to Motorization and Control (gearing ratios, motor blocks, computer control systems). The Lego® Dacta™ materials come with very structured student exercises that move from basic to more advanced and open-ended types of questions and activities. These materials include activity cards with color diagrams that provide step-by-step instructions to help students build the Lego® models used for instruction.

Before the projects began, we scanned the exercises and questions (using character recognition to convert to text) and organized these into the VS notebooks. We also scanned the diagrams on the activity cards and included these models in the notebook for reference. Examples are shown below in Figure 4.13.



A flywheel is a wheel that is made heavier with added weight. When a flywheel is made to turn, it stores energy. This stored energy keeps the flywheel turning. Let's investigate how a flywheel can be used with a vehicle.

Build the vehicle model in Blue Card 5 but stop at Step 10. The large tire on top of the vehicle is a flywheel.

Hold the model in your hands and turn one of the back wheels. Notice how this also turns the flywheel.

Put your vehicle on the floor. Push down on it a little and roll it firmly along the floor for about one meter (one yard). Then let it go.

How far did your vehicle travel?

Write down what you could do to make your vehicle travel even farther.

Try it! Where you right?

Figure 4.13. Lego® Dacta™ Materials that were scanned and integrated into the Virtual School collaborative notebooks.

Students in an eighth grade science class worked more or less as tutors for students in a sixth grade class. The tutors edited the Lego® activities imported into the VS notebook with details about what to do, and then the eighth graders helped the sixth graders with difficult material and worked in concert with them on much of the material. The VS mediated most of their interaction, but some of the groups that were located nearby were able to meet face-to-face. For example, groups with members at Auburn Middle and other members at Auburn High often walked over to the other classroom to discuss troubles with the computers or items when the computers or network were not working properly. In other cases, groups met outside of school. For example, one group working with a professor on an acoustics project was able to go to the Virginia Tech acoustics lab to meet for a field trip for a demonstration in the lab. In other cases, groups met after school to complete work that they were not able to finish in class.

These projects were considered the biggest successes of using the VS in classrooms for a number of reasons. They were purely voluntary by the teachers. The students were very excited and engaged by the tools, much more so than previous projects, and various outcome measures demonstrated that the students engaged in more cooperative (positive interdependence) behaviors and talked about content vocabulary and concepts to a much higher level (Dunlap 2000).

Investigators Data Collection

In order to investigate and evaluate the activities that took place using the Virtual School, we developed several observational methods for "capturing" the interactions. Our technique for collating the information from various sources changed over the course of the Virtual School activities, but the general methods for gathering the data remained relatively constant. First, for each set of activities or projects, we chose two cross-classroom groups to monitor. This means that we were observing one group from each of the four classrooms that were collaborating, which meant that we were observing both sides of two whole cross-classroom groups.

For each scheduled collaborative activity, where students planned to interact with their group members in another classroom, we usually had one or two investigators observing. Before the class began, we positioned Hi-8 video cameras to record a "long-shot" video and audio of a group using the computer. In addition we used scan converters to capture a "screen-shot" of the computer monitor screen of the group on Hi-8 videotape. We used a time stamp and visual cues to synchronize these tapes for later analysis.

We took advantage of the CORK server client capabilities and functions to log a range of activities involving the use of the Virtual School. Anytime a group or student initiated an action in the Virtual School that required a change message to be sent to a server object, it was possible to record that change message in a log. For example, anytime a student opened up a chat window, sent a chat message, sent an email message, open a collaborative notebook, or made a change to a collaborative notebook, that was recorded in a computer log complete with identifying information and timestamp information.

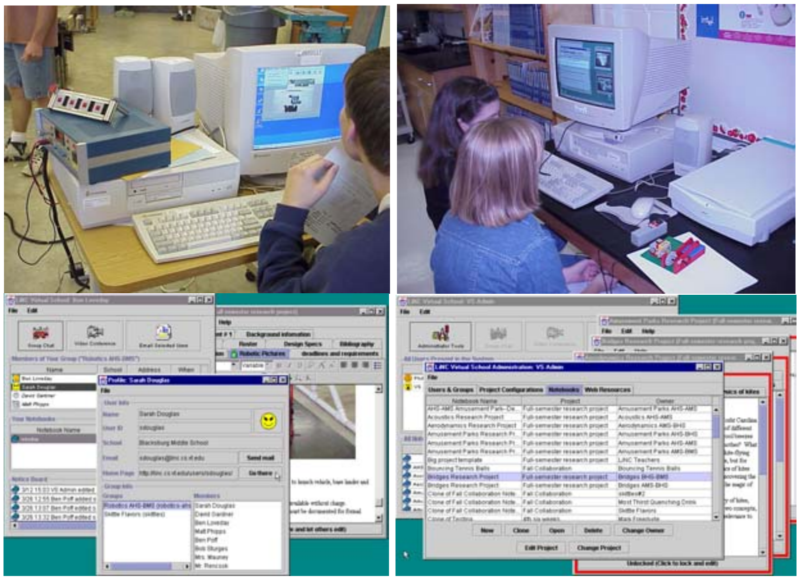


Figure 4.14. Four-way split screen showing both sides of a collaborative activity with the Virtual School. The four videotapes were synchronized and collated onto VHS video in order to allow a unified view of the dispersed collaborations including one long shot plus one screen-shot for each side of the group.

At first, we simply kept the data in two distinct forms, video and computer logs. We synchronized all four pieces of video from a group session (two long-shots plus two screen-shots), and then we recorded them in a four-way split screen onto VHS tape so that we could view all of the video in one view (see Figure 4.14). In a separate process, we organized and tallied the computer logs into text files. This proved cumbersome in considering the range of actions taking place during a session, and it did not suggest a convenient way to code and index the events for quick retrieval.

Around early 1999, we decided to look into qualitative analysis software used for text-based analysis. We examined several packages and chose a software package by Qualitative Solutions and Research known as NU*DIST, which was later upgraded to NVivo (http://www.qsr.com.au), because of its ability to handle very large and complex projects. The other option we considered was MacShapa, a package that allowed coding and indexing of video material, but it was not particularly well suited for indexing text. Using a text-based qualitative analysis application required that we transcribe the audio of the recordings. This meant that we lost some subtle visual cues, but we attempted to annotate the transcription as much as possible with observer comments.

We used a software program known as CVideo (Roschelle 1996) to help transcribe and index with time-stamp the long-shot video taped activities. We then developed the Java server to collate both sides of the transcripts of the group activity and integrate them with the computer logs from the Virtual School server indicating with font style and color the different sources of the text material. This final comprehensive document of the session of the groups' activity was called the integrated activity script. An example of a segment from a script is shown in Figure 4.15 below.

09:57:32
BMS: Ted to BHS: Hi.
09:57:33
BHS: BMS to Elise: Hi.
09:57:42
BMS: Ted to BHS: What is the other stuff that we need?

```
09:57:43 BMS: updated notebook section (936375482585)
--- 13,16 ----
    Cloth On Table
+     blind fold on person
+     have them smell all the things
    How will the data be recorded?
```

09:57:48
BHS: Elise to BMS: Okay. Read off what you have.

```
09:57:59 BHS: updated notebook section (936375483394)
--- 5,9 ----
    -pickles
!   -nail polish
!   -peanut butter
!   -strawberrys
    What procedures will you follow?
09:57:59 BHS: unlocked notebook section (936375483394)
```

09:58:00
BMS: Ted to BHS: Blindfold, vinegar, peanut butter, shampoo, strawberries....
09:59:19
BHS: Allan to Elise: Tell them to go into groups and that I've got all the materials written down.
09:59:22
BHS: Elise to BHS: Okay, if you go into group procedures, you'll se the final list of our materials.
You see that? Okay, now what procedures will you follow? Do you see what I'm talking about?

```
09:59:24 BMS: Opened section "BMS Procedures" in notebook "Clone of Scientific Method Template (1999 Scientific Method Activity)"
09:59:29 BMS: Opened section "Group Procedures" in notebook "Clone of Scientific Method Template (1999 Scientific Method Activity)"
```

09:59:32
BMS: Ted to BHS: Okay, I see it.

```
09:59:43 BMS: updated notebook section (936375482585)
--- 13,15 ----
    Cloth On Table
!   blind fold on personb
    have them smell all the things
09:59:44 BMS: locked notebook section (936375483394)
```

```
09:59:48 BHS: Opened section "BHS Procedures" in notebook "Clone of Scientific Method Template (1999 Scientific Method Activity)"
```

09:59:49
BHS: Elise to BMS: Okay, we need to type up our procedures. But we already have it typed up under BHS procedures.

Read that and tell us if it's okay. We can just put that procedure into the group procedures or if you want to change it, we can change it.

10:00:25 BMS: Opened section "BMS Procedures" in notebook "Clone of Scientific Method Template (1999 Scientific Method Activity)"
10:00:27 BHS: Opened section "Group Procedures" in notebook "Clone of Scientific Method Template (1999 Scientific Method Activity)"

10:00:36
BMS: Marty to BHS: Whose smelly sneaker are we going to use?
10:00:43
BHS: Elise to BMS: We're going to use one of our group members' and you guys can use one of yours. Just get someone's gym shoe.
10:00:45
BMS: Marty to BHS: Okay.

Figure 4.15. Sample Integrated Activity Script that contains a typical dialog among collaborative group members and logged computer events. All dialog and computer activities were designated by font size and color according to source and entry was time-stamped.

The integrated scripts were then imported into the NVivo where they could be coded. Coding occurred over a long period of time and in a number of different stages. In addition to the huge amount of data contained in the integrated scripts, there were a number of other types of data collected throughout the project. During the execution of the Virtual School projects, starting around 1999, a web-based discussion tool called the Collaborative Critical Incident Tool was introduced. The tool was a web-based discussion forum that allowed threaded discussions of important or “critical” incidents relating to the activities. Teachers and investigators participated in these threaded discussions, and all of the discussions were logged, and these were also imported into NVivo for coding.

There were also a number of recorded interviews with teachers about various aspects of the project and also recorded interviews with students and even student community mentors that were all transcribed and imported into NVivo for coding. In addition, there were surveys given to students once or twice per year and surveys given to teachers in the early stages of the project. In many cases, researchers kept field notes from meetings and often these were typed and imported into NVivo.

Research from the Teachers’ Perspective

Teachers expressed their opinions about the validity and execution of research in the project throughout the project. While teachers were involved in participatory design of the technology, they had little to do with the research. They were engaged in some research question with the aid of the CCIT, and they expressed their beliefs and ideas about research. But they were not systematically involved in the formulation, production, and analysis of data and results. The following remarks demonstrate some of their thoughts about the processes. In this first passage, the concern is how much teachers need to intervene to encourage collaboration and how that affects the validity of the “research.”

> I think the teacher can encourage and cajole students but only to a point. After that kids just have to be allowed to make choices. Some kids don't care, some kids decide they only want to participate if they have control and some seem to be ego centric to the point that they only feel responsibility for their own work and make no apologies for it. Certainly we are seeing all the subtle and not so subtle nuances of the human psyche. The question is can we learn from this and build a better collaboration in the future? How valid will the research be if we have to disguise the collaboration in ways that will make it more attractive?

In this next passage, a teacher provides a vivid example of the extent to which observation and intervention from researchers transforms the behavior of the participants.

> It's Friday. Dennis shows up, sets up a camera. It's aimed straight at the Aerodynamics group. [Student A], usually the only one present, asks Dennis questions about the other group, what they are doing and along those lines. When present, [student B], with her hyper personality, constantly complains about the “stupid thing” (virtual school) when it is slow or behaves “unexpectedly.” Dennis helps her with the technical issues by telling her to wait a second, reminding her about steps and buttons to click, etc.
>
> From an evaluation point of view, is LiNC supposed to be a fly on the wall? We have a program that's been fairly stable for several months. What does it say if we need to have extra staff in the rooms to make it all happen?

Another teacher justified the intervention of the observers from a practical standpoint, suggesting that researchers were significant assets to the classroom.

> From a middle school perspective it has been helpful to have [the researcher] here each Friday if for no other reason than to be able to monitor the VS groups while I'm running around helping other kids. I have certainly been guilty of making suggestions to various VS groups when I see that they are frustrated or seem to be just sitting there waiting for something to happen…From a strictly research point of view I don't think we ever clearly defined what was too little and what was too much intervention. As a teacher of middle schoolers I cannot in good conscience just back off completely especially if I'm going to assess the work at some later date.

One of the researchers attempted to explain that “objectivity” had certainly been compromised, but that it was somewhat justified, and, moreover, the active role taken by observers was not being hidden under the guise of “objectivity.”

> In many ways, the role of "pure evaluator" has been compromised by a need to help w/ technological issues, especially early in the project. However, concern for the students, acknowledgement of the demands on the teachers' time during each class period, and perhaps frustration regarding the progress of students has perhaps driven further interventions. These are clearly documented in the data and will be taken into account when analyses are conducted. In no way has this project been a true experiment; our conditions are confounded in numerous ways.

In an earlier questionnaire, one teacher expressed expectations of his role in the research involved in the project. "I thought we'd be involved mostly with trial runs of software and possibly some data collection. The possibility that this was a double blind experiment was also present." Several teachers also conveyed their reservations about the validity of the research especially with regard to the lack of control.

> The difficulty is determining how well this measures what the student can do when they're not being tested.
>
> I don't see a control anywhere. This reminds me of a long discussion we (LiNC) had two summers ago about assessment, but I died on that day. We have to be very careful in what effect we are looking for. I made the argument that we will never affect what kind of grade they get. If we want to measure performance in the class how do you do it? How do you measure a significant improvement when they're such high achievers anyway? There's nowhere to go.
>
> One of the questions that hasn't been raised by this project in an organized way is: How do we find the changes the teachers will generate by using this equipment? Now you're working on some of this stuff. But what instructional changes should come about from having these new tools available. And one of the reasons this is research is I don't think anybody knows yet whether collaboration can be done at this level effectively as an instructional tool.

Summary

This chapter described the formulation and execution of the LiNC project. I began by explaining some of the most important factors related to the writing of the main grant that supported the LiNC project, but the majority of the chapter described the classroom activities and research. The project had a variety of continuities and discontinuities that contributed to the design and implementation of the technology in the classrooms. There was work preceding the writing of the planning grant and the LiNC grant that significantly shaped the prospects and outcomes of the project. The establishment of relationships with BEV and MCPS were crucial to the shaping of the grant and project.

The different groups involved in the project had very different perspectives related to the project. Their roles and backgrounds contributed to the exchanges that constituted the social processes of the project. The early drafting of the proposal and preceding grants formed social networks and relationships that influenced the group makeup and beliefs. The exchanges among investigators and teachers, their contentions, assistances, and ignorance, influenced alliances, tensions, relationships, and outcomes. The internal interactions among groups of investigators and teachers reflected different understandings of the others' work. These transfers and negotiations greatly contributed to the development of the technical and larger project related outcomes.

For NSF, the LiNC grant was the proposed fruit of the planning grant. Kavanaugh recognized the social networks that were seeded in the work in the planning grant that carried over to the LiNC grant. Carroll claimed that there was little development and conceptual work in the planning grant that ended up contributing to the LiNC grant. Most of the footwork for the LiNC grant, according to Carroll, was accomplished in Laughton's dissertation work. From my perspective, these ventures were somewhat related by a variety of common factors including similar teachers, schools, administrative support, and general synergy associated with the Computer Science department, BEV, and Montgomery County School system personnel. Carroll acknowledges this in hindsight. At the time, it was much less obvious.

There were a variety of stages and changes in the interactions between teachers and the researchers and managers at Virginia Tech. Initially, most of the teaches were very enthusiastic. One was somewhat reluctant to be involved but did contribute a great deal and with a positive attitude. By the middle of the second grant period, the teachers "revolted" against being "told" what they were going to do in their classrooms. They became more assertive about what they wanted to do with the LiNC activities. This was, in some ways, provoked by one investigator who disagreed with another investigator on a number of issues related to the course of the project. For these investigators, it was partly a conflict over how to evaluate the project activities. For Carroll, it was a positive step toward the teachers taking greater control and responsibility for their part in the project. As I understood the events, they had some positive and some negative effects. The teachers did take it on themselves to assert their desires and to genuinely formulate a plan as a team regarding what they believed would be useful to them in their teaching. But while they took more responsibility for their role, it also indicated that the teachers had lost some degree of confidence in the project and its management and leadership. Given the circumstances, Carroll was correct to see this in positive terms. Alternatively, the teachers might have become totally disinterested, detached, and unmotivated. On the other hand, had this situation been anticipated, there may have been ways to engage the teachers better from the onset by providing them with the freedom and understanding that they had ownership over their roles in their classrooms. Again as Carroll noted, this was another indicator of some of the aspects related to the lack of preparedness of investigators for the organization of teaching work.

Even more surprising were the issues that surfaced between teachers in their collaborations. In some ways, they appear unprepared for the challenges of collaborating with one another. This may not have been surprising for teachers. They were picked to be part of the project mainly on the basis of the subject that they taught. They did not select their collaborators. Despite their common interests in project-based learning and their common subject area, their teaching style, grading methods, and so on were different. The greater successes with the Virtual School were with the teachers when they had chosen their partner. As a former teacher, this did not surprise me, but I certainly understood why it might have surprised researchers outside of education.

Moreover, it was not surprising that teachers often had somewhat ideal visions of research. They assumed, like most common perceptions, that even qualitative research is tidy and well controlled. Some investigators strived for experimental control. Others did not, and this created some tension among investigators in evaluation and research design. Carroll was familiar with social science research, but he also valued rigorous evaluation and results. For me, it was unclear what those results should be. On one hand, I believed I understood how to *describe* the processes, but I did not understand how to *explain* them in terms of "findings" and causal relations. Moreover, the action and intervention approach to the research entailed difficulties with objectifying claims about the processes that students were engaging. I could describe problems, but I was not sure *why* these problems were so critical. In short, I perceived some tension in the descriptive, explanatory, and action research approaches, but to some degree, all of these approaches were employed in the research design at various points.

The project was unique. It focused on networking classrooms, and, as such, required that the work of developers, researchers, and teachers interact and be negotiated in ways that were very difficult to predict. The project was also extensive. Work that laid the foundation for the proposal was taking place years prior to the grant, and the project extended years beyond the proposed three-year period. The extensive effects of the project continue to reverberate today in the social networks and socio-technical infrastructure emerged around the project. The project was also unique in the ways that the goals of participatory design of technology with teachers were realized and the activities and research were carried out. The social and technical processes involving the work of researchers, developers, and teachers were complex and dynamic. The transfers and negotiations among the various groups critically shaped the events and interactions of participants. Investigators anticipated working with teachers, but they were unprepared to deal with nuances and realities of the classrooms. Teachers also did not anticipate the nuances of participating in the development of computer technologies, being involved in university research and development, and even collaborating with each other. Teachers and researchers expressed a fascinating range of beliefs about pedagogy, teaching practices, technology, and research. This chapter described and interpreted what I consider to be the most important and enlightening events, products, and discourse that constitute the context of the activities of the LiNC project.

Chapter 5: Conclusions

"With every mistake we must surely be learning." (Harrison 1968)

Introduction

The LiNC project was ambitious for a host of reasons. First, as one teacher noted,

> One thing that's been unique about the LiNC project, I'm sure other projects have done this, but I think very few teachers and researchers have the opportunity to be involved in a project that has gone on as long as this one has. You usually do a project and it's a summer commitment or perhaps it's a year. You meet off and on during the year and you do a workshop in the summer. Those are the kinds of collaborations I've been involved in outside my classroom. This is the first time; I mean, to have a relationship, a working relationship, with people for three solid years!

The project encompassed a long period of time, and the extended duration allowed for a significant transformation in the depth and qualities of the relationships and interactions, both positive and negative. For example, a teacher spoke of the likelihood of collaborating further with the other teachers: "I'm not afraid of working with these people. I feel like I can read [the other teachers'] minds, and they can read my mind. We're like brothers and sisters now." That is a significant outcome of the extended period of time the over that the teachers interacted.

Second, the project did what many others have attempted. It proposed to use NSF grant money to investigate and develop technological assistance for public school teachers. Moreover, the LiNC project proposed to do in a participatory fashion, and that goal requires that very distinct work cultures coordinate and collide.

Third, the project proposed to facilitate teachers' collaborating with each other. This may seem to be a modest goal to most people, but as one of the teachers said to me recently, "Teachers don't do that." Of course, teachers do collaborate, many do so to varying degrees, but the general point is well established. Teaching is notoriously and surprisingly autonomous, isolated, stylistic, and idiosyncratic work (Garrison 1995, Rosenholtz 1991, Goodlad 1984, Lortie 1975). This project illustrates how difficult achieving such a "modest" goal can be.

Fourth, the project was built on the prospect of facilitating collaborations among students in different classrooms. So many recent efforts have sought to study and encourage cooperative learning and collaboration among school students. Using technology to facilitate the collaborations adds another layer of complexity. Dispersing those students in different classrooms, different schools, different levels, and different teachers compounds an already difficult goal.

Finally, developing state-of-the-art computer network technology dead in the middle of the most rapid whirlwind of computer network technological change may have, in the beginning, seemed simple and straightforward. In hindsight, given for example the recent rise and fall of the "dot-coms" and astonishing growth of the Internet, it may seem to have been a rather silly time to embark on such a project. Politically, it was timely. The federal initiatives were ripe for the effort. The local school system and the university entities were poised to receive and capitalize on the notoriety, momentum, and hope of networking computers for educational purposes. Technologically, it was not so timely, for the computer world dramatically changed in the years of the LiNC project. Few could have predicted and anticipated the remarkable growth and extremely rapid changes in computer network and software capabilities. A striking example is the profound development and transformation of vocabulary and technical terminology in such a relatively short period of time. Language rapidly changed in relation to tool-use. Terms like "Java," "network," "MOO," Web," "client," "interface," "cyber," and "virtual" came to describe and invoke entirely new images that provided critical meanings to the tools being developed and used.

Individually, any one of these goals may appear overwhelming for a three-year project that turned into a five-year venture. Taken together, the goals were, at minimum, extremely ambitious, but in hindsight, the goals faced, in many respects, insurmountable odds. In some respects, what the project accomplished was awe inspiring, especially given the mangle that was soon to unfold as the future in the early 1990s. In other respects, modest and confusing "findings" were totally unsurprising given the context and history of teaching, instructional technology, and research intervention.

In this concluding chapter, I address these various goals in an attempt to draw some conclusions about each of these aspects of the LiNC project. I describe what I take to be the most important conclusions, outcomes, and lessons relating to the social, political, and technical infrastructure that shaped the technology and development process, the interaction and negotiations among teaching and research work, and the realizations and insights regarding collaborations among teachers and among students in the context of participatory design and study of collaborative technologies. I also situate my conclusions in the context of the social production of the technology.

In discussing conclusions, I roughly try to parallel the order of topics as they appeared above. First, I draw some conclusions about the technological infrastructure and development work of the LiNC project. Second, I draw conclusions about the political context and funding of the LiNC project. Third, I offer some conclusions regarding the LiNC project that are designed to help researchers in similar situations to better anticipate, cooperate, and interact with the work of teachers. Fourth, I reiterate, situate, and provide examples of the issues most relevant to STS research and this present work, and finally I describe opportunities for further research, some that are currently being pursued and others that contain promise for the future.

Technological Infrastructure and Development Work

The general idea of the Virtual School long preceded the introduction of the computer application with that name in the classrooms of the LiNC project, but the technical detail of the Virtual School, or that there would be such a "thing," was not inevitable or anticipated by the vision or even the functional requirements gathered later. Although the Virtual School was in many ways very much like the very early prototype mock up by Abrams, the design mock up, the requirements gathered later through participatory design, and the technical functionality all underdetermined the technology that was produced in the LiNC project.

There were a wide variety of twists and turns from the early vision on to the grant and then on to the development of the Virtual School. There were also a number of complex and principally "technical" resources, work, and tools including the Internet, the World Wide Web, Java, Java Beans, Sun Microsystems, C++, Object Oriented programming, Sieve, CORK, and so on. Each of these occurs in a context of social networks, interactions, negotiations, and transfers of technical know how and tools. Developers and other researchers joined and left the project, and with them, technical know-how, artifacts, documents, plans, and social relationships came and went.

When finally deployed in fall 1998, the Virtual School activities experienced numerous unanticipated technical problems and usability issues. There were problems with stability, for example computer "crashes" related to the Netmeeting software that was being used to videoconference across the classrooms. Machines often locked-up and required rebooting in the middle of conferencing thus interrupting the group interactions considerably. There was also an unanticipated installation of a firewall in MCPS that required a work-around. This hindered use of the Virtual School and eliminated the possibility of using video-conferencing as planned for community mentors located at Virginia Tech and other locations outside of MCPS.

In the time-line above (Figure 2.3), I illustrated several important aspects of the development processes. The development of the technology was non-linear, shaped fundamentally by social forces. Its trajectory was highly unpredictable. There were a multitude of possible paths, and there were many design tradeoffs, losses, and sacrifices along the way. For example, the VS featured an interface designed by and for teachers conducting student collaborative projects. As such, the interface focused on the tools and features most directly applicable and ready-to-hand for students involved in these projects. While MOOsburg III was a step forward in other respects, it lost a great sense of focus of purpose. As the interface became more multi-purpose and diverse, it obligated developers to look for a greater range of awareness mechanisms and flexibility in interface design. It also lost, temporarily at least, the ability to use video-conferencing capabilities.

Despite the understanding that some advantages were lost in "progress," there were social and even psychological forces that encouraged reconstructions that emphasized linear and progressive accounts. The need to publish in journals, defend theses, and report to funding agencies compelled the developers and managers to recreate and simplify descriptions of the process of development. Actors in the LiNC project, to varying degrees, knew this. Moreover, they explicitly used this knowledge to reflect and reconsider their own technical practices. This was important.

Political Context and Funding of the LiNC Project: NII and Research

The LiNC grant was timely with regard to the political climate affecting the federal funding initiatives. The early 1980s "crisis in education" rhetoric had turned to a focus on the rapid advances in computer network technologies and hope that they would ameliorate U.S. schooling. A big question was "how?"

Answers to this proliferated in the massive federal initiatives aimed at two important areas. First, the Internet had to be realized. Two related federal goals saw to that. The network needed to be able to survive the destruction of any one of its pieces; thus it needed to be a *decentralized* network. The network also needed to be able to grow beyond the narrow support of military use. It needed to be able to serve public information dissemination as well as private sector interests. For that, the Internet needed accommodate and integrate heterogeneous elements.

As such, the production of the Internet was not a straightforward technical matter. It involved massive infrastructure development. It required developing and changing social and technical relationships, and these relationships corresponded to complex and "fluid" boundaries. Over the last several decades, military values intertwined with public and private sector development to favor options that shaped the Internet we see today (Noble 1991). As such the history was complex and multifarious. It involved government initiatives and military centered development, but it also involved critical initiatives, development, and cultures related to commercial and private groups. Some critical developments that shaped the Internet and particularly LiNC technologies derived from users and groups with values and practices that have been deemed "underground" and "subversive" with respect to military and government goals and values. While government funding constitutes the bulk of the development of the infrastructure that makes up the Internet and the LiNC technology, many other forces were critical to the shaping of the Internet as it was realized; however, computer network initiatives represent a particular set of large-scale programs that, in many ways, were analogous to "big science" and, in some ways, contrasted and even opposed growth of "big science."

Big Education and Network Technology: NSF, NREN, and NIE

In Chapter 3, I explained that the federal government shifted emphasis in its funding initiatives in ways that departed from goals that directly represented and paralleled "big science" as described by Galison and Hevly (1992) toward goals that contrasted and directly opposed aspects of the huge science experiments and infrastructure. NREN epitomized the "big" approach to technology development for education. It attempted to centralize initiatives and funding and channel funding toward national social and political goals; however, the explicit shift in government funding emphasis from super computing to super networking contrasted with and opposed large-scale experiments, such as those in particle physics. The shift explicitly and implicitly embodied a decentralization of resources and development; "creation of architectures that enable the integration and interoperation of separately designed information resources," and "the requirement for interoperability" (Vernon, Lazowska, and Personick 1994. p.8 and 9). This shift, however, significantly shaped the prospect for the funding of the LiNC grant through the expansion of NREN and particularly through the inception of the NIE program at NSF. This "big education" policy effort that resulting from the confluence of technical developments of the Internet and a long history of national education policy produced two major objectives, develop publicly accessible information technology and apply it to education.

Social Networks, Education Research, and The Center for HCI

The formulation and stabilization of the social network that would enable the creation of the infrastructure needed to carry out the LiNC project began long before the actual LiNC grant was proposed. The planning grant and BEV laid the foundation for the social network that eventually helped institute the Center for HCI at Virginia Tech. The NSF NIE program and its synergy significantly shaped the political groundwork. During this period, Carroll learned a great deal about building social networks and socio-technical infrastructure. Moreover, his description of the construction of the infrastructure invoked a social analytical framework. In other words, he was not naïve to the social implications and technical ramifications of the construction of the social networks that shaped the forces that enabled his work goals. That is not to say that he subjugated "technical" aspects of the work he managed to "social" forces and contingencies. How he recognized these two aspects of the work he proposed and managed was important to describing how the work was accomplished and controlled.

The second area, and a kind of second step, critical to the proliferation of answers to the question, "How can network technologies ameliorate U.S. education" suggested that Internet technologies be "studied" for possible direct application to the improvement of science and math learning. NIE directorates described the need to fund projects that represented consorted efforts to study social relations and technology or "people and wires." The state of technologies that exploited network and computer capabilities at that point in time, the early 1990s, required very specialized expertise to develop and implement software. Skill in programming languages like C++ and Java and technical skills required to put together functioning computer networks were limited mainly to experienced and university-educated computer science experts. Advances in software and hardware design and availability have lessened these requirements as access to the Internet has immensely increased, but there remains a "digital divide" in ability to author innovative network software and hardware tools. In addition to the requirements for experts in such networking technologies, NIE goals demanded that computer science specialists coordinate with social science and education researchers in order to produce meaningful outcomes that might further NIE goals. These demands were negotiated in the shaping of the LiNC proposal. NIE directorates were convinced that the project aimed to establish technology that suited the NIE program, but NIE counseled the LiNC grant proposal authors to place more emphasis on the educational research components of the proposal and project. This illustrated the NIE program directors' realization of the need to develop technology but that that development should be closely coordinated with educational research that produced "findings" about how the technologies could be successfully "applied" to classrooms. While the NIE directors did not explicitly target HCI experts, the demands implicitly appealed to and favored the kinds of dual expertise and interest (human and computer or "people and wires") characteristic of HCI research. This goal was, at least implicitly, calling for the coordination, interaction, and negotiation of different sets of work practices.

Like government programs, academic fields were trendy for many of the same reasons. Both responded to and attempted to capitalize on cultural forces and popular social movements. While computer science and social/behavioral sciences had been around for a long time, the 1980s and 1990s were particularly ripe for their redirection toward education research goals. Both the NII initiatives and the field of HCI aimed to join the "hard" technical field of computer science with the "soft" human-oriented fields of psychology and sociology. In some ways, this obligated diverse research cultures to interact with one another in new ways.

Border Crossing

NII initiative recommended research and development in a number of areas. One specific area was "distributed cooperative learning environments" (Vernon, Lazowska, and Personick 1994. p.6). The response from, for example, the NIE initiatives required at least three different kinds of work. Computer programmers were needed to develop computer programs in C++, Java, and related programming languages. Social and psychological researchers were needed to study and develop usable interfaces that meshed with real-world human work practices, and education researchers and teachers were needed to study, adapt, develop, and deploy the technologies for school classrooms.

Carroll employed a number of diverse researchers for the LiNC project. Some came from strictly technical fields, and others from more "people-oriented" backgrounds. Some computer scientists had traditional programming backgrounds, and others had more diverse HCI experience. Some researchers came from "people-oriented" engineering, for example Industrial Systems Engineering (ISE), and others came from social sciences like psychology. I was from STS with a background in philosophy and teaching. Carroll himself represented an eclectic mix of background. His education was in psychology, but he had worked extensively with computer corporations investigating better ways for learning object-oriented programming and designing such systems. His wife, Mary Beth Rosson, had direct training and experience with programming, especially with early development of object-oriented programming. When Carroll came to Virginia Tech, he was made department head of Computer Science. The field of Human-Computer Interaction also represents an eclectic range of research, expertise, and understandings.

From the inception, it was a challenge to envision a plan that would satisfy all of the goals of the NIE program. Technology had to be developed, implemented, and then studied in classrooms. Generally, computer scientists, especially programmers, developed software and interfaces; most could also handle hardware and network setup and configuration. Few came prepared with qualitative research skills. Human factors engineers and social and psychological scientists at Virginia Tech were generally skilled in research methods including quantitative analysis involving statistics, and some qualitative experience involving interviewing and other social science methods; however, few had experience with educational and classroom teaching contexts. Educational researchers were generally skilled in qualitative research at Virginia Tech, but there were few, if any, included in the LiNC project. Thus, there were tensions, negotiations, and interactions among researchers and between researchers and teachers over appropriate goals, data, research questions, analysis, classroom activities, and tools.

Over the years, researchers collected a large body of quantitative survey results, but the changeover in personnel and changes in the project caused there to be significant variation in survey questions and administration. That made analysis of much of the quantitative data problematic. Similarly, the collection of qualitative data changed dramatically as the project progressed. Classroom activities and students changed. The technology changed, and researchers changed. As a result, many of the focusing research questions shifted and were transformed. In the first years, there was no Virtual School to be studied. Collection of qualitative data concerned the gathering of requirements and observations of classroom activities that either involved use of particular applications, such as videoconferencing, or activities that did not involve computers at all. Later in the project, the use of the Virtual School allowed a wide range of qualitative (and quantitative) data to be collected, and very complex methods for collecting and collating the data were developed. In the early stages of the project, the data were taken to have limited power in answering the big research questions. In the latter stages, the abundance of data became somewhat overwhelming, and again the big research questions became lost.

Some of the tensions, tradeoffs, and compromises in negotiating and deciding on research methods and analytical framework resulted from the different expectations, interests, and backgrounds of investigators. Some favored quantitative study while others favored very qualitative study. Some were interested in usability and more traditional computer science and HCI concerns while others were more interested in educational, learning, social science and psychological questions related to the project. Early on in the project, the data that were collected dealt broadly with the general use of computer technology by students and their interest in science subject matter. In the latter phase, the data that were collected centered on the use of the Virtual School related activities. Some of the questions centered on usability, some on managing and improving the student activities, and some on general evaluation of the software and project outcomes. While research goals developed throughout the project, they remained broad partly because investigators made efforts to remain flexible and be comprehensive in the face of a number of uncertainties and tensions surrounding classroom activities and the HCI research.

Teaching, Technology, and Research

Carroll's admission that he was "unprepared for culture of teaching" was revealing. In many ways, teaching is highly structured by the workspace (classrooms and schools), schedule, and curricula (Cuban 1993), but in many other ways that are less visible to common perceptions, teaching is very flexible and subjective. Teachers are, on one hand, often highly scrutinized by administration, community, and parents, but on the other hand, their routine work is done in relatively isolated and autonomous ways since they are usually the lone managers of their classrooms (Rosenholtz 1991). This tension creates, on one hand, misconceptions about teachers' work by the public, and on the other hand, opportunities for particular, albeit limited, forms of control and resistance to external pressures and structure.

In the course of the LiNC project, Carroll noticed how teachers engaged in interesting and distinctive ways of resisting administrational and similar top-down political pressures. Typical school time classroom activities are not generally events that the public frequents, except under special circumstances, for example when teachers invite members for special events, parent-teacher meetings, or other times when teachers anticipate visitors to their classrooms. Teachers develop rapport with students that is in one sense dependent on outside support for custodial authority, and in another sense, easily disrupted and in some cases even challenged by outside intervention and attention. Thus, teachers come to rely on their ability to direct the class with limited fear of scrutiny and intervention. As with any leadership, teachers generally have ways of complying while conveying their own values and rules even when they may not be consistent with those perceived as external. Limited resistance and noncompliance can often be easily achieved and somewhat unnoticed in classrooms.

The idiosyncrasies, lack of uniformity, isolation, autonomy of teaching practices has led some to consider teaching practices more amenable to "artistic" than "technical" terms. For example, teaching has been described as a "craft" culture that "clashes" with the "technical" culture of instructional technology (Aquila and Parish 1989). Specifically, with regard to efforts such as represented by the NIE, they argue that many of the problems with initiatives that seek to encourage adoption of technology by teachers fail because "teachers are artisans with a craft orientation rather than technology-oriented technocrats" (p. 49). "Teaching is a craft culture, and members of a craft culture utilize knowledge differently than do members of technical cultures" (p. 53).

> There is, we would argue, a clash in schools between the two cultural types, technology and craft, with each having a different view of the teaching role. It is the old (or, perhaps, again new) question of whether teaching is an art or a science. The authors [Aquila and Parish 1989] believe that teachers are essentially members of a craft culture and will, therefore, resist technical cultural programs and ways of implementing change (p. 54).

This point is interesting, but it should be considered very carefully. It is a common misconception that classroom teaching involves straightforward application of specific and determinable "methods" that derive from a well articulated, well established, and agreed upon body of knowledge; however, even the most highly "technical" practices, such as those in scientific laboratories, involve tacit or informal rules, knowledge, and practices (Polanyi 1966) and "craft" (Latour and Woolgar 1986, p. 28-29). A significant body of STS research involves describing these informal and often invisible or "black boxed" practices in the most "technical" fields like engineering and the so-called "hard" sciences. Moreover, how one construes "method," "art," and "craft" and their relation to teaching can fundamentally alter the discourse regarding the ways that teachers and their "craft culture" resist or "clash" with "technical" cultures. For example, Garrison (1995) invoked Dewey's ideas to describe how, like other arts, style in teaching requires "method." "In order to achieve their purposes every artist must have methods and techniques to do their work. Intelligent method is inseparable from a fine pedagogical performance" (p. 54).

Aquila and Parish (1989) claim that "in essence, teachers said: 'They don't understand us'; 'they use funny words'; 'they don't recognize the tools of our craft,' and 'they're asking us to do things we don't see the use for, and we don't trust them'" (p. 54). We can make similar observations about teachers in the LiNC project. When asked, "What other information or data would have been useful in the design of educational software," one teacher stated that it would have been useful "making others understand the teacher terminology and what we wanted and what we were asking for." The implication is that teaching has "terminology," and related "technical" knowledge associated with it. Teachers suggested that their role was to tell developers "the best way to use computer technology and the virtual school in science class to benefit the students most in learning the skills and materials" and "what would work" in classrooms. This implied that teachers believed they could reliably distinguish good and bad teaching and learning in their own classrooms. In many ways, teachers in the LiNC project did understand their work as highly technical. In other ways, their work appeared very non-technical and stylistic to investigators.

What is important to understand, and one thing I have tried to describe in this work, is that there were critical negotiations, transfers, and connections among investigators, managers, teachers, and others involved. These interactions involved expectations, not only about one's own work, but also about others' work. Teachers had ideas of what teaching consists, what network technology development can offer their work, and what they can offer to the development process. Among teachers, these ideas varied, but, partly because most investigators had never taught in a public school classroom, investigators did not share many of the understandings and common "technical" knowledge, methods, and techniques that were shared by the teachers. Investigators had different ideas of what teaching consists, what can be studied in classrooms, and what teachers and classrooms can offer the development process. Among investigators, these ideas varied, but partly because teachers had little to no experience doing university and HCI research, teachers did not share many of the understandings and common knowledge, methods, and techniques that were shared by the investigators. Teachers sometimes displayed somewhat naïve perspectives about university research, science, and technology, just as investigators displayed naïve perspectives about classroom contexts, technical, and social dimensions of teaching. The boundaries and categories needed to understand and define these roles in the LiNC project were fuzzy and "fluid."

Again, one important outcome of the length of time spent interacting with teachers in their work was that teachers began to believe that the researchers and developers were learning about the realities and constraints of genuine teaching work. Teachers even described this is one of the best things about the design process. Specifically they commended the project for allowing researchers to engage in "analysis of real classroom activities" and for giving computer developers and classroom teachers the opportunities "to understand each other better." Similarly, discussed below, teachers claimed that they also appreciated the unique opportunities to learn about *each other*. One aspect that is unfortunately often downplayed or hidden was the way that investigators and teachers learned about their own practices, that is, the ways that they reflected on their own practices as a result of the intervention. I have described some of the events that demonstrated this reflection throughout the LiNC project from the social networking in writing the grant, to the negotiations with NSF, communication among teachers and investigators, investigations in the classroom, and so on.

Teachers' Work in the LiNC Project

The LiNC grant proposed to study collaborative technologies in classrooms. The goal was to study students, and in the proposal, there was little to no suggestion that teacher practices, culture, and collaborations be a subject of study. Teachers were to be participants in design, and there may have been hints that they were to be participants in the research and analysis processes as well. By the time that the Virtual School was implemented, I was part of the research team, and I was not alone in noting the great extent to which teachers played critical roles, as did investigators, in the producing Virtual School collaborations. This should have been no surprise since a great deal of research suggested that differences in teachers' style and delivery of curricula fundamentally influenced the substance, content, and enactment of curricula. Interestingly, similar issues and questions arose about the roles of researchers in the classrooms, their intervention in helping students, and their influence on the outcomes of the activities. Some of these issues are discussed below.

In conversations with other investigators, mainly Neale, I emphasized some of the historical research that recognized the critical role of the teacher in shaping curricula. Noting similarities to problems with past attempts to study "common curriculum," we discussed how our observations of the different classrooms and teaching styles indicated problems in the assumption that there is substantive commonality in the "materials" and "curricula" across classrooms that allowed meaningful comparisons. We agreed that, contrary to many ordinary views of curricula, teachers were fundamentally the "makers" of curricula rather than mere vehicles for delivering it (Gallagher 1967, Darling-Hammond and Snyder 1992, and Clandinin and Connelly 1992).

Putting machines into classrooms with the intent to facilitate student collaborations intervenes into teaching work. This was a crucial realization that many researchers in similar positions have ignored or missed. Neale pointed out early in his work with the LiNC project that the teachers' practices were not trivial and irrelevant to the Virtual School activities. He explicitly raised concerns about our attention to what the teachers were doing to prepare, coach, and motivate the student collaborations. Specifically he worried about the ramifications of collecting data about the teachers' practices. There came a point where the investigators realized that teachers could not be left out of the evaluation the Virtual School. They were part and parcel of the use of the technology. Neale pointed out that, in studying the Virtual School, we were unavoidably studying teachers, and this point that described explicitly in Dunlap, Neale, and Carroll 2000. Neale and I worried about how the teachers might feel about becoming subjects of the study rather than merely participants in technology design, but it was obvious to us that there was a growing sense that prior assumptions about the division between student-activity, teacher style, and the Virtual School needed to be considered and challenged.

Teacher Collaboration in LiNC

In late 1998, I led work on a paper on teacher collaboration in the LiNC project that was later published (Dunlap, Neale, and Carroll 2000). The abstract from that paper describes the work:

> In this paper, we examine the collaboration problems teachers encountered in the course of instructing students using collaborative computer software to connect distributed classrooms. We describe issues surrounding teacher collaborations arising from three types of sources: organizational chaos of teaching, physical and temporal dispersion of events and causes, and individualism in teaching practices. We illustrate how our situation presents new challenges and opportunities to better facilitate and motivate teacher collaborations, ones that may become typical in the future of education and thus are important to analyze now. Finally we describe some technological solutions to problems arising from traditional and novel teacher collaborations.

The paper was important because it suggested that in developing technologies like the Virtual School, researchers need to pay special attention to the work and circumstances that characterize public teaching professions. In developing and deploying technologies for student collaborations, researchers radically alter the practices of teachers in a number of fundamental ways, and researchers face particularly difficult obstacles to implementing collaborative technologies in classrooms because of circumstances related to teaching practices and culture. While it was clearly a goal of the LiNC project from the onset to involve teachers intimately in the design process, participatory design involving teachers required considerations that went well beyond those that took into account student interactions and pedagogical preferences. Often teachers and researchers needed to step back and consider the interactions not only between teacher and student but also between teacher and teacher. In short, the attempt to mediate student collaborations had ramifications that impinged on the work involved in the teaching profession, especially the culture of isolation and autonomy so often described in teaching (Garrison 1995, Rosenholtz 1991, Goodlad 1984, Lortie 1975). Researchers have identified several barriers to increased teacher collaboration: cultural norms of individualism, structural conditions in schools, teachers' differing pedagogical orientations, and the absence of "shared professional identity" or common beliefs and expectations of teachers and their colleagues (Mitchell 1997, Rosenholtz 1991).

Again, LiNC teachers blamed differences in their teaching style for major problems with their collaborations, but teachers expressed an important commonality among their pedagogical principles, namely their belief that students needed to have a voice in their learning. Two related features summed up the teachers' conception of constructivist learning. First, learning needs to build on prior knowledge, and second, students need to take an active role in their learning choices, that is, learning activities need to be responsive to their voices and experiences.

Clearly these teachers valued project-based, collaborative, cooperative, and inquiry learning. The teachers were all accustom to assigning student projects, which involved students designing, constructing, and/or presenting a project. Learning was collaborative when two or more students worked together. Collaborative work is generally called cooperative when it requires some form of interdependence among students, for example, when the individual tasks or roles depend on each other to make a whole or to make sense. Several statements made by teachers illustrated their appreciation of collaborative and cooperative learning. One teacher said, "In many cases students have more opportunity to learn from other students than from me." Another teacher said simply, "Lectures don't work well," and another stated, "It's important not to make the class teacher-centered. A discovery approach is better. The interest level is higher, and comprehension is greater."

Collaborative and Cooperative Learning in the Virtual School

Rochelle (1995) invoked Dewey's view of experience, inquiry, and technology to distinguish "a technological situation for collaboration and a collaborative technology." Technology provides new situations for communicating and transferring information, but according to Rochelle's distinction, a truly collaborative technology entails "a more encompassing and powerful goal: the construction of communal ways of seeing, acting and knowing." A collaborative technology is a tool that enables individuals to jointly engage in active production of shared knowledge" (p.2). "The key difference is the use of technology in the construction of shared resolutions to problematic experience" (p. 3). I was tackled the question of how to distinguish or measure the degree to which students were cooperating using the technology. Research on cooperative learning provided some help.

In an effort I directed, we studied differences in cooperation in the student Virtual School activities. I presented this project at SRI's Center for Innovations in Learning Technologies conference in October 2000 (Dunlap 2000). It became clear to the teachers and the investigators involved in the final round of projects that some of these latter projects were visibly more successful than prior activities. This was an impression and general feeling on which we all agreed, but we lacked tangible evidence that substantiated that feeling. No one involved believed that we could demonstrate conclusively that these later activities were “better,” but the conviction that we all shared was enough to attempt some kind of study to demonstrate an effect since we did have a great deal of data about the activities. We also realized that the activities were so different that direct comparison was not totally fair since so many intervening variables or auxiliary assumptions made the prospect of experimental control and comparison dubious. Nevertheless, the exercise in developing a method and instrument to corroborate our intuitions by counting the frequency of types of verbal interactions was too tempting for me to ignore.

Content analysis is an established research method for examining the presence of certain words, phrases, and concepts in text. It is related to rhetorical, discourse, and conversational analysis, all of which have serious problems associated with inferences about the presence and frequency of certain parts of speech. For example, Kaye (1992) warns that “when we look at transcripts of conference discussions, it would be naïve in the extreme to equate the number or frequency of messages in a conference, or the recognizable links between messages, as an indicator than [sic] any form of useful ‘collaborative learning’ is occurring”….“To establish whether meaningful collaborative learning is occurring, it is necessary to undertake an analysis of the messages in a conference, and to situate the analysis within the social and organizational context of that particular conference” (18). Nevertheless, content analysis has been used to analyze computer-mediated communication (Henri 1992; Henri and Rigault 1996), group dynamics in computer conferencing (McDonald 1998), learning processes in computer conferencing systems (Rueda 1992), interactions in cooperative groups (Wild 1997), and critical thinking in computer conferencing (Newman 1995), so the methodology had backing in the research literature, for whatever that was worth. I believed that the method was a useful way to corroborate our intuitions and help develop a more general instrument for investigating computer-mediated cooperative learning.

In earlier projects there appeared to be more procedural problems that involved task delegation among the groups. For example, while many groups created two sets of physical models, one for each side of the group, some delegated the model building to only one side. Rarely did there appear to be the kinds of deep level task interdependence suggested by cooperative learning researchers. Since the students were in different classroom, they had different goals, directions, and expectations. This caused confusion and problems.

Our assumption was that there was a much greater degree of cooperation and meaningful interaction among the groups in the later activity than in the prior activities, so I looked to literature on cooperative learning for some summative conclusions about characteristics associated with high achievement in cooperative group interactions. Johnson and Johnson (1992) provided a survey of research on cooperative learning describing characteristics of high achieving groups. They identified a particular feature called “positive interdependence” which is, in short, behaviors that indicated cooperative or non-cooperative attitudes, “we instead of me” or “all for one.” They argued that groups that showed these behaviors were groups that were more likely to achieve or succeed overall, and groups that did not behave with these characteristics and engaged in behaviors that countered or obstructed these types of interactions tended to be less productive.

Behaviors that are indicative of positive interdependence include things like giving assistance, providing feedback to others, challenging and mutually influencing the group, motivating and advocating increased effort, and evaluating and processing how well the group is working together. Behaviors that oppose positive interdependence include giving uncritical responses or going along passively with the dominant response of the group, "social loafing" or hiding in the crowd and "free riding," losing motivation as a result of perceived inequality in effort and contribution to the group work, "group think" or avoiding disagreement and discussion or negotiation, and frustration with the group due to lack of communication, teamwork, and organization. These characteristics and categories are well known and often cited in the cooperative learning literature. Johnson and Johnson argued that these particular characteristics promoted more than just greater levels of cooperation and interdependence, but they were also correlated with higher levels of achievement and indicated better group problem solving skills. It is somewhat counterintuitive that several of the *positive* characteristics reflect behaviors that appear confrontational and may encourage dispute and disagreement. Similarly, some of the *negative* behaviors suggest that group members were being passive and agreeable. Also, some of the indicators were run-of-the-mill, like giving and receiving information, while others, like influencing and motivating the group, indicated deeper level cooperation.

The next step I took was to operationalize the indicators with respect to the synchronous activities of the Virtual School interactions. We then coded the scripts accordingly, checking for inter-rater reliability, and then tallied the number or "frequency" of the positive and negative indicators. The results corroborated the intuitions that the researchers and teachers had about the groups. According to the measures, the later groups engaged in far greater frequency of positive cooperative interactions and fewer negative interactions just as we expected.

Group problem solving skills, like those described by things like positive interdependence, are related to personality characteristics. Shyness and passivity, for example, can be gender and culture specific. However, I do not believe that this is reason to focus attention away from them; rather, we can help students address those aspects of their personality, culture, etc. that may hinder group problem solving. Educators and developers of collaborative technologies can do this by developing methods that help students rehearse strategies that reinforce group-learning skills. For example, when asked to consider a plan of action, a student can be encouraged and given structures that help to develop multiple options (critical thinking) rather than settling for passive agreement (group-think). Moreover, developing ways for technologies to feed back indicators of positive interdependence to teachers and students can help teach collaborative skills.

The cooperative activities raised a number of novel problems since they involved interactions between teachers and students that were not typical. Student attention was diverted and directed toward computer screens. Students spent significant portions of class time using chat or video-conferencing with distant group members. Teachers were sometimes managing as many as five separate computer-mediated group activities in a class. Students were dealing with choppy audio and video because of network speed and related technical problems.

Problems encountered in using the Virtual School naturally impacted the considerations of design features. For example, teachers evaluated collaborative work that crossed grade level and classrooms when it was often unclear where the pieces of the work had originated. This led to an added feature called "authorship tracking" that allowed users and teachers to see the origin or author of passages in the collaborative notebook. Several vivid incidents continue to be referred to in thinking about design features. There continues to be discussion of how to feed data that is logged on the server back to teachers and users for better understanding and assessment of progress and contributions to the collaborative work. A key set of the concerns comes under the label "awareness." In HCI, the term generally refers to how well users can keep track of processes, activities, and information relevant to the user. Attention to the issues led to the proposal and award of yet another NSF grant designed to study and develop awareness features in the use of the collaborative technology (Activity Awareness in Computer-Supported Collaboration NSF ITR/PE (IIS) 0113264).

School and University Collaboration

Above, I discussed issues related to collaborations among teachers and collaborations among students. The LiNC project also deeply involved teachers in collaborations with university researchers. In many ways, this is where one might expect the greatest conflicts because these two groups operate in very different work practices, environments, and with very different professional interests. The LiNC project explicitly aimed to unite the common interest of teachers and university researchers in designing and deploying collaborative applications for classrooms. While there were mutual interests driving the groups' efforts, there were also significant tensions in the practices and work of the groups.

Teachers, Technology, Research, and Participatory Design

First, there were epistemic values and differences in knowledge and expertise that created challenges for participatory design goals. This was a challenge in both directions. Teachers needed to know a great deal about what was possible with the technology. They had interesting ideas about how to design useful tools, but these were often far too ambitious for the developers and the existing technical infrastructure and capabilities. Teachers expressed this sentiment in a number of ways. Many of the early conversations and brainstorming sessions were very disappointing and uninspiring to the teachers because their ideas could not be implemented. One teacher was very direct. "When present, the developers would be critical about our ideas saying things like, 'that's not possible' or 'we can't do that.' It killed the creative process." Teachers stated similar ideas repeatedly. For example, they said that they had "great ideas and design, but then it couldn't be developed." "I was naive in thinking it was a simple process." Teachers had unrealistic and vague ideas about what kinds of technical tools could be produced. In suggesting ways to improve the process, a teacher stated, "I would want to first find out from the developers what they have in mind -- that would help me to better organize my ideas." Teachers expressed their ignorance of feasibility numerous times. One suggested that they needed to "develop consensus on what tools are needed and feasible." Another said that the information or data that would have been useful in the design of computer-based learning activities concerned "knowing what was probably, possible, and impossible to do -- we might not have asked for so many 'pie in the sky' features."

The research followed many tenets of "action research," and Carroll should be commended for taking steps toward the goal of empowering teachers to take responsibility for their part in the research. Though "action research" was never articulated as an explicit goal in the project, it was implicit in the ideas of participatory design. But "design" is not "research." Nevertheless, the processes in the LiNC project, the interactions and engagement of teachers in the research processes entailed "action research" outcomes. What is "action research?"

> The first requirement, then, is that teachers' existing ideas are articulated, analyzed, criticized, compared and contrasted with others. Thereafter, attention switches to the development and, crucially, to the critical evaluation in action of the new teaching and learning activities. Teacher development, however desirable, cannot be achieved by trying to compel, or even to exhort, teachers to change. Nor can the precise nature and extent of change be pre-determined. Control of the direction and the pace of development must rest with the teachers themselves. However, there is an important role for a facilitator, acting as a critic and support for the group…
>
> In the action research model of curriculum development/professional development adopted by the group, thought and action (theory and practice) are dialectically related. They are mutually constitutive (Pedretti and Hodson 1995, p. 469)

The LiNC project involved a large range of researcher and teacher interactions. Some directly contradicted the kinds of engagement and dialectical development of theory and action recommended by Pedretti and Hodson, but, on the other hand, there was a great deal of interactions that did exactly the kind of deep discussion and serious criticism mentioned above. Teachers and researchers debated and negotiated. That should be clear from discussions above. But researchers and administrators also, at times, compelled and coerced teachers.

Much of this can be explained in terms of the interactions and negotiations among the workers. Teachers know their practice, and researchers know their theory. While the two coincide to some degree, the problems involved in teacher research in LiNC were not as simple as anyone expected. Garrison's (1997) explains some of the problems with interactions involved in research about teaching:

> *Technē* for the ancient Greeks meant craft, skill, art; it is the knowledge of poiēsis, involving knowing how to create what the craftsperson desires. By contrast, *theōria*, from which the *theory* is derived, meant speculation, contemplation, or "a spectator above." Theōria assumes an attitude of detachment and distance from everyday life and practice. The form of knowledge associated with theōria was *epistēmē*, which meant certain knowledge of perfectly clear, immutable, and timeless truths. Epistēmē opposes technē because technē is knowledge of how to do things in this vague, changeable, and ephemeral world. The Greeks put theōria and epistēmē at the top of the hierarchy of knowledge. Poiēsis and technē were at the bottom. Nothing has changed over the millennia. Today educators research teaching as they should, but too much of it is done *on* teachers rather than *with* them. Theoreticians and technocrats sometimes assume their wisdom is at the top of the knowledge hierarchy and that of teachers is at the bottom. (p.8 - 9)

Teachers' View of "Research" and Researcher Intervention

In addition to researchers' misconceptions about teaching practices and teachers' lack of advanced expertise with computer programming, teachers also had preconceptions about university and HCI research and the role that researchers and evaluators would be taking in the classrooms. There were concerns about the lack of structure and control in the research observations and implementation. Some of this centered on how much intervention was needed to encourage students to collaborate with one another. Other concerns were about the kinds and amount of assistance with the technology and content that investigators were contributing.

These discussions were part of on-going research decisions concerning how to conduct observations, what data to collect, how to identify and document researcher roles in observations, and what affect and meaning researcher interventions entailed. We did not take these issues lightly, and we did not pretend that we were conducting controlled experiments. We knew we were influencing the collaborations and the behaviors of students and teachers. Realizing that that was unavoidable given the kinds of activities we wished to manage and the resources we had available, our main concern was to comprehensively document our activities and interventions and not to hide them beneath a guise of "objective evaluation." This was partly because we did not see the value in attempting a controlled experiment. From an experimental standpoint, we did not even begin to speculate about what variables would be dependent, independent, and so forth, and from an ethical standpoint, we did not want to consider the ramifications of "withholding treatment" from certain students since that would have educational implications. Nevertheless, we believed that there was a great amount of information that could be mined from the data we were collecting, and we attempted to be consistent in the kinds of assistance that we offered to students. For example, we made every effort to refer content related questions to the respective teacher and to try to offer only technical help in trouble-shooting the Virtual School application and computers.

The data collected by researchers in the LiNC project amounted to a huge store of text and survey data from participants. Evaluation was never to date comprehensively completed in Carroll's view. There were fairly detailed plans to write several papers providing summative evaluations of the material, but these are still being completed. There have been a very large number of publications relating to the project, and there were some examples of focused work utilizing pieces of the data.

Researchers' Ignorance of Teaching

It was surprising and frustrating to several investigators that they could not address, in a clean experimental way, a wide variety of interesting outcomes, for example those related to learning outcomes involving the use of the Virtual School or networked technology in general. Early on Burton opposed comparing outcomes related to the technology intervention to some sort of "control" group. Carroll never saw this a major goal of the project anyway. Investigators collected some student project grades and graded reports, but little or nothing was done with them.

Teachers clearly saw their role initially as experts in teaching practices with knowledge of what is feasible and realistic for classroom application. Researchers early in the project shared this perception since they had little realistic experience with classroom practice. For example, one teacher remarked, "I bring my classroom experiences to the table to help you CS guys and gals have a realistic view of public schools." Another said, "[I] come up with ways to implement the technology created by the programmers in my classes," and another said, "[I explain] how to create the best way to use computer technology and the virtual school in science class to benefit the students most in learning the skills and materials." Teachers also described changes in their roles as the project advanced. "Initially, I was functioning as one of a group of area experts. Eventually, that expanded to include some general support functions. Now I employ the system we've built and help coordinate data collection." Another said, "I think I was expecting to be more of a guinea pig - you build it and I test it - you pick my brain and leave."

The subtle wording used by the teachers in these passages may be indicative of the some of the challenges that researchers were unprepared to face. Note that teachers generally refer to their singular experience as a teacher rather than a sense of collective experience of teachers as a group. Like most teachers, these participants did not consider collaboration an ordinary part of their professional work. Their teaching was largely autonomous and isolated to their individual classrooms. The project sought to engage them in participatory and collaborative activities, but to a large extent, this was counter to their work culture.

This lack of preparedness for the teaching practice and culture was reflected in a number of other ways. Some issue probably could not be anticipated, and others may have had more to do with personality conflict. For example, the "revolt" described above where teachers took it upon themselves to insist on the implementation of long-term projects in LiNC collaborations was partly a result of resistance to the heavy-handed demands of one researcher. This resistance might be expected by persons familiar with ordinary pressures characteristic of the profession of teaching. But the shift was also partly the result of typical, tacit, and practical understandings of the kinds of activities that work well in the contexts that constituted the Virtual School activities and the curricula and students familiar to these teachers. Again, cultural beliefs and practices were instrumental to the conflicts and interactions that led to teachers' actions. The outcome permits multiple interpretations. The conflict was most likely considered an act of defiance to one researcher and a rally cry to another. For Carroll, it was an important sign that teachers were advancing and taking greater responsibility for their role and actions in project, a favorable move that was in keeping with the goals of participation. In the same way that some characteristics of cooperative interdependence appear somewhat "negative" or "counter-productive," "revolt" was indicative of an active acceptance of responsibility, charge, and control. The event was interpreted in several different ways.

Social Construction of Technology Revisited

The actor-network approach emphasizes interactions and relationships among various kinds of elements in the production or construction of knowledge. In turning to technology, the focus on these associations holds promise. The LiNC project embodied a multitude of specific instances of actors describing, explaining, and articulating various dimensions of their social and technical realities and how they interact in their work involving the production and use of technologies. I tried to recognize and explore how the actors' conceptualizations direct and influence the social production and use of the technologies.

In other words, following Button's and Woolgar's lead, I wanted to exploit the "analytical ambivalence" inherent in the theoretical position of SSK as it relates to how "the technical" and "the social" are understood *in* the production processes. For example, investigators and teachers in the LiNC project spoke about the functionality and development of the technology as a work process. They, often seamlessly, related these processes of writing computer code and connecting computer hardware to the grant funding processes, teaching practices, and numerous other aspects of their work culture, social organizations, and economic interests. Using actor-network theory to describe the technological development in the LiNC project, or more generally, the application of SSK to SST, provided a foundation offering a reflexive sociological description of the production process. It allowed for the understanding of technological infrastructure in terms of human production, or "humanity at work," and it allowed for a sociological account that recognized instrumental differences in how technical development interacted with their work.

However, in some of the current research, actor-network explanations tend to take the social networks, power relations, and economic order as the objects to be explained, that is, they subsume description of the technology *as it is found in the work done by the actors* with explanations in terms of the social-networks that are abstractions of sociological analysis. Thus, they hide or, in effect, make the technical understandings irrelevant to the description *of* the production or subservient to social causes. Sociological analyses can go too far in focusing on social description and explanation over "internal" technical description. In doing so, that which is recognized by workers or participants as "the technical," can become replaced and dominated by "social" explanations and descriptions. The technical objects become a *function of* the social network. The technology becomes the explanandum of social analyses rather than an important component of the actors' categories and work practices that constitute ordinary production processes.

The danger is in creating a situation where the actors' own understanding of "the technical" (and "the social") appears to have little relevance to production processes. In part, I described ways that actors distinguished and operated on ideas about "the social" and "the technical" in their work, and ways that they also reflected and integrated these understandings in their technical work; this applied not only to "technical" but also to "social" understandings. These actors were *not* altogether naïve about and separated from the construction of their own social relations, economic interests, and cultural entrenchment. Actor-networks were themselves *a production*, one encountered in technical production, reflected in that production, and transformed by that production.

Technology and Anthropomorphosis

Pitt (2000) was justified in criticizing Winner (1986) for going too far and attributing characteristics like "intention" and "ideology" to things like technology or bridges. For example Pitt asks, "What does it mean to say, for example: 'Technology is taking over our lives?' One way to understand this claim is to interpret 'Technology' as a thing in itself that has its own set of causal powers and operates on its own, independent of human interference" (71). Pitt argues "that tools and technical systems *are inherently ideologically neutral*. Individuals with particular axes to grind may employ a tool to achieve their ends, but this does not make the tool itself ideological" (72). On the other hand, Blacker (1994) points out the tension between some of our ordinary modes of communicating about technology, for example, in the metaphors, analogies and close and often intimate relation to the tools we use, and our recognition of their lack of human intellect.

> On the one hand, we experience tools as things that we *use*; we regard them as morally neutral in the sense that they seem to await a human purpose to animate them with moral life…On the other hand, however, is an equally prevalent common sense intuition, especially since the advent in this century of science-based "high-tech." In our homes, workplaces and even at play, we are awash in a veritable flood tide of tools ever-more refined and complex. As Don Ihde has put it, our lifeworld has become irrevocably "technologically textured." … Technologies are thus often regarded as the bearers of intentions and are encountered in what Daniel Dennett [1987] calls the "intentional stance" (for example, "my car doesn't want to start," "the computer won't let me do that") (p.1).

Similarly, Dewey (1958) wrote that a tool "possesses an objective relation as its own defining property. Its perception as well as its actual use takes the mind to other things. The spear suggests the feast not directly but through the medium of other external things, such as the game and the hunt, to which the sight of the weapon transports imagination (122-123).

Carroll described how he acted on social and technical aspects of production. He regards these as different aspects of the infrastructure that he built and leveraged, but he also did not regard them as wholly distinct. How he understood the social networks, cultures of teaching and research, and technical dimensions of his work was central to understanding the production process in which he engaged. It was crucial to understanding his description of the production process, which was ultimately critical to describing his work and role in the production of the LiNC technology. The Virtual School and MOOsburg embodied social and objective relationships precisely as a product of how they were constructed, purposed, and understood. They conjured images and embodied values because of the contexts and purposes for which they were constructed and employed; however, all of that depended on the social context in which they were considered and reconstructed. It changed from meeting to meeting depending on the grant being written, the group being presented to, or the newly developed feature being demonstrated.

Opportunities for Further Research

The LiNC project research opened avenues and suggested a wide range of further opportunities for advancing beyond this study. I will touch on four suggestions. First there were several grants that have been awarded to the Center for HCI at Virginia Tech to continue similar work, and there were others being composed and submitted that proposed to leverage the current technology and infrastructure created mainly as an outcome of the LiNC project. The most significant grant to me is a three-year NSF award by the Research on Learning and Education (ROLE) program from the directorate for Education and Human Resources (EHR). The $710,000 grant, entitled "The School as a Knowing Organization: Knowledge Management as a Strategy for Continuous Teacher Development," proposed to investigate organizational knowledge management in public schools. This project will use the CORK infrastructure as a platform to refine and further develop tools that adapt knowledge management concepts and techniques, and the information technology they employ, to understand and help local public school teachers better utilize the knowledge resources they share in Montgomery and Giles County school divisions. As described above, the infrastructure was adapted from the Virtual School and its components. I played a large role in developing, writing, and negotiating this grant, and I was proposed as the manager for the execution of the grant.

In addition, a number of other grants support the development and refinement of MOOsburg. For example, another NSF grant that was also awarded, entitled "Activity Awareness in Computer-Supported Collaboration" is designed to study aspects of computer collaboration tools and opportunities to provide greater awareness about users' online collaborations and work. Many of the issues addressed in this proposal came directly out of problems and concerns recognized in the Virtual School collaborative activities.

The second significant area of opportunity for further research involves the data and outcomes of LiNC project itself. There remains a significant prospect to engage and mine the rich data collected in the LiNC project for further analysis and evaluation. For example, while a number of focused analyses were performed and presented about the project, there remains the potential to pull together some higher level and more summative conclusions and evaluations about the student computer-mediated collaborations, the technology, and the project outcomes.

The third area of opportunity for further research is closer to the goals of the present work. I recognized a lack of engagement of critical STS kinds of understandings and approaches, especially those related to technology development, in the related fields of Human-Computer Interaction, Computer Supported Collaborative Learning, Computer Supported Collaborative Work, Computer-Mediated Communication, and Distance Learning. The danger, as has happened in STS critiques of science, is that STS becomes viewed as an adversary to the research in these fields. For example, STS is sometimes viewed as purely a critique of knowledge and technology production with nothing productive to contribute to other fields. STS researchers are viewed as debunkers, opponents, and radical activists that can only criticize and dispute production rather than critically negotiate with organizations and groups in order to empower participants. STS researchers should engage these fields, and this may mean that sometimes they do it from the inside, as participants in the fields rather than as outside and peripheral critiques.

I note two areas where STS researchers could offer particularly unique and valuable insights into the social, political, and historical contexts of HCI work and Internet development. First, I touched briefly on the relationships among fields such as HCI and government organizations like NSF. These social and political contexts and relationships were instrumental to the funding channels, public, and academic perceptions and work related to Internet and other computer related technology development. More detailed analysis of these relationships could provide a great deal of context and additional insight into the social processes of funding and technology development employing government and academic resources. Second, there needs to be more critical and comprehensive descriptions of the early historical development of Internet cultures and their related technologies. I briefly described the several areas that have been largely ignored in histories of the Internet, the MOO cultures and even earlier network related communities that evolved around electronic bulletin boards and other such computer network services that were non-commercial and often subversive but very instrumental to the technological developments experienced today.

This leads to the fourth area of opportunity that I recognize for further research. There remains a cultural divide between university research and other organizational work. The present work suggested, interestingly, a cultural divide among university and public school teaching. This is a huge but very sensitive area of concern to many people.

University researchers often know little about school teaching. Teachers know little about university research.

I suggested above that the ways that technology developers construe the “technical” and “social” dimensions of their work have ramifications to their work, and thus to descriptions of those work processes. In this present work, I fell short of offering a parallel claim and description of the work of teachers, but here I would suggest that the ways that teachers construe the social and technical dimensions of their work also has ramifications to how they practice their work; however these dimensions are, of course, different for teachers than they are for developers of technology. The social dimensions of teaching include culture and practices of the craft of teaching as well as the administrative, custodial, and collaborative aspects of their jobs, as I briefly described above. Technical dimensions include those that have been the focus of American educators throughout the past century. These are contested and heterogeneous with fluid and dynamic boundaries. Teachers and researchers vary with respect to how they construct meanings and what they consider to be implications for practices. Teachers operate with technical knowledge and practices, but these understandings can be at odds with curriculum and pedagogical standards imposed on teachers. Teaching reform often represents recurrent attempts to constrain and mold teaching into structured and technical practices. Such efforts have been the focus of educators since the factory model of production was imposed on schooling in the early 1900s with Tyler’s (1949) principles and in the latter half of the century with devices like Hunter’s (1967) highly structured model of lesson planning, and more recently, with standardized curricula and testing. How teachers distinguish and construe the technical and social dimensions of their work often diverges from the ways in which sociologists of education describe teaching. There is a great opportunity for STS researchers to provide alternative and critical insights into the descriptions and interactions among teachers and researchers.

Computer network technologies are beginning to bridge the gap between public school classrooms and universities in new ways by providing distance learning and collaborative resources for teachers and learners; however, the ways that these diverse groups are co-engaged is critical to the producing positive outcomes. They often need to know more about each other and their respective work contexts, but educating them creates a chicken-and-egg dilemma. Academic researchers and teachers need to learn about each other, but they also need to know how to engage each other. In order to learn, they have to engage, but in order to engage fruitfully each other, they have to know something about the work with which they are interacting so that expectations are realistic and productive.

To this end, I offer this present work. My hope is that researchers and teachers involved in similar ventures, by reading this, better understand that their collaborations, especially those involving the development of innovative technology and research, are complex. Such work will not be straightforward and simple, partly because we live in complicated worlds with very intricate and multifarious beliefs and practices that do not always mesh in the ways we might desire and expect. I intended to describe the LiNC project in such a way as to impart sympathy and understanding among a remarkable group of researchers and teachers in an amazing period of technical development and world change and in a fascinating set of organizations and politics.

References

Abbate, J. (1999). *Inventing the Internet*. Cambridge: MIT Press.

Abrams, M. (Ed.). (1998). *WWW- Beyond the Basics*.: Prentice-Hall.

Akrich, M. (1992). The De-Scription of Technical Objects. In W. E. Bijker & J. Law (Eds.), *Shaping Technology / Building Society: Studies in Sociotechnical Change* (pp. 205-224). Cambridge: MIT Press.

Ashworth, K. P. (1990). Math and science: a nation still at risk. *Principal, 69*, 15-17.

Begole, J. B., Rosson, M. B., & Shaffer, C. (1999). Flexible Collaboration Transparency: Supporting Worker Independence in Replicated Application-Sharing Systems. *ACM Transactions on Computer-Human Interactions, 6*(2), 95-132.

Belsky, J. (1995). A Nation (Still) At Risk. *National forum, 75*(3).

Bennett, C. K. (1994). Promoting Teacher Reflection Through Action Research: What Do Teachers Think. *Journal of Staff Development, 15*(1), 34-38.

Bennett, W. J. (1999). Our Nation Is Still at Risk. *The St. Croix review, 32*(1).

Bijker, W. E., Hughes, T. P., & Pinch, T. (Eds.). (1987). *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge: MIT Press.

Blacker, D. (1996). *Philosophy of Technology and Education: An Invitation to Inquiry*. Philosophy of Education 1996. Available: http://www.ed.uiuc.edu/EPS/PES-yearbook/94_docs/BLACKER.HTMOctober 20, 2001].

Branscomb, L. M. (1992). Information Infrastructure for the 1990s: A Public Policy Perspective. In B. Kahin (Ed.), *Building Information Infrastructure* (pp. 15-30). Boston: McGraw-Hill Primis.

Bruckman, A. (1998). Community Support for Constructionist Learning. *Computer-Supported Cooperative Work*, 47-86.

Bruckman, A., & Resnick, M. (1995). The MediaMOO Project: Constructionism and Professional Community. *Convergence, 1*, 94-109.

Button, G. (Ed.). (1991). *Ethnomethodology and the Human Sciences*. New York: Cambridge University Press.

Button, G. (1993). The Curious Case of the Vanishing Technology. In G. Button (Ed.), *Technology in working order: studies of work, interaction, and technology* (pp. 264). New York: Routledge,.

Button, G., & Sharrock, W. (1998). The Organizational Accountability of Technological Work. *Social Studies of Science, 28*(1), 73-102.

Byous, J. (1998). *Java Technology: An Early History*, [html]. Sun Microsystems. Available: http://java.sun.com/features/1998/05/birthday.html [2000, 11/10/00].

Callon, M. (1986). Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieue Bay. In J. Law (Ed.), *Power, Action, and Belief* (pp. 196-233). Boston: Routledge and Kegan Paul.

Callon, M. (1986b). The Sociology of an Actor-Network: The Case of the Electric Vehicle. In M. Callon & J. Law & A. Rip (Eds.), *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World* (pp. 19-34). Basingstoke: Macmillan.

Card, S. K., English, W. K., & Burr, B. J. (1978). Evaluation of Mouse, Rate-controlled Isometric Joystick, Step Keys, and Text Keys for Text Selection on a CRT. *Ergonomics, 21*, 601-613.

Carroll, J. M. (Ed.). (1995). *Scenario-based design: Envisioning work and technology in system development*. New York: John Wiley & Sons.

Carroll, J. M. (1999). *NSF REC Project Information 1999: Leveraging Networks for Collaborative Education In The Blacksburg Electronic Village* (Grant Final Report): Virginia Tech Center for Human-Computer Interaction.

Carroll, J. M. (2001a). Scenario-based design, *McGraw-Hill 2001 Yearbook of Science and Technology*. New York: McGraw-Hill.

Carroll, J. M. (2001b). Interview by Daniel Dunlap. June 21, 2001.

Carroll, J. M. (Ed.). (2002). *Human-Computer Interaction in the New Millennium*. Reading, MA: Addison-Wesley.

Carroll, J. M., Burton, J. K., Rosson, M. B., & Shaffer, C. (1996). *Leveraging Networks for Collaborative Education in the Blacksburg Electronic Village*, [Grant award]. NSF. Available: http://www.ehr.nsf.gov/EHR/RED/NIE/awards/a9554206.htm.

Carroll, J. M., Chin, G., M.B., R., & Neale, D. C. (2000). The development of cooperation: Five years of participatory design in the virtual school, *Proceedings on Designing Interactive Systems: Processes, Practices, Methods, and Techniques* (pp. 239-251). New York: Association for Computing Machinery.

Carroll, J. M., & Rosson, M. B. (2000). *Interdisciplinary Views of the Blacksburg Electronic Village*, [Grant Proposal]. NSF.

Carroll, J. M., Rosson, M. B., Chin, G., & Koeneman, J. (1998). Requirements Development in Scenario-Based Design. *IEEE Transactions on Software Engineering, 24*(12).

Carroll, J. M., Rosson, M. B., Isenhour, P. L., Ganoe, C. H., Dunlap, D. R., Fogarty, J., Schafer, W. A., & Van Metre, C. A. (2001). Designing Our Town: MOOsburg. *International Journal of Human-Computer Studies*.

Chin, G., & Carroll, J. M. (2000). Articulating Collaboration in a Learning Community. *Behaviour & Information Technology, 19*(4), 233-245.

Chin, G., Rosson, M. B., & Carroll, J. M. (1997). *Participatory analysis: Shared development of requirements from scenarios.* Paper presented at the Proceedings of Human Factors in Computing Systems, CHI'97 Conference, New York.

Clandinin, D. J., & Connelly, F. M. (1992). Teacher as Curriculum Maker. In P. Jackson (Ed.), *Handbook of Research on Curriculum: A Project of the American Educational Research Association*. New York: Macmillan.

Clark, R. E. (1983). Reconsidering Research on Learning from Media. *Review of Educational Research, 53*(4), 445-459.

Cochran-Smith, M., & Lytle, S. (1992). *Inside/Outside: Teacher Research and Knowledge*. New York: Teachers College Press.

Cohill, A., & Kavanaugh, A. (Eds.). (2000). *Community Networks: Lessons from Blacksburg, Virginia* (Second ed.). Boston: Artech House.

Collins, H. (1981). Stages in the Empirical Programme of Relativism. *Social Studies of Science, 11*, 3 - 10.

Commerce, U. S. D. o. (1993). *The National Information Infrastructure: agenda for action* (PB93-321272). Springfield, VA: National Telecommunications and

Information Administration; U.S. Information Infrastructure Task Force; Chair: Ronald Harmon Brown.

Cook, D. W. (1986). *The Effect of Computer Use and Logo Instruction on Third and Fouth Grade Students' Perceived Control.* Unpublished Unpublished Doctoral Dissertation, Virginia Tech, Blacksburg, VA.

Cook, G. (1992). The National Research and Education Network: Whom Shall It Serve. *COOK Report on Internet*.

Cuban, L. (1986). *Teachers and Machines: The Classroom Use of Technology Since 1920*. New York: Teachers College Press.

Cuban, L. (1993). *How Teachers Taught: Constancy and Change in American Classrooms 1890 - 1990* (second ed.). New York: Longman.

Darling-Hammond, L., & Snyder, J. (1992). Curriculum Studies and the Traditions of Inquiry: The Scientific Tradition. In P. Jackson (Ed.), *Handbook of Research on Curriculum: A Project of the American Educational Research Association*. New York: Macmillan.

de Laet, M., & Mol, A. (2000). The Zimbabwe Bush Pump: Mechanics of a Fluid Technology. *Social Studies of Science, 30*(2), 225-263.

Dennett, D. (1987). *The Intentional Stance*. Cambridge: MIT Press.

Dewey, J. (1958). *Experience and Nature*. New York: Dover Publications.

Dunlap, D. R. (2000, October 26-29). *Gauging Cooperative Learning in the Virtual School: Positive Interdependence in Computer-Mediated Group Science Projects.* Paper presented at the CILT2000: Technology, Equity, and K-14 Learning, Hilton McLean Tysons Corner, VA.

Dunlap, D. R., Neale, D. C., & Carroll, J. M. (2000). Teacher Collaboration in a Networked Community. *Educational Technology and Society, 3*(3).

Ehrich, R. (1995). *Managing the Evolution of a Virtual School in the Blacksburg Electronic Village.* Paper presented at the Human Computer Interaction Consortium (HCIC) 1995.

Ehrich, R. (1996). *Testing a Network-based Approach to Home-School: Coupling in Elementary Education*, [Grant Proposal]. U.S. Department of Education. Available: http://pixel.cs.vt.edu/edu/fis/fis96.html.

Ehrich, R., & Kavanaugh, A. (2000). Managing the Evolution of a Virtual School. In A. Cohill & A. Kavanaugh (Eds.), *Community Networks: Lessons from Blacksburg, Virginia* (Second ed., pp. 143-169). Boston: Artech House.

Fitts, P. M. (1954). The Information Capacity of the Human Motor System in Contolling the Amplitude of Movement. *Journal of Experimental Psychology, 47*, 381-391.

Fuhrman, E., & Oehler, K. (1986). Discourse Analysis and Reflexivity. *Social Studies of Science, 16*, 293 - 307.

Galison, P., & Hevly, B. (Eds.). (1992). *Big Science: The Growth of Large-Scale Research*. Stanford: Stanford University Press.

Gallagher, J. J. (1967). Teacher Variation in Concept Presentation. *BSCS Newsletter*(30).

Garfinkel, H. (1967). *Studies in Ethnomethodology*. Englewood Cliffs, N.J.: Prentice-Hall.

Garrison, J. (1997). *Dewey and Eros: Wisdom and Desire in the Art of Teaching*. New York: Teachers College.

Garrison, J. W. (1995). Style and the Art of Teaching. In J. W. Garrison (Ed.), *The Educational Conversation: Closing the Gap* (pp. 41-60). New York: State University of New York Press.

Goodlad, J. I. (1984). *A Place Called School: Prospects for the Future*. New York: McGraw-Hill.

Grudin, J. (1995). Groupware and Social Dynamics: Eight Challenges for Developers. In J. G. R. M. Baecker, W. A. S. Buxton and S. Greenberg (Ed.), *Readings in Human-Computer Interaction: Toward the Year 2000* (pp. 762-774). San Francisco: Morgan Kaufmann.

Hall, G. E., Wallace, R. C. J., & Dossett, W. A. (1973). *A Developmental Conceptualization of the Adoption Process Within Educational Institutions*. Austin, TX: The University of Texas.

Hammersley, M., & Atkinson, P. (1995). *Ethnography: Principles and Practice* (2nd ed.). New York: Routledge.

Harrison, G. (1968). *While My Guitar Gently Weeps* [Song]: Apple Records.

Helmreich, S. G. (1998). *Silicon Second Nature: Culturing Artificial Life in a Digital World, Updated With a New Preface*. Berkeley: University of California Press.

Hendrix-Frye, H. (1991). *Vocational Learning Styles Inventory*. Cleveland, GA: Piney Mountain Press.

Henri, F. (1992). Computer Conferencing and Content Analysis. In A. R. Kaye (Ed.), *Collaborative learning through computer conferencing : the Najaden papers* (pp. 117-136). New York: Springer-Verlag.

Henri, F., & Rigault, C. R. (1996). Collaborative Distance Learning and Computer Conferencing. In T. T. Liao (Ed.), *Advanced educational technology : research issues and future potential*. Berlin ; New York: Springer.

Hevly, B. (1992). Reflections on Big Science and Big History. In P. Galison & B. Hevly (Eds.), *Big Science: The Growth of Large-Scale Research* (pp. 355-363). Stanford: Stanford University Press.

Hunter, M. (1967). *Theory Into Practice*. El Segundo, CA: Tip Publications.

Isenhour, P. L. (1998). *Sieve: A Java-Based Framework for Collaborative Component Composition.* Masters' Thesis, Computer Science, Virginia Tech, Blacksburg, VA.

Isenhour, P. L. (2001). Interview by Daniel Dunlap. June 11, 2001.

Isenhour, P. L. (2002). Email Interview by Daniel Dunlap. March 12, 2002.

Isenhour, P. L., Begole, J. B., Heagy, W. S., & Shaffer, C. (1997). Sieve: A Java-Based Collaborative Visualization Environment. *IEEE Visualization '97 Late Breaking Hot Topics Proceedings, October 22-24, 1997*, 13-16.

Isenhour, P. L., Carroll, J. M., Neale, D. C., Rosson, M. B., & Dunlap, D. R. (2000). The Virtual School: An integrated collaborative environment for the classroom. *Educational Technology and Society, 3*(3).

Isenhour, P. L., Rosson, M. B., & Carroll, J. M. (2000). Supporting Interactive Collaboration on the Web with CORK. *Interacting with Computers, Special Issue: Interfaces for the Active Web*(1).

Johnson, D. W., & Johnson, R. T. (1991). *Learning Together and Alone* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Johnson, D. W., & Johnson, R. T. (1992). Positive Interdependence: Key to Effective Cooperation. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interaction in Cooperative*

Groups: The Theoretical Anatomy of Group Learning (pp. 174 -199). Cambridge: Cambridge University Press.

Johnson, D. W., & Johnson, R. T. (1996). Cooperation and the Use of Technology. In D. H. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology* (pp. 1017-1045). New York: Simon & Schuster Macmillan.

Kahin, B. (Ed.). (1992). *Building Information Infrastructure*. Boston: McGraw-Hill Primis.

Kahin, B. (1992). Overview: Understanding the NREN. In B. Kahin (Ed.), *Building Information Infrastructure* (pp. 5-14). Boston: McGraw-Hill Primis.

Kavanaugh, A. (2001). Interview by Daniel Dunlap. May 30, 2001.

Kavanaugh, A., Hix, D., & Ehrich, R. (1994). *Planning for Virtual Schools in Electronic Villages*, [Grant Proposal]. NSF. Available: http://www.ehr.nsf.gov/RED/NIE/awards/a9454803.htm.

Kemmis, S., & McTaggart, R. (Eds.). (1990). *The Action Research Reader*. Victoria: Deakin University.

Koenemann, J., Carroll, J. M., Shaffer, C. A., Rosson, M. B., & Abrams, M. (1999). Designing collaborative applications for classroom use: The LiNC Project. In A. Druin (Ed.), *The design of children's technology* (pp. 99-123). San Francisco: Morgan-Kaufmann.

Latour, B. (1987). *Science in Action*. Cambridge: Harvard University Press.

Latour, B. (1988). *The Pasteurization of France*. Cambridge: Harvard University Press.

Latour, B., & Steve, W. (1986). *Laboratory Life: The Construction of Scientific Facts*. Princeton: Princeton University Press.

Laughton, S. (1996). *The design and use of Internet-mediated communication applications in education: An ethnographic study.* PhD. Dissertation, Computer Science, Virginia Tech, Blacksburg, VA.

Law, J. (Ed.). (1986). *Power, Action, and Belief*. Boston: Routledge and Kegan Paul.

Law, J. (1987). Technology and Heterogeneous Engineering: The Case of Portuguese Expansion. In W. E. Bijker & T. P. Hughes & T. J. Pinch (Eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (pp. 111-134). Cambridge: MIT Press.

Lortie, D. (1975). *Schoolteacher: A Sociological Study*. Chicago: University of Chicago Press.

Lynch, M. (1985, April 14 - 18, 1985). *Artifacts and Laboratory Research: Electron Microscopy.* Paper presented at the CHI '85 Conference on Human Factors in Computing Systems, San Francisco, CA.

MacKenzie, I. S. (1992). Fitts Law as a Research and Design Tool in Human-Computer Interaction. *Human-Computer Interaction, Lawrence Erlbaum Associates, 7*, 91-139.

May, W. T. (1993). Teachers-as-Researchers or Action Research: What is it and What Good Is It for Art Education. *Studies in Art Education, 13*(1), 114-126.

McDonald, J. (1998). Interpersonal Group Dynamics and Development in Computer Conferencing: The Rest of the Story. *Distance Learning '98. Proceedings of the Annual Conference on Distance Teaching & Learning (14th, Madison, WI, August 5-7, 1998).*

McKay, J. A. (1992). Professional Development Through Action Research. *Journal of Staff Development, 13*(1), 18-21.

Means, B., & Olson, K. (1995). Technology's Role within Constructivist Classrooms.

Meyers, B. A. (1998). A Brief History of Human Computer Interaction Technology. *ACM Interactions, 5*(2), 44-54.

National Academy of Sciences (Ed.). (1994). *Revolution in the U.S. Information Structure.*: National Academy of Sciences.

Newell, A. (1985, April 14 - 18, 1985). *Plenary Address.* Paper presented at the CHI '85 Conference on Human Factors in Computing Systems, San Francisco, CA.

Newman, D. R., Webb, B., & Cochrane, C. (1995). A content analysis method to measure critical thinking in face-to-face and computer supported group learning. *Interpersonal Computing and Technology, 3*(2), 56-77.

Noble, D., D. (1991). *The Classroom Arsenal : Military Research, Information Technology, and Public Education*. New York: Falmer.

Norwicki, S., & Strickland, B. R. (1973). A Locus of Control Scale for Children. *Journal of Consulting and Clinical Psychology, 40*(1), 148-154.

Pedretti, E., & Hodson, D. (1995). From rhetoric to action: implementing STS education through action research. *Journal of Research in Science Teaching, 32*, 463-485.

Pinch, T. (1996). The Social Construction of Technology: A Review. In R. Fox (Ed.), *Technological Change: Methods and Themes in the History of Technology* (pp. 17 - 35): Harwood Academic Publishers.

Pitt, J. C. (2000). *Thinking About Technology: Foundations of the Philosophy of Technology*. New York: Seven Bridges Press.

Polanyi, M. (1966). *The Tacit Dimension*. Garden City, N.Y: Doubleday & Co.

Price, D. d. S. (1963). *Little Science, Big Science*. New York: Columbia University Press.

Rogers, J. D. (1996). *Implementation of a National Information Infrastructure: Science and the Building of Society.* PhD Dissertation, Science and Technology Studies, VPI&SU, Blacksburg.

Roschelle, J. (1995). *What Should Collaborative Technology Be? A Perspective From Dewey and Situated*

Learning. Paper presented at the Computer Support for Collaborative Learning '95, Indiana University, Bloomington, IN.

Roschelle, J. (1996). *Video annotation and analysis tool*. Available: http://www.slip.net/~jeremy/CVideo/index.html.

Roschelle, J. (2000). Choosing and using video equipment for data collection. In A. Kelly & R. Lesh (Eds.), *Research Design in Mathematics & Science Education*. New Jersey: Lawrence Erlbaum Associates.

Rosenholtz, S. J. (1991). *Teachers' workplace : the social organization of schools*. New York: Longman.

Rosson, M. B. (2001). Interview by Daniel Dunlap. June 20, 2001.

Rosson, M. B., & Carroll, J. M. (1996). The Reuse of Uses in Smalltalk Programming. *ACM Transactions on Computer-Human Interactions, 3*(3), 219-253.

Rueda, J. (1992). Collaborative Learning in a Large Scale Computer Conferencing System. In A. R. Kaye (Ed.), *Collaborative learning through computer conferencing : the Najaden papers* (pp. 87-101). New York: Springer-Verlag.

Sabelli, N. (2001). Email Interview by Daniel Dunlap. April 24, 2001.

Schön, D. A. (1983). *The Reflective Practitioner*. New York: Basic Books.

Schön, D. A. (1987). *Educating the Reflective Practitioner*. San Francisco: Jossey-Bass Publishers.

Sears, C. (1996). *(Re)visions of the village : building and participating in the Blacksburg Electronic Village*. Masters' Thesis, Science and Technology Studies, Virginia Tech, Blacksburg, VA.

Slavin, R. E. (1987). Cooperative Learning and the Cooperative School. *Educational Leadership, 45*(4), 7-13.

Staudenmaier, J. M. (1985). *Technology's Storytellers*. Cambridge: MIT Press.

Stencel, S. (Ed.). (1995). *Networking the Classroom* (Vol. 5).

Street, J. (1992). *Politics and Technology*. New York: The Guilford Press.

Sutherland, I. E. (1963). SketchPad: A Man-Machine Graphical Communications System. *AFIPS Spring Joint Computer Conference, 23*, 329-346.

Tang, J. C., Yankelovich, N., & Begole, J. B. (2000). *ConNexus: Instant Messageing for the Workplace*.: Sun Microsystems Inc.

Traweek, S. (1985, April 14 - 18, 1985). *The Organization of Research and the Design of Research Equipment in High Energy Particle Physics.* Paper presented at the CHI '85 Conference on Human Factors in Computing Systems, San Francisco, CA.

Tyler, R. W. (1949). *Basic Principles of Curriculum and Instruction*. Chicago: University of Chicago Press.

U.S. Senate (1983). *A nation at risk: the imperative for educational reform: a report to the nation and the Secretary of Education United States Department of Education* (Senate Congressional Record, Education and Public Welfare Division 83-509 EPW, LTR83-461). Washington, D.C.: United States Dept. of Education.

Vedantham, A., & Breeden, L. (1995). Networking for K-12 Education: The Federal Perspective. *Internet Research: Electronic Networking Application and Policy, 5*(1), 29-39.

Vernon, M. K., Lazowska, E. D., & Personick, S. D. (Eds.). (1994). *R&D for the NII: Technical Challenges*. Washington, D.C.: Interuniversity Communications Council Inc. (EDUCOM).

Vygotsky, L. S. (1978). *Mind in Society*. Cambridge, MA: Harvard Press.

Walberg, H. J. (1986). What works in a nation still at risk. *Educational Leadership, 44*, 7-10.

Wild, M., & Braid, P. (1997). A model for measuring children's interactions in small groups using computers. *Journal of Computing in Childhood Education, 8*(2-3), 215-225.

Winner, L. (1986). *The Whale and the Reactor*. Chicago: University of Chicago Press.

Woolgar, S. (1991). The Turn to Technology in Social Studies of Science. *Science, Technology, and Human Values, 16*, 20-50.

Zakon, R. (2000). *Hobbes' Internet Timeline*, [Web page]. Robert Zakon. Available: http://www.isoc.org/zakon/Internet/History/HIT.html [2001, Jan 24, 2001].

Appendix A: Acronyms

AAT	Applications of Advanced Technologies (NSF)
AHS	Auburn High School
AIM	AOL Instant Messenger
AMS	Auburn Middle School
AOL	America Online
ARPA	Advanced Research Projects Agency
BEV	Blacksburg Electronic Village
BHS	Blacksburg High School
BMS	Blacksburg Middle School
CAD	Computer Aided Design
CCIT	Collaborative Critical Incident Tool
CCITT	Consultative Committee on International Telegraphy and Telephony
CERN	European Organization for Nuclear Research
CHCI	Center for Human-Computer Interaction
CILT	Center for Innovations in Learning Technologies
CISE	Computer and Information Sciences and Engineering Directorate (NSF)
CIV	Collaborative Interactive Visualization “Sieve”
CMC	Computer-Mediated Communication
CORK	Collaborative Object Replication Kit
CRLT	Collaborative Research in Learning Technologies
CRT	Cathode Ray Tube
CS	Computer Science
CSCL	Computer Supported Collaborative Learning
CSCW	Computer Supported Collaborative Work
CSNET	Computer Science NETwork
DARPA	Defense Advanced Research Projects Agency
DNS	Domain Name Servers
EHR	Education and Human Resources Directorate (NSF)
FAQ	Frequently Asked Question
FY	Fiscal Year
GOMS	Goals, Operators, Methods, and Selection
GRA	Graduate Research Assistantship
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HCIC	Human-Computer Interaction Consortium
HPCC	High Performance Computing and Communications (NSF)
HTML	Hypertext Markup Language
HTTP	HyperText Transfer Protocol
ICP	Initial Connection Protocol
IIS	Information and Intelligent Systems (NSF)
IITF	Information Infrastructure Task Force
IP	Internet Protocol
IRB	Institutional Review Board (Virginia Tech)
ISE	Industrial Systems Engineering
ISO	International Organization for Standardization
ISP	Internet Service Providers
IT	Information Technologies
ITR	Information Technology Research (NSF)
ITR/PE	People and Social Groups Interacting with Computers and Infrastructure (NSF)
JAMM	Java Applets Made Multiuser
LCD	Liquid Crystal Display
LiNC	Learning in Networked Communities
MCPS	Montgomery County Public Schools

MIT	Massachusetts Institute of Technology
MOO	MUD Object Oriented
MUD	Multi-User Dungeons/Domains/Dimensions
NASA	National Aerospace Administration
NTIA	National Telecommunications and Information Administration
NCP	Network Control Protocol
NCSA	National Center for Supercomputing Applications
NIE	Networking Infrastructure for Education (NSF)
NII	National Information Infrastructure (NSF)
NIIAC	National Information Infrastructure Advisory Council
NPL	National Physics Laboratory (Britain)
NRC	National Research Council
NREN	National Research and Education Network (NSF)
NRN	National Research Network
NSF	National Science Foundation
NSTC/CET	National Science and Technology Council's Committee on Education and Training
NTIA	Nation Telecommunications and Information Administration
NVT	Network Virtual Terminal
PARC	Palo Alto Research Center
PC	Personal Computer
PI	Principal Investigator
REC	Division of Research, Evaluation and Communication (NSF)
RFC	Requests for Comments
RPG	Role Playing Game
ROLE	Research on Learning and Education (NSF)
SCOT	Social Construction of Technology
SGML	Standard Generalized Markup Language
SRI	Stanford Research Institute
SSK	Sociology of Scientific Knowledge
SST	Social Studies of Technology
STS	Science and Technology Studies
TIIAP	Telecommunications and Information Infrastructure Assistance Program
TCP/IP	Transmission Control Protocol / Internet Protocol
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
VS	Virtual School
WWW	World Wide Web
WYSIWIS	What-You-See-Is-What-I-See

Appendix B: Related Grant Awards

Planning for Virtual Schools in Electronic Villages
NSF NIE
9454803
September 19, 1994 – August 31, 1995
Norman Dodl, Andrea Kavanaugh, Deborah Hix, Roger Ehrich
$99, 824

Leveraging Networks for Collaborative Education in the Blacksburg Electronic Village
NSF NIE
9554206
October 1, 1995 – September 30, 1998
John Carroll, John Burton, Mary Beth Rosson, Clifford Shaffer
$1,117,128 ($324,254 / $430,228 / $362,646) plus $58,000 in cost sharing from the Montgomery County Public Schools and $61,200 from Apple Computer

Supplements:

Postdoctoral Research Associate in Experimental Computer Science
NSF CISE
9625577
April 1, 1996 - March 31, 1998
J.M. Carroll; Postdoc: Juergen Koenemann
$46,200

Research Experiences for Undergraduates
NSF
REC-9641002
May 1, 1996 - April 30, 1997
John Carroll
$12,720

Research Experiences for Undergraduates
NSF
REC-9740851
May 1, 1997 - April 30, 1998
John Carroll
$22,560

Research Experiences for Undergraduates
NSF
REC-9841030
May 1, 1998 - April 30, 1999
John Carroll
$18,480

Building Community in Rural America – A Replicable Model for Community Networks
U.S. Department of Commerce: TIIAP, NTIA
October 15, 1995 – March 15, 1998
Andrew Cohill, Andrea Kavanaugh
$266,710

Internet mechanisms for collaborative learning
State Council of Higher Education for Virginia administration of federal Dwight D. Eisenhower Professional Development Program
97-0905-01
John Carroll, Juergen Koenemann, Larry Arrington
May 1, 1997 – April 30, 1998
$35,400

Testing a Network-based Approach to Home-School Coupling in Elementary Education: PCs for Families
U.S. Department of Education
CDA-9303152
September 1, 1996 – August 31, 1999
Roger Ehrich, Melissa Matusevich, Keith Rowland
$879,529

Facilitating the Community as a Learning Community
Hitachi Foundation: Role of Information Technology in Education Initiative
98-111
September 1, 1998 – August 31, 2000
John Carroll, Mary Beth Rosson
$100,000

Navy Collaborative Integrated Information Technology Initiative (NAVCIITI)
Office of Naval Research
BAA 98-014
K.L. Reifsnider (Carroll and Hix were among 13 investigators)
September 1998-September 2002
$60,000

ROLE: The School as a Knowing Organization – Knowledge Management as a Strategy for Continuous Teacher Development
NSF Research on Learning and Education
0106552
December 1, 2001 – November 30, 2004
John Carroll, Daniel Dunlap, Mary Beth Rosson, Robert McCracken,
Frederick Morton IV
$710,232

Activity Awareness in Computer-Supported Collaboration
NSF ITR/PE (IIS)
0113264
January 1, 2002 – December 31, 2003
John Carroll, Daniel Dunlap, Philip Isenhour, Donald McCrickard, Dennis Neale
$499,833

Appendix C: Surveys and Interviews

Survey Round	Administrator	Type	Semester	Year
Baseline Survey	Chin	Student	Fall	1996
Stages of Concern	Chin	Student	Fall	1996
Collaborations Before VS	Chin	Student	Spring	1997
Collaborations Before VS	Chin	Student	Fall	1997
Collaborations Before VS	Chin	Student	Spring	1998
Claims Analysis	Chin	Teacher	Summer	1998
Science/Technology Attitudes	Neale	Student	Fall	1998
Science/Technology Efficacy	Neale	Student	Fall	1998
History and Demographics	Neale	Student	Fall	1998
Science/Technology Attitudes	Neale	Student	Spring	1999
Science/Technology Efficacy	Neale	Student	Spring	1999
History and Demographics	Neale	Student	Spring	1999
Short-term Activity	Neale	Student	Fall	1999
Lego Project Activity	Neale	Student	Spring	2000

Interview Round	Administrator	Type	Semester	Year
General Practices	Chin	Teacher	Spring	1997
Collaborations Before VS	Neale	Teacher	Spring	1998
Outcomes Assessment	Neale	Teacher	Fall	1998
Collaboration	Dunlap	Teacher	Fall	1998
Long Term Projects (Email)	Dunlap	Teacher	Spring	1999
Large Interview	Neale	Student	Spring	1998
Fall Activity	Neale	Student	Fall	1998
Pros and Cons of VS	Dunlap/Neale	Student	Spring	1999
Long-Term Projects	Dunlap/Neale	Student	Spring	1999
Lego Projects	Dunlap	Student	Spring	2000

Vita

Daniel R. Dunlap

B.A. Philosophy, Virginia Tech, 1987
M.S. Science and Technology Studies, Virginia Tech, 1995

Appointments

Research Associate, Center for HCI, Virginia Tech, 1998 – present.
NSF Graduate Research Traineeship, Virginia Tech, August 2000 – December 2001.
Graduate Assistantship, Interdisciplinary Studies, Virginia Tech 1993 – 1997.
Graduate Student Representative, IDST Curriculum Committee, Virginia Tech, 1995.
Instructor/Supervisor, Virginia Tech
  IDST 3114 (Fall 1998); EDCI 2114 (Fall 1995,6, and 7); EDCI 4964 (Spring 1996-8)
Co-Instructor, STS Ethnographic Research Methods: Virginia Tech (Fall 1996)
Science and Mathematics Teacher, Montgomery County Public Schools 1987-1991

Publications / Presentations

Carroll, J. M., Rosson, M. B., Isenhour, P., Ganoe, C., Dunlap, D., Fogarty, J., Schafer, W., & Metre, C. V. 2001. Designing Our Town: MOOsburg. International Journal of Human-Computer Studies (54). Dunlap, D., Neale, D.C. & Carroll, J.M. 2000. Teacher collaboration in a networked community. Educational Technology & Society, Special Issue on "On-Line Collaborative Learning Environments".

Neale, D.C., Dunlap, D.R. & Carroll, J.M. 2000. Collaborative critical incident development. 40th annual meeting of the Human Factors and Ergonomics Society, Santa Monica, CA, Human Factors and Ergonomics Society.

Isenhour, P.L., Carroll, J.M., Neale, D.C., & Dunlap, D. R. 2000. The Virtual School: An integrated collaborative environment for the classroom. Educational Technology & Society, Special Issue on "On-Line Collaborative Learning Environments".

Carroll, J.M., Rosson, M.B., Neale, D.C., Isenhour, P.L., Dunlap, D., et al. 2000. The LiNC Project: Learning in Networked Communities. Learning Technology, 2(1), http://lttf.ieee.org/learn_tech/issues/january2000/, ISSN 1438-0625.

Gauging Cooperative Learning in the Virtual School: Positive Interdependence in Computer-Mediated Group Science Projects. Presented at CILT2000: Technology, Equity, and K-14 Learning, Hilton McLean, VA., Oct. 26-29, 2000.

Minds on Science Activities. Presented at the National Science Teachers Association Conference, Boston, March 26, 1999

Dunlap, D.R. 1998. Scientific Learnings. Science as Culture, 7(1). Book Review.

Reeves, B.J. & Dunlap, D.R. 1996. Science Literacy Theories as Ethical Theories. Pp. 23-29 in Proceedings of the Eleventh National Technological Literacy Conference (National Association for Science, Technology and Society Annual Meeting), Arlington, VA, February 8-11, 1996. (Eds.) D. W. Cheek and K. A. Cheek. Bloomington, Ind.: ERIC Clearinghouse for Social Studies/Social Science Education.

Contributing author: LaPorte, J.E. & Sanders, M.E. (1995). Technology, Science, Mathematics Connection Activities. Lake Forest, Ill: Glenco.

Research Activity

Investigator, NSF Grant: *ITR/PE(IIS): Activity Awareness in Computer-Supported Collaboration.* Award # 0113264.

Investigator, NSF Grant: *ROLE: The school as a knowing organization - Knowledge management as a strategy for continuous teacher development.* Award # 0106552.

Investigator, NSF Grant: *ITR: Interdisciplinary Views of the Blacksburg Electronic Village.* Award # 0080864.