NORTHWESTERN UNIVERSITY

Engaging Science Practice Through Science Practitioners: Design Experiments in K-12 Telementoring

A DISSERTATION

SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

for the degree

DOCTOR OF PHILOSOPHY

Field of Learning Sciences

by
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Evanston, Illinois
June, 1998

Acknowledgments

I dedicate this work to all those who have prepared me, inspired me, encouraged and supported me in it. I cannot mention you all here, but I will mention a few.

To Laura D'Amico, my constant companion, guide, and partner. You help me to find joy in life, goodness in people, and faith in myself.

To Rory Wagner and Judith Lachance-Whitcomb, from whom I have learned so much about the noble and unappreciated profession of teaching. I count myself fortunate to be among your students.

To the many students who participated in this research with patience, curiosity and enthusiasm. I hope it does you justice.

To the many volunteer scientists who continue to support efforts to improve science teaching through telementoring. Our students thank you, and I thank you.

To my parents, Garry and Idris O'Neill, and my sister Laura, whose unflagging support has preserved me from despair, foolishness and poverty more often than I care to remember.

To my new family, especially Frank, Joyce, Kat, Michael, Sal and Trina. I look forward to a long life in your good company.

To all my mentors, especially Louis Gomez and John Mitterer. I can aspire to nothing better than to honor your work with my own.

To the members of my dissertation committee, including Richard Beckwith, Allan Collins, Danny Edelson and Roy Pea, who generously shared their insights and dispensed much-needed advice throughout this project. Your thoughtfulness, frankness and comradeship have no substitute.

To my friends and compatriots of the Learning Sciences Ph.D. program and the CoVis project at Northwestern University: especially Brian Smith, Joe Polman and Joey Gray. Your humor and commitment to your crafts have sustained me through the most difficult parts of this journey.

To the professors and students of the Liberal Studies Program at Brock University, who were my first and best teachers in the meaning of scholarship. Without your dedication, I would have been ill prepared for this task.

To Lyman Casey, who assisted me in thinking through and implementing the CoVis Mentor Database, and taught me a lot about Perl and SQL.

Last of all, to the staff and proprietors of several excellent cafes in which I became a regular in the course of this work: the Unicorn in Evanston, Illinois (try their double mocha); Kaffien, also in Evanston (they serve an incomparable mocha shake); the Blue Moon cafe in Neenah, Wisconsin (best coffee within a hundred miles); Chat in St. Catharines, Ontario, Canada (does the city deserve you?); and Copeland Court Coffee in Pittsburgh, Pennsylvania. Cheers!

Notes on the text

In a report such as this, which takes written communication as data, the researcher always faces a choice: to correct, or not to correct? In the following pages I have elected not to touch up any errors in spelling or grammar that I found in the e-mail communications or written reports I took as data. I have placed myself foursquare in the "no correction" camp because in many cases, altering students' and telementors' original text would misrepresent the academic abilities of the students involved, and the formality or informality of the exchanges between them and volunteer scientists. In both cases, I believe correction would not serve my readership.

Another general issue for research of this type is the preservation of anonymity. In all instances, the names of students and volunteer telementors which occur in the text have been changed to preserve their anonymity. Two important exceptions to this rule are the teachers who collaborated with me in this work, Rory Wagner and Judith Lachance-Whitcomb. Their names appear here with their express consent.

One final note is necessary on the vocabulary I have used to describe e-mail-based relationships between students and volunteer scientists. The traditional word for a mentor's young counterpart, "protégé", carries connotations of personal devotion which are often inappropriate to describe the relationships I will discuss here. To avoid these connotations where they seemed inappropriate, I have used the less-traditional term, "mentee".

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Chapter 1

Preamble: An Ambition for K-12 networking

In 1915 the father of the progressive education movement, John Dewey, complained that American schools often attempted to force the accumulated knowledge of adults upon children who had no need for it, and were unable to assimilate it. He argued that this tendency reflected a fundamental error on the part of educators to understand learning:

> Probably the greatest and commonest mistake that we all make is to forget that learning is a necessary incident of dealing with real situations. We even go so far as to assume that the mind is naturally averse to learning — which is like assuming that the digestive organs are averse to food and have either to be coaxed or bullied into having anything to do with it. (Dewey, 1915, p. 4).

Despite enormous change in public education in North America, much of it positive (Bracey, 1991), the Deweys' criticism remains largely valid today. Moreover, school curricula and activities which are professedly aimed at preparing students for the contingencies of adult life often have little apparent relation to them. This segregation of the events in schools from those outside has wide-ranging implications for students' attitudes toward school, and for what they learn. In this chapter, some of the implications for science education will be explored, and one path to a solution will be proposed.

The chapters that follow will report on a series of unique educational design experiments (Hawkins and Collins 1997) that I conducted between 1994 and 1997 in partnership with two Chicago-area teachers: Rory Wagner, an Earth Science teacher at New Trier High in suburban Winnetka, and Judith Lachance-Whitcomb, a middle school general science teacher at Jordan Community School in Chicago. The purpose of these experiments, carried out as part of a National Science Foundation project called CoVis (Pea, 1993, May), was to design and test practical ways for volunteer scientists to become routinely involved in the daily work of students, using the Internet services newly available in schools. Volunteers from various walks of academia, industry and government took on the role of research mentors, providing a supportive and critical external audience for students' research in school. The primary purpose of this dissertation was to investigate and develop the potential for these sorts of relationships to support and enhance project-based science learning (Ruopp, Gal, Drayton & Pfister, 1993) on a large scale.

My collaborators and I believe that this approach to connecting the worlds of school and adult practice, which I refer to as "telementoring" (mentoring over a distance), has great potential to support the growth of innovative pedagogies that demand intellectual resources not commonly available in classrooms. Equally important, telementoring relationships have the potential to alter the educational experiences of students in unique ways by engaging them in productive work with adults whom they would not otherwise meet. The ideal outcome of these relationships, in my view, would be what Dewey (1899, p. 179) described as "a real intellectual and moral division of labor....not only the friction of mind, but the contagion of mind with mind": strong relationships that would motivate, inform and influence students’ aspirations to learn and their later career choices.

Mentoring relationships are known to occur across diverse settings (school, corporate, academic, etc.) and their production has historically been the target of a great deal of institutional and personal effort (see discussions in (Jacobi, 1991; Kram, 1985; Noe, 1988; Rhodes, 1994)). Unfortunately, in the field of education, most of this effort has not been put forward in the interest of reform-oriented pedagogy but of teacher training (e.g. (Dodge, 1994; Wighton, 1993)) or violence and dropout prevention (e.g. (Green, 1993); (Hill, 1993); (Hunter, 1994; Rhodes, 1994; Tomlin, 1994)). Traditionally, school-based mentoring programs have been quite limited in scope, largely as a result of the dislocation they cause in volunteer mentors' work lives. Breaking away from the office for hours at a time to visit schools is not something that many managers will allow their workers to do regularly. The rapid expansion of the Internet into businesses, schools and homes across

North America has created the opportunity for a vast new intellectual volunteer force to be mobilized. However, there is a great deal to be learned before we can tap it.

The vision I will describe in this chapter is quite different from that which many researchers and developers have for the Internet in K-12 education. Many educational networking enthusiasts think of the Internet primarily as a medium for delivering new learning resources to classrooms in electronic form: for example, very recent texts, data sets, multimedia documents or software. In this camp, enthusiasm centers around the Internet's ability to overcome the traditional paper publication lag time, traditional publication costs, or the inconvenience of visiting the library. In contrast, the camp to which I belong sees the Internet's greatest value as a bridge between people, institutions and work routines. Here, enthusiasm centers around the potential to make new kinds of human influences and relationships possible in schools: to bridge communities of discourse and practice which have traditionally been isolated from each other. The ultimate extension of this idea is a network-based "knowledge society" (Scardamalia & Bereiter, 1996) in which students and researchers at all levels participate together in learning.

There are, of course, a host of social and institutional hurdles to be leapt on the way to realizing this ideal of the networked knowledge society. Educational historians recall that the promise of more widely distributed expertise was also made in reference to radio, film and television when they were fledgling technologies; yet each failed to fundamentally alter the insular nature of the North American classroom (Cuban, 1986). The naive techno-romantic might argue that all that was missing from these earlier technologies was interactivity: if they had permitted two-way transmission rather than simply one-way, they might have been greater successes. However, accounts such as Cuban's suggest that the largest obstacles to the widespread use of these technologies were social and institutional rather than technical. To fully realize the Internet's potential for educational change, research needs to develop an understanding of these obstacles.

With this in mind, part of the research reported here was directed at identifying social and institutional barriers that might prevent the promise of telementoring from being realized. Two important foci of my work with Wagner and Whitcomb were the development of practical classroom activity structures and network services that would be necessary to guide and support telementoring on a large scale, and in the long term. Our work in these areas will be described in Chapters 2, 7 and 8. Of course, knowing how to carry off telementoring on a large scale would be of little import if it could not be shown that students learn something valuable from it. To address this issue I have drawn upon research in traditional mentoring and the sociology of science to study the varying nature of students' relationships with their telementors and the influence of these relationships on students' performance in one arena of scientific discourse: written arguments about scientific research. This constellation of issues was one that my collaborators were concerned and curious about in their own teaching practice, but did not have the luxury of time to explore themselves. This portion of my research will be discussed in Chapter 7.

Research of the sort I have embarked on here touches upon a host of issues that in the end cannot be fully explored here. If asked what the essential message of this work is, I would say the following. Telementoring holds great promise as a means of helping teachers, students and researchers realize pedagogical reform in science, and in other curricular areas. The greatest challenge to making curriculum-based telementoring fruitful on a large scale, and on an ongoing basis, is to help volunteers to serve as a responsive *audience* for students’ work, rather than simply a source of “help”, at their beckon call. I believe this can be done, and in the following pages will begin to show how.

Abandoning Coverage, Engaging Practice: How Telementoring can Improve Science Education

> Now, all principles by themselves are abstract. They become concrete only in the consequences which result from their application. Just because the principles set forth are so far-reaching, everything depends upon the interpretation given to them as they are put into practice in the school and the home. (Dewey, 1938), p. 20)

In this Chapter, I will lay out an argument against traditional approaches to scientific literacy based on the coverage of an ever-increasing body of scientific content. In opposition to this self-defeating uphill struggle, I propose an approach based on the idea of making students more familiar with scientific *practice.* In my conception, this approach strives to provide students with experiences through which they can construct personal understandings of how and why practitioners of science produce and defend knowledge-claims before a critical audience. In the implementations I have developed with my collaborating teachers, this audience includes volunteer telementors.

Some of my readership may feel that the argument presented in this Chapter is neither necessary nor interesting; but I believe it is both. For while the idea of scientists mentoring students at a distance is simple and appealing, in practice it faces a variety of practical and intellectual problems. In the abstract, it may be thought that knowledgeable volunteers could add value to any curriculum related to their expertise; but unfortunately my experience suggests otherwise. When the curriculum that organizes students' and teachers' time does not give them freedom and incentives to spend longer on single “topics” than is the norm, and when that curriculum and its supporting materials are formulated to make the classroom entirely self-reliant, a distant expert is incapable of being very helpful to students. In this context, telementors are relegated to the role of helping students to interpret their textbooks: an activity for which they are quite unlikely to volunteer more than once.

I will not bother to argue that science curricula should be turned inside-out simply to provide an opportunity for volunteer scientists to chat with students on-line. The necessary changes are too extensive and too difficult to be justified on this basis alone. There are, however, several other strong reasons to change the way that science is taught in our schools, and telementoring can help us to accomplish those changes.

Many Students Don’t "get" Science

While there continues to be considerable debate over what the purposes of science education are, and ought to be (e.g. (Pitt, 1990), (Shamos, 1995), I would argue that much of the science curriculum currently acted out in North American classrooms is based on the notion of “making students familiar with” science. There can be little other explanation for curricula that overwhelmingly emphasize breadth of coverage over deep knowledge. The motivations to take this approach are understandable enough: while we cannot expect all of our students to become scientists (in fact, only 5-10% of high school students in the U.S. will major in science), we would like them all to appreciate some amount of what modern science has discovered about the world in which we live, and how this was done. At least some teachers, administrators and parents believe that this breadth of knowledge is important for citizens to be able to participate in public policy debates and to vote responsibly. Those who no longer hold to such democratic ideals may still believe that it is important (perhaps more important) to "turn students on to science" and encourage them to study it at the university level, in order to support national economic prosperity (Pearson & Fechter, 1994). In this view, we must ensure a steady supply of young scientists by teaching all students a little about a broad spectrum of scientific topics and methods.

This objective of general familiarity leads teachers and administrators to develop a survey approach to science education, in which students learn just a little about an enormous range of topics, each of which constitutes a major subspecialty in the world of adult science. In the typical 8th-grade general science course, for instance, students might study electricity and magnetism for three weeks, heat and energy for two, and simple machines for another two. Despite the best efforts of teachers to help students link their understandings across these domains, students' knowledge becomes compartmental and inert: the natural consequence of units taught, tested, and forgotten in turn. This mode of science learning is something like touring a country by airplane: passing over historic buildings, monuments, homes and roads in seconds. Naturally, one can learn very little this way about what makes Germany different from France or England or Holland. This is science at ninety miles an hour.

According to reports from the Third International Mathematics and Science Study (TIMSS), which compares student achievement in science and mathematics in 50 countries, the aerial-survey approach to science weakens academic achievement in the U.S. relative to other countries. Nations that spend far less per capita on science teaching are, at least by TIMSS' criterion, able to teach far better because they opt to teach less (Schmidt, McKnight & Raizen, 1997). By comparison to those of other countries, U.S. science curricula are, in the words of one report, "a mile wide and an inch deep" (Vogel, 1996, October). This seems to be the case because each year of curriculum committee meetings brings an accretion of new topics which are considered a "must" for students to touch upon, but no additional curriculum time in which to teach and master them.

This ambition of complete coverage inevitably leads to embarrassing failures. Periodic news reports attempt to shock us with what young students and their parents do not know about science. For example, a 1995 NSF report exposed the fact that fewer than 10% of adults could describe a molecule beyond noting that it was small, only 20% could even minimally define DNA, and slightly fewer than half know that Earth rotates around the sun once a year (Science News, 1996). Should we respond to such reports by cringing and wringing our hands in shame? I think not, unless we direct our shame at the teach-test-forget pedagogy that makes it so difficult for students to acquire and retain science content. As the TIMSS results suggest, teaching more may turn out to be teaching less; especially since what passes for science education under the rubric of general familiarity will inevitably grow more vacuous with each passing year.

In *The Myth of Scientific Literacy* (Shamos, 1995) , Shamos argues that given how little adults retain of their schooling in science, the common brand of science education is a foolish way to attempt to create widespread scientific literacy:

> However one chooses to define scientific literacy, its objective seems clear enough: society (and the individual) will somehow benefit if its members are sufficiently literate to participate intelligently in science-based societal issues. Assuming this is true, and on the surface it seems perfectly sensible, is the proper target audience the student or the adult population? ...while students may attain some level of scientific literacy relating to the individual science courses they take in school, what good is it if they fail to retain this knowledge into adulthood? (Shamos 1995, p. 74)

Shamos' statement is an eerie echo of Rousseau's over a century before:

> Try to teach a child what is of use to him as a child and you will find that it takes all of his time. Why urge him to the studies of an age he may never reach, to the neglect of those studies which meet his present needs? But, you ask, will it not be too late to learn what he ought to know when the time comes to use it? I cannot tell. But this I know; it is impossible to teach it sooner, for our real teachers are experience and emotion, and adult man will never learn what befits him except under his own conditions (Rousseau, quoted in Dewey and Dewey 1915. pp. 3-4).

In what follows I will argue that what is more scandalous than students' lack of knowledge of specific science content or process is their lack of understanding of scientific *practice*: that is, why scientific research is done and how it is accomplished, not only in the sense that we attempt to teach via hands-on work with materials and instruments, but also in a broader sense relating to the defense of knowledge-claims about the natural world in a community of critical minds. An enormous amount of purposeful human activity surrounds the stereotypical white-smocked researcher in the science lab, without whom what we know as science could not be done. This part of science not only has important implications for those who choose to study and practice science at advanced levels, but has more direct contact with citizens through public policy debates and the popular press. Students know astoundingly little about this, either.

Not Getting Scientific Practice

High school students' ignorance about the nature and motives of scientific research began to come clear to me a few years ago while I was administering a set of surveys in a high school Earth and Space Science class participating in the CoVis project. In casual conversations, my young research subjects betrayed complete disbelief that I, or anybody else for that matter, would bother to read, code, and analyze these surveys. What could we possibly get out of this tedium, they wondered? Through no fault of their own, most of them were incapable of imagining. Year after year of classroom research further broadened and reinforced my impression that these students fundamentally lacked an understanding of empirical research.

We do not, however, need to rely on anecdotal experiences to persuade us of what little students understand about scientific practice, and the failure of traditional science instruction to help them learn about it. In a large-sample survey using a unique instrument called VOSTS (Views on Science-Technology-Society), (Aikenhead & Ryan, 1992) demonstrated that high school graduates in Canada thought of science largely in terms of specific content or processes studied in school, rather than as the large-scale social and institutional enterprise that it is. These graduates' views of what constituted "science" were also confused and confounded with the technological products built upon scientific research. We may ask, is this the most societally useful impression of science for nonscientist adults to have? Does it, for instance, give voters a useful grasp on the research enterprises fueled by their tax dollars and, supposedly, serving their interests?

I think the answers to both of those questions are no; but putting them aside for the moment, we may equally well ask how such restricted views of the scientific enterprise serve the small number of students who will choose to pursue careers in science. A new CoVis teacher in 1994 was wondering this himself when he made a series of postings to Internet newsgroups frequented by geoscientists, asking simply, "what do scientists do?" He prefaced his question by stating that he was a high school teacher who was attempting to involve his students in "real science" by conducting long-term projects in his class. The following quotations are from e-mail responses that he received from practicing scientists:

> I really like your idea of having students do "real science" so long as it is presented in a realistic way. Unfortunately the popular ideas of science are pretty far off base. For example there is an incredible amount of "grunt work" that has to be done before even small discoveries are made, let alone big discoveries. There are also lots of blind alleys that get trodden. Politicians love to pounce on these things as wasteful but real science really does plod at a slow pace, and it is incredibly honest. Scientists must look at any ways in which their ideas might be wrong. They have to do this themselves, AND expect that their colleagues will do the same, not because they are vicious, but because that is what science is all about.
>
> Good Luck, and that's a great idea!!

Scientific Practice and Research Genres

This message is instructive because it makes clear that the construction of scientific findings is not a solo rational enterprise proceeding toward a certain goal; rather, it involves much uncertainty and wasted effort which are examined and judged through continuous public or semi-public debate. The traditional lecture, lab and demo approach to science education, which is streamlined to expose students to as many scientific findings, principles and methods as possible in the shortest space of time, systematically obscures these unproductive and argumentative elements of the scientific enterprise.

Another response to the teacher's Usenet posting from a volcanologist further emphasizes the prominence of oral and written argument in scientific practice. This message is uniquely useful in the way that it estimates the relative amounts of time the scientist spends on various activities. Note that most of the professional activities listed above, and the majority of the researcher's time, involve either the production or the review of written arguments about research findings. No doubt, these activities necessitate a great deal of thinking about what science teachers would, in their work context, call "content"; but this thinking is driven by the need to understand arguments made about natural phenomena in a professional community; to persuade or to be persuaded in social situations that honor and demand it:

> I am a physical volcanologist, and I spend my time looking at physical processes in volcanic flows and volcanoes.
>
> Daily Activities (intermingled)...
>
> - I spend a few weeks a year in the University Library on background research, reading and copying recent and historic articles from research journals.
> - I spend a few weeks a year at national meetings presenting results, and discussing current research and possible collaborations with other scientists.
> - I spend a few weeks a year (total) on various seminar presentations in my department and at other institutions presenting detailed descriptions of current research.
> - I spend a few months a year writing up results in either journal paper form or presentation form. (this is all on a computer and includes tasks like drawing figures and diagrams, typesetting equations, processing NASA images for figures, typing text, and shooting slides of it all)
> - I spend about a month each year with collaborators discussing, researching, and writing proposals for future research.
> - I spend a few weeks to a month each year reviewing papers and proposals from other scientists (peer review).
> - I spend a few weeks each year reading current articles and books on my research area.
> - Every few years, I visit an active volcano for some field work observations. A few weeks every year are spent reviewing satellite data for both terrestrial and planetary volcanoes.
> - I spend a varying amount of time teaching and preparing for teaching a variety of people about my field of work (high school students, teachers, college students).
> - I spend the rest of my time solving fluid dynamics problems analytically (paper and pencil and integral tables), plotting simple solutions to the equations on a computer, and programming computers to work out more complex solutions. This is done almost exclusively on various computers using either existing software or writing my own.
>
> I'd be happy to talk to students via e-mail. I love this field.

The acts of persuasion and evaluation that occupy most of this researcher's time in reviewing or writing up research findings are integral parts of a large, institutionalized process which (Suppe, 1995) refers to as the "credentialing" of scientific claims. This is the process through which scientists' claims are integrated into a public body of knowledge which is more or less "tried and true". Below I will argue that current science education ignores these important processes almost completely, though a knowledge of them would likely be more useful to the general public than a great breadth of content knowledge that is easily and quickly forgotten.

Despite its great diversity, one thing that all professional science has in common is the production and defense of knowledge-claims about the natural world, usually in written form. For scientists to be involved and to remain involved in the scientific enterprise requires the regular construction and defense of new knowledge-claims in a small variety of customary forms, including the research article and the grant proposal (Berkenkotter & Huckin, 1995).

Because the work of most scientific labs revolves around securing grant money in order to continue costly research and train new researchers (Dickson, 1984), written defenses of knowledge claims come to serve as a kind of currency (Latour & Woolgar, 1979), (Myers, 1990). Knowing that this is the case, mature scientists strategize about their work with consideration to the form in which they must eventually present it, to whom they must present it, and how that audience is likely to respond (see accounts in (Bazerman, 1988) and (Myers, 1990)). Professionals-in-training become full professionals through a gradual process of greater and more central involvement in this enterprise.

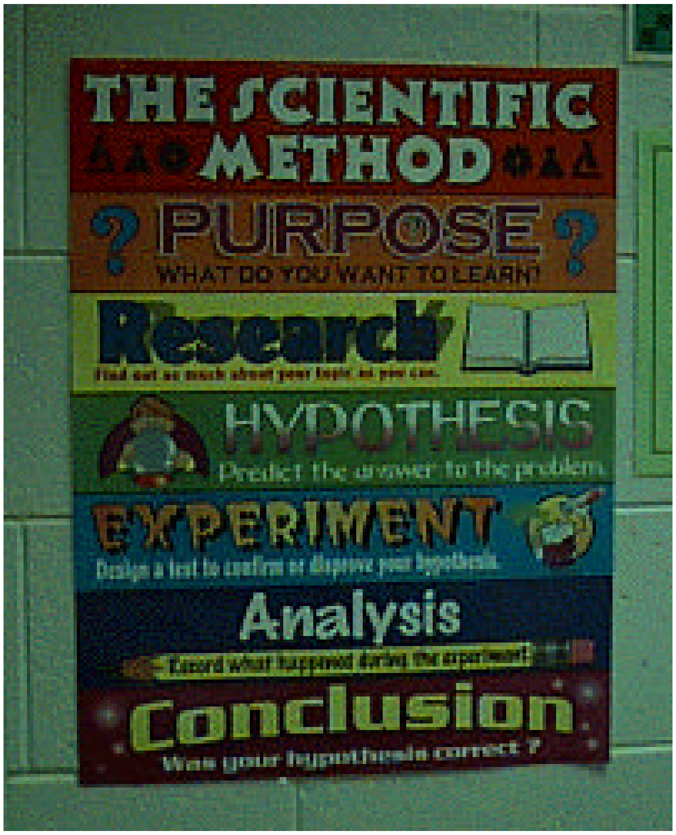
Because the conduct of research is so strongly influenced by the norms of reporting and the shape and concerns of audiences, the customary genres of scientific research are a critical element in understanding it. Because science teachers have known this for some time, they have a long tradition of using genres of writing that mimic those of professional science to structure activity and assessment in the classroom. (Sutton, 1989) provides a comparison of guidelines provided to students for writing up labs as far back as 1898:

> Looking into the origins of this pattern of writing...it is very interesting to see the variation in the flexibility allowed, and in how much emphasis is placed on the preliminary statement of ideas. One extreme may be represented by C.B. Owen of Stowe School in his *Methods for Science Masters* (1956). He offered the mnemonic: High Powered Motors Often Crash, to trigger recall of the need for Heading, Picture, Method, Observations and Conclusion....MacNair (1904) suggested: ‘The Object Aimed At’, ‘What Was Done’, ‘What Was Seen’ and ‘What the Result Proved’....A.G. Hughes (1933) advocated the headings ‘Purpose’, ‘Apparatus’, ‘Observation’, ‘Inference’.... He stressed the importance of discussion before practical work to clarify its purpose.... ((Sutton, 1989), p. 139)

Clearly, each of these sets of guidelines reflects different ideas about the purposes behind students' imitation of adult scientific practice. In the course of his review, Sutton characterizes two general classes of guidelines among those he observed: those that depict science as a regimen of careful recording ("Science as 'Describing What Happens'"), and those that depict science as a regimen of withholding judgment until all the data are in ("Science as 'Data First and Theory Later'"). Both classes of guidelines send particular messages to students about the nature of scientific practice, as indeed such guidelines do in the world of adult professional practice (Bazerman 1988, Chap. 9 discusses the messages of the APA guidelines). In effect, these guidelines emphasize different sets of rhetorical problems for authors and identify different genres through which solutions to those problems can be developed.

Lest there be any doubt, educators still develop and use a variety of guidelines for science writing. The poster shown in Figure 1 was observed in a middle school science classroom in 1996. In it you will notice some similarities to the guidelines Sutton describes above, though I might argue that this poster presents a more inclusive view of scientific practice. Unlike most of Sutton's examples, it does not focus narrowly on the act of observation, and actually encourages students to generate hypotheses *before* the outcome of an experiment is known.

However, it has its own flaws. Through its illustrations, the poster actually mystifies the process of hypothesis-generation (which it pictures as a child gazing into a crystal ball), and encourages the idea that "research" is something bookish, done in the library alone. By placing Research in order after Purpose, it also obscures the possibility that the Purpose of an investigation might emerge out of *reading* something (such as a peer's research). In itself this does considerable violence to the idea of a scientific community and obscures the relationship between genres of reporting and the conduct of research. Finally, like Sutton's examples, this poster continues to give preferential place to experimental protocol in the development of scientific knowledge. In fact, a great deal of scientific practice does not involve much laboratory experimentation (for instance Astronomy, Atmospheric Science, Botany, or Ecology).



The captions to the sections read:
"Purpose: What do you want to learn?"
"Research: Find out what other people know..."
"Hypothesis: Predict the answer to the problem"
"Experiment: Design a test to confirm or disprove your hypothesis"
"Analysis: Record what happened during the experiment"
"Conclusion: Was your hypothesis correct?"

Figure 1: "Scientific Method" poster observed in a middle school science classroom

Appropriating Research Genres in the Classroom

> The student has to appropriate (or be appropriated by) a specialized discourse, and he has to do this as though he were easily and comfortably one with his audience, as though he were a member of the academy or an historian or an anthropologist or an economist; ...He must learn to speak our language. Or he must dare to speak it or to carry off the bluff, since speaking and writing will most certainly be required long before the skill is "learned." (Bartholomae, 1985)

Bartholomae's words provoke us to consider what students are being asked to do when their teacher assigns them to write a scientific research article, and how they view this task. This sort of article, which contains sections labeled Introduction, Methods, Results, and Conclusions, in that order, is an instance of the genre in which much of the archival knowledge of Physics, Chemistry, Biology, Psychology, and other experimental sciences is presented. If this mimicry serves a purpose, it is presumably to link the students' classroom experience with the wider sphere of scientific practice: to give them a sense, however indirect, of what it is that professional scientists do.

Some adherents of the philosophy of science may object that customary reports of scientific research present a falsified, or "cleaned up" version of the research process which conceals false starts and the guidance of a researcher's intuition (Merton, 1973). While this may be true, I do not believe it is damning. The methods and customs of "doing" science are, in the end, no more or less important than the methods and customs of reporting it. As Bartholomae and Myers have shown, the two go hand in glove, and one is indispensable to the other. Perhaps this is why, despite the many doubts that new students in Wagner's project-based science class may have about the work they are asked to do, I have not met one yet who doubted the sense of writing a report. With surprising frequency, students even see the utility of this task in helping them climb out of the chaotic activity of carrying out their research, and focus their attention on persuading others that it was done well. Here is one example from an interview with one of Wagner's students:

> Student: (referring to writing his research report) I like that.
> O'Neill: (surprised) You like it?
> Student: Well I like it because it's HARD! When we were writing the paper, everyone would be like, "what's our Abstract?" It's like, "where's the Method and Results?" And you've got to take all that chaos [the work you've been doing]...(makes a grasping motion with his hands) and fit it into this! (pushes the chaos into an imagined reporting structure in front of him) Instead of just doing basically a paper of the Conclusion, which we might have just done!

As Bartholomae suggested in the quotation at the top of this section, writing discipline-appropriate pieces requires students to reconcile themselves with a tradition, and as it happens, the scientific research article has quite a long one. This tradition began in 1665 with the first issue of the *Philosophic Transactions of the Royal Society of London*. Charles Bazerman, who has studied the emergence of the experimental report genre through the issues of the *Transactions* from 1665 to 1800, provides us with a useful description of what a genre is and how it influences the writer's task:

> A genre is a socially recognized, repeated strategy for achieving similar goals in situations socially perceived as being similar. A genre provides a writer with a way of formulating responses in certain circumstances and a reader a way of recognizing the kind of message being transmitted.... Thus the formal features that are shared by the corpus of texts in a genre and by which we usually recognize a text's inclusion in a genre, are the linguistic/symbolic solution to a problem in social interaction. (Bazerman 1988, p. 62)

It follows from this definition of a genre that it is, inevitably, situated in a particular discourse community. Since it emerges from a community in response to its own recurring needs, it is not portable in any straightforward way to communities whose problems differ much. That students have trouble in appropriating the genre of the research article, should hardly surprise us then, given that the genre has emerged from a social and institutional setting that is dramatically different from that of the typical North American classroom. In this vein, (Freedman, 1993) has argued that

> ...the "internal dynamic"...of a genre can be learned only within the relevant context. That is, as social actions governed by social motives within recurrent socially-constructed contexts, genres can only be learned when that social motive is

> experienced by the rhetor; and that experiencing can only take place within the relevant context. (Freedman 1993, p. 273)

Just how different are the rhetorical contexts in which students and scientists report their work? In the world of scientific research, articles are part of a continuous "cycle of credit" (Latour and Woolgar 1986) that connects published, "credentialed" (Suppe, 1995) knowledge claims to grants of money and other resources. Figure 2 is Berkenkotter and Huckin's (Berkenkotter & Huckin, 1995), p. 62 depiction of the cycle of credit in the sciences. In this larger context, practitioners must be concerned to present clean, concise and persuasive accounts of their findings. These accounts must be crafted to convince first the reviewers, and then the wider audience of a scholarly journal, that the researchers have made unique contributions to the knowledge of the field. However, these contributions must nonetheless be continuous with and built upon the work of previous researchers in order to gain favor and have credibility[1].

In this way, genres effect not only *how* research is reported, but in the end, *what* research (or what aspects of it) gets reported and, perhaps, whether it gets done at all. If the "mold" laid out by publishers and review panels does not put a piece of research in its best light, the implication is that this research does not follow the prevailing view of worthwhile research in a given field or specialization. In this way, genre customs serve as one of many gatekeepers to public venues in professional spheres. They thus effect how, in Nespor's (Nespor, 1994) term, research can be "mobilized" from the lab into other contexts.

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[1] An insightful account of this rhetorical tightrope-walking is provided by Greg Myers (1990) through his examination of multiple drafts of biologists' grant proposals and research articles.

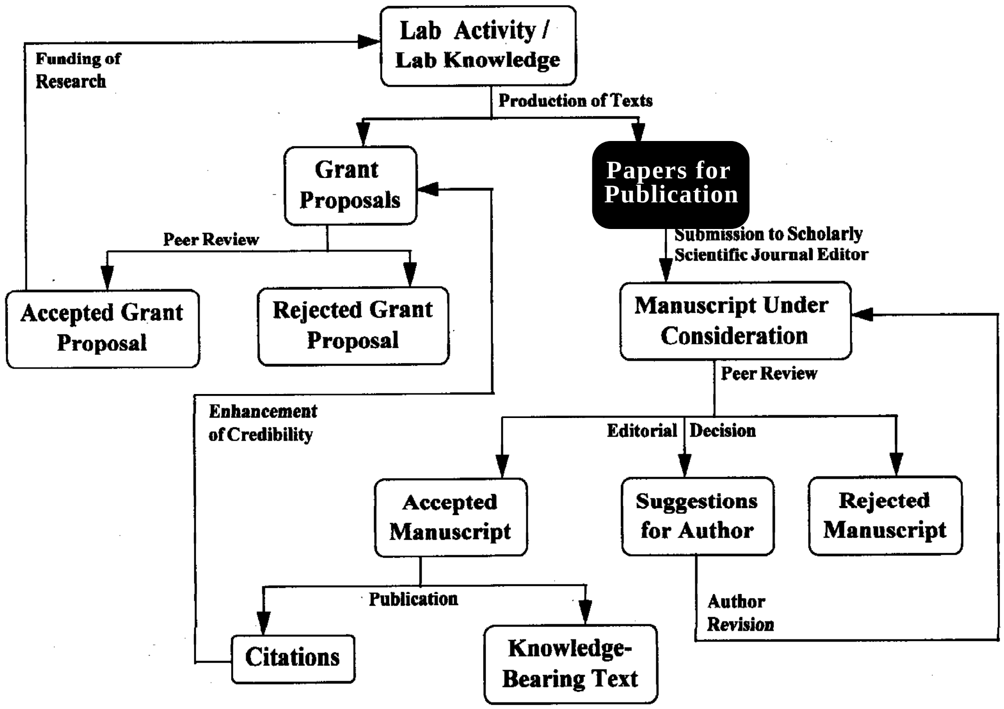


Figure 2: Place of scientific research articles in professional practice

In the typical North American classroom, the stakes of science research and the rhetorical practices surrounding them are dramatically different from those in the professional context. To begin with, the likelihood that anyone will be interested in reproducing students' research results seems practically nil, since in most cases the results that students present are already scientific dogma. This is particularly the case with textbook labs. This difference in expectations brings about dramatic rhetorical differences, which are particularly apparent in the Methods sections of students' articles. Rather than hiding many of the messier details of the research process in order to make the report more readable and to save space for persuasion (as a scientist would), the high school students whose work I have read are more likely to write accounts that emphasize the most tedious aspects of their work.

Take, for example, this section from a poorly-graded paper on earthquake prediction:

> **Method:** We began researching by looking through textbooks, encyclopedias and other related literature, in order to find out exactly how and why earthquakes occur. After finding this information we were able to go on and search the Internet for all of the possible information we could find on earthquakes and earthquake prediction. Although we discovered good information on the United States' greatest earthquakes, *we found it extremely difficult to find sufficient data focusing on California and its history of great "quakes"*. We analyzed our data tables and found that they were strictly based upon recent earthquakes and were of no help to us in determining long term earthquake prediction. *We looked through magazine articles, and found little information on prediction, rather interviews and personal stories of those involved in earthquakes.* We watched various movies on earthquakes and earthquake prediction, and found a lot of helpful information. *We came up with the idea to look for patterns in the history of earthquakes in California, but we were unable to obtain the necessary data.* After searching through the Internet (Mosaic, Newswatcher, etc.) we decided to post a note to all the newsgroups and people in the Internet. Although a few people responded to our note, including our mentor, the information that we received was all data that we had already acquired. We utilized to the fullest extent all resources available to us, and *the data we found, although valuable, was minimal, and of little assistance to completing our project to the degree that we would have liked to*.

Accounts like this one have the advantage of being simpler to write, helping to fill blank pages, and most important, helping to achieve the students' principal aim: to argue for a grade. They are clearly formulated with the teacher in mind as the sole audience.

In contrast, a Method section's traditional rhetorical purpose is to persuade the readership (first the reviewers, then the more general audience) that the researchers have made a series of strategic decisions, and that these were reasonable given the goals and the practical constraints of the research effort. In the quotation above, there is indeed some effort toward this kind of persuasion. I have marked the portions of the quotation that I believe suit the generic form with italics. These italicized sections reveal that the students had initially decided to search for patterns in the occurrence of earthquakes in California (an initial research plan), but were unable to turn up the data required to realize this plan (a practical constraint). At this point, they seem to have given up hope.

This is the sum of what these particular students have to say as regards their strategic decision making, and if you take a second look at the quotation you will see that it nearly gets lost amid assessment-related rhetoric. The strength or the uniqueness of the knowledge-claims put forward (the most important stake in scientific journal articles) most definitely take a back seat to stories about the hours of hard work committed to the project and complaints about critical resources that were not available. In fact, the balance of the quotation above (the non-italicized part) is less like a scientific paper than a kind of adventure story, told by a group of students to their teacher, about their difficulties in completing his assignment. Because the students' only audience is their evaluator, their greatest concern must be to argue that they deserve a decent grade. The only way they have to do this is to say that they have worked hard and have used all the resources that were available to them.

This sort of assessment-related rhetoric is not the refuge of weak students. On the contrary, it is clearly present in many of the stronger papers that I have read. Take, for example, this Method section from a young woman’s paper on photochemical smog in Los Angeles:

> **Method:** My problem with this topic was that *all I found was the temperature and precipitation data*. I sat at Mosaic and Netscape for hours just cruising through the information endlessly. *I even tried Lycos and all of the other searching mechanisms in order to find the rate of photochemical smog. Nobody had it*. This time period was quite frustrating. Finally, I posted on a newsgroup. For awhile, I did not hear anything, but finally a very nice person wrote me back. A man on the California Air Resources Board sent me quite a bit of information. As a result, *I had to change my topic. I decided to try and find a correlation between the precipitation and temperature and ozone statistics between 1970 and 1979.* That is when I could get down to business.

Again in this quotation there is some amount of attention to strategic investigative decisions. In an earlier passage the writer explains her goal to search for a link between photochemical smog and air temperatures in Los Angeles (an initial plan). She explains here how, in accordance with this plan, she searched for data on the rates of photochemical smog in Los Angeles, but was unable to find it (a practical constraint). At this point, she sought help in a public forum and wound up reformulating her research plan to suit the available data. This is a strategic choice. There is a clear presentation here of the investigator making practical concessions in order to make progress toward the larger goal.

Although this passage comes closer to fulfilling the expectations implicit in the professional genre, it still engages in a good deal of assessment-related rhetoric. For instance, the writer makes sure to point out how long she hunted for the smog rate data, and how frustrated she was not to find it. There is clearly a competition going on in both papers, as there is in most of my sample, between the rhetorical functions which the genre was developed for and the writers' personal goals of persuasion. While the genre would prescribe a Method section that merely describes the procedures followed by the researchers and why a reasonable person might expect them to lead to a solution to the stated problems, the students clearly want to tell a series of adventure stories about their research. In order to impress the teacher with their hard work, they manage to tell these stories, though in Wertsch's (Wertsch, 1991) vocabulary, they must be clumsily "ventriloquated through" a genre of professional science.

The point I am after is that what we observe when we observe genre form and its use is not simply a writer's whimsy, but the more or less deliberate (in any case, purposeful) appropriation of custom to a writer or writers' personal persuasive goals. Implicit in these goals is the desire to change one's relationship with an audience: an audience which is, as Gaonkar (Gaonkar, 1997) has put it, "simultaneously positioned as spectator and participant". This view coincides more or less with that of (Flower, 1980) and with most rhetorical theory since Aristotle.

Enhancing Genre Appropriation Through Telementoring

My argument to this point might lead one to suspect that teaching students to write in the customary genres of professional science is a hopeless cause. After all, in the examples I have given, these genres appear to have created more problems for students than they solved. However, to take this line would mean surrendering a great deal of educational potential which, as I argued earlier, may be more realizable and more useful than the goal of general familiarity at which science curricula currently aim. I would contend that the genre of the experimental report is difficult for students to master for the same reason that it is worthwhile mastering: it embodies a set of cultural practices that are relatively foreign to students. This is a very influential set of cultural practices which students should be empowered to observe in a knowledgeable fashion, even if they do not choose to participate in them. This is my own definition of scientific literacy.

In order to foster scientific literacy, I believe that educators need to face the essential differences between it and other varieties of literacy head on. We cannot ignore the important shaping role that research reporting, its audiences and its genres have in scientific practice; but we also cannot expect students to develop a rich understanding of scientific research and reporting through school situations so radically different from those in which these genres were developed and are used. In most science teaching, students produce work for an audience of one person, the teacher, and for a single purpose: evaluation. The emphasis in this situation is on offering evidence that work has been done according to a previously-revealed specification. This is a kind of persuasion, to be sure; but one quite different from that which is honored and developed in science.

To clarify the differences between the rhetorical situations that professional scientists and average students face, examine Figure 3. This diagram depicts my own impression of the place of paper writing in the life of a middle school or high school student. In the school environment, there are many more ways to gain credit with the powers that be than by writing. A significant portion of a student's grades may actually derive from the teacher’s first-hand observations of how he or she behaves in class: attendance, on-task behavior, contribution to discussions, cooperation with classmates, and so on. This variety of credit mechanisms necessarily makes writing less important for the student than for the adult professional, whose stock of credit can go up or down tremendously from writing (or lack of writing) alone.

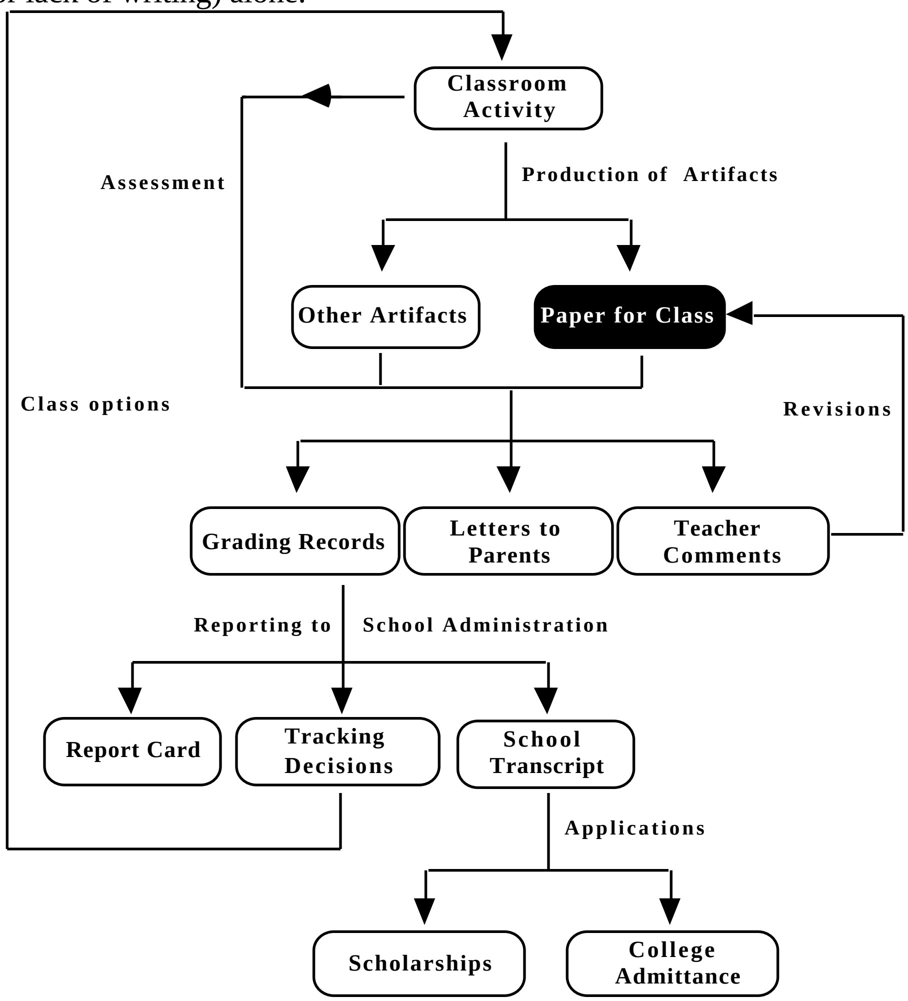


Figure 3: Place of students' written reports in school life

This raises the question of how incumbent professionals learn to faithfully appropriate the genres of professional science. What situations foster this learning? (Russell, 1991), who has studied historical shifts in writing instruction extensively, tells us that since the beginnings of graduate education in North America, the research community has relied almost exclusively on informal mentoring to provide necessary instruction in writing (Russell, 1991, p. 48). While quite labor intensive, one strong advantage of this form of instruction is that it is richly intertwined with other research and professional activities, and thus highly situated. In this respect it stands in stark contrast to the remedial approach that is dominant in K-12, in which writing instruction is often as isolated from other learning activities as it can practically be. According to the remedial mindset, the production of grammatically-flawless narratives about "my summer vacation" and 5-paragraph persuasive essays ("school uniforms: yes or no?") are prerequisites to the production of scientific research articles.

In the few K-12 environments that seriously attempt to mimic the kind of teaching and learning that take place in research communities, mentoring is pursued as a natural and adaptive teaching strategy. It is, for instance, an important component of students' preparation for success in the Westinghouse Science Talent Search (Berger, 1994); unfortunately it is a rare student who has the opportunity to participate in this contest, and a rare school that dedicates itself to supporting students in the endeavor.

In the work reported here, my participants and I have been able to orchestrate distant mentoring relationships for students in "regular-level" science classes, to aid them in relatively independent scientific research. What is most exceptional about these classes, other than the dedication of their teachers and a level of access to technology which is somewhat (but not outrageously) beyond the norm, is that students are given the time and support they need to formulate and pursue relatively independent research for periods of weeks at a time. To be certain, students' research does not reveal findings that professionals in the field would consider new. Often, there are significant failures and missed opportunities in the formulation of the research questions, and the choice and interpretation of data. However, a lot can be learned from these failures, and the lessons can be memorable because they are hard-earned.

In the following chapters, I will discuss a number of these projects and the crucial role that telementoring relationships played in realizing them. In Chapters 4 and 5, I present two detailed case studies of telementoring relationships which reveal their shapes, their potential, and their limits. Chapter 7 will put these relationships in context with a broader-brushed analysis of the telementoring dialogues that Wagner, Whitcomb and I orchestrated. In Chapter 6, I will present an analysis of research articles produced by Wagner's students, showing an apparent relationship between the sophistication of students' science rhetoric and their experiences of telementoring. Finally, Chapter 8 will look to the future of telementoring, its potential for growth and how this can be supported with specially-tailored technological tools. To begin with, however, I would like to lay some essential groundwork by discussing how Wagner, Whitcomb and I worked together with our volunteer telementors to make telementoring happen in two classrooms. This is the subject of Chapter 2.

Chapter 2: Design Experiments in Telementoring

> As the births of living creatures are at first ill-shapen, so are all innovations, which are the births of time. Yet notwithstanding, as those that first bring honor into their family are commonly more worthy than most that succeed, so the first precedent (if it be good) is seldom attained by imitation. (Francis Bacon, "Of Innovations")

In the previous chapter, I laid out an argument for a new kind of science education that would sacrifice coverage of content in favor of experiences that would help students construct more sophisticated understandings of scientific practice. In particular, students would learn more about why scientific research is done and reported as it is, and about the important influences that the tasks of research and reporting have upon each other. This brand of school science, I argue, would be more useful both to students preparing for careers in the sciences, and to students whose formal science education ends in high school. A key element in this pedagogy would be to provide students with a critical and supportive audience for their work beyond the walls of the school: an audience of telementors who would volunteer just a few minutes a week to guide students' research via Internet services.

Having presented this idea, it is not immediately obvious how to go about accomplishing it, even on a small scale. So many practical questions need to be answered. For instance, who might be encouraged to volunteer as telementors? What would they want to get out of the experience, in return for their efforts? How would telementoring activity be integrated into a meaningful curriculum, and what practical challenges would teachers face in organizing correspondence between their students and telementors?

The exploratory research reported in the following chapters was designed to provide initial answers to these questions, based on close collaborations with teachers. It takes the form of what are termed "design experiments" (Brown, 1992), an increasingly popular paradigm of research in the field of educational technology. At its heart, the design experiments approach is meant to help researchers cope with and learn from events in classroom environments in which it is impossible to control many variables (e.g., students' prior academic achievement), and where the objective of the research itself is often to come to a better understanding of the variables involved in progressively refining a technological system, a curriculum, or a mating of the two. Further arguments for this approach will be presented in Chapter 3 under the heading "Analytical Approaches". Here, I would like to begin by explaining some of the context in which my design experiments took place.

Context for this Research

Traditional Mentoring Programs and their Limits

Mentoring is, of course, a very old idea. The term dates back to Homer's epic poem, the Odyssey, in which a wise old sea captain named Mentor counsels Telemachus, the son of Odysseus. More recently, formal mentoring programs have been created to bring adult professionals to classrooms on a regular basis (e.g. (EDC, 1994)) or to bring students into laboratories or other adult workplaces periodically (e.g. Waltner, 1992, March). However, these programs, while arguably worthwhile, have not become widespread enough to have much influence on students' formal education. This is partly explained by the fact that they entail large disruptions in the work routines of the volunteers.

For some time there has been interest in the idea of using the Internet to support ongoing relationships between adult volunteers in a variety of fields, and K-12 students in school. One of the principal appeals of this idea is a reduction in the travel required for volunteers to maintain an involvement in students' work. This reduction in inconvenience affords more lengthy and intellectually involved discussions. Volunteer telementors involved in the work reported here, for instance, responded to electronic messages from students at the times of day most convenient to them, allowing these relationships to fit comfortably into the natural breaks in the volunteer's work day. As one physicist, Dan, said of his experience:

> I really enjoyed it, and for me it was great. I'd be sitting down, coding all day, writing [computer] programs, and I'd be able to take, you know, a half hour, an hour break every couple of days to answer this e-mail and look up something that I wanted to learn about. So from my point of view, I really enjoyed it.

The time-staggered (or asynchronous) communication that e-mail permits also promises some direct benefits for students, as one of my collaborators in this research, Judy Whitcomb, explained in an interview:

> You know, for years in the educational environment we've been saying, oh yeah, we need these partnerships, and people coming in from businesses, and things like that. And those are great, but it's a very limited amount of time in your students' [lives].... For instance...the Constitutional Rights Committee sent lawyers into the classroom. And this is a very nice program, they'd be there every week for a period, over three weeks or four weeks, whatever it was. And it was a great activity. But what if the kid, in that interim, thought of something, or had a dimension that they wanted to talk about? If the classroom teacher wasn't in a position to discuss it with them, or didn't have the knowledge to discuss it with them, then it was on hold for a week. And when I read [what you had written about telementoring, Kevin,] I thought, you know, that's going to be a factor that's really kind of neat for kids. That as they're looking at something or thinking about something they can put it [in an e-mail message], and here get some information about it when they feel like they need it, before it diminishes in their view of things that are crucial and important.

Engaging Science Practice: the CoVis Project

The Learning Through Collaborative Visualization Project (CoVis) began in 1992 as a testbed directed at finding ways to heighten the authenticity of high school science teaching and learning. The use of project-based pedagogy (Ruopp et al., 1993), enabled by high-performance computing and communications technologies, lay at the heart of the plan (Pea, 1993, May; Pea & Gomez, 1992). Beginning in 1992 with funding from the National Science Foundation, and later the Illinois State Board of Education, technologies used in the realm of adult science were adapted for use by middle and high school students in their classroom work. These technological tools are now used by a community of teachers and students across the United States to support a variety of implementations of project-based and project-enhanced science learning.

To support the transition to more authentic project-enhanced learning, the CoVis project developed a suite of software that makes the scientific visualization technology developed by researchers in atmospheric sciences usable by students in middle and high school (Gordin & Pea, 1995). To be more faithful to the collaborative fashion in which science is often practiced (Lederberg & Uncapher, 1989), CoVis staff and teachers also developed curriculum resources which encourage teachers and students to use a variety of Internet-based media to discuss their research and studies with one another, and with distant researchers and science educators at a number of partnering institutions. These media include the project's own groupware application for project learning, called the Collaboratory Notebook (O'Neill & Gomez, 1994; O'Neill, Gomez & Edelson, 1994).

Telementoring was one of the core ideas behind the CoVis project from its beginning (Pea, 1993, May; Pea & Gomez, 1992); however, in the early phases of our work the team hoped that high-speed networks would make it so convenient for teachers and students to communicate with adults outside the school that it would happen as a matter of course. To a very limited extent, it did. For instance, in the second year of the project, a group of freshmen at Evanston Township High School, with no help from their teacher or CoVis staff, got in touch with a seismologist in Japan and corresponded about his work for a short time. However, while this episode was appreciated by the teacher and generated some enthusiasm, it proved to be an isolated incident.

Later, as part of my work with this same teacher in connection with the development of the Collaboratory Notebook software (O'Neill & Gomez, 1994; O'Neill et al., 1994), I helped to orchestrate telementoring experiences for a small number of high school freshmen. Like most early experiments with a new piece of educational software, this one was brief and isolated. It was also not particularly successful. The practice of telementoring did not begin to be developed in a concerted fashion by CoVis staff until Rory Wagner, one of the participants in this research, provided the important proof of concept that was required (Wagner, 1996). I will discuss his work in detail later in this chapter.

Project-based Telementoring Versus Traditional Mentoring

Before describing the telementoring relationships that my collaborators and I orchestrated for students, I would like to briefly explore the similarities and differences that telementoring bears to other well-known helping relationships. Some of the differences are substantial. For example, while a great deal of mentoring occurs in the workplace between workers and their managers, telementoring relationships often span organizations whose day-to-day work is unrelated. Hence, telementors cannot rely on bumping into their mentees on the elevator or in the lunch room to touch base; nor can they learn incidentally from co-workers how their mentees are getting along. As a result of these and other factors, telementoring relationships develop differently from their traditional counterparts, and serve different functions for the participants.

In light of such important differences, some may ask whether telementoring is similar enough to traditional mentoring to deserve comparison at all. Is it, perhaps, more like tutoring than mentoring? This is not a simple question to answer, since despite widespread public recognition of the role of mentors and mentoring in people's personal and professional lives, research on mentoring relationships is diffuse and lacking in consensus (for a useful review emphasizing this dissensus, see (Jacobi, 1991)). The dissensus is exacerbated by the fact that the small body of empirical research on mentoring relationships is scattered through the literatures on organizational dynamics (Dalton, Thompson & Price, 1977), adult development (Levinson, 1978), teacher training, nursing and other fields.

Researchers often divide mentoring relationships into two broad categories: "natural" ones in which the parties are initially drawn to one another by personal affinity or chance opportunities, and "formal" ones which are fostered through the initiatives of a company, school, or non-profit organization (such as Big Brothers or Big Sisters). Detailed studies of “natural” mentoring relationships and are difficult to conduct for obvious reasons. One can only identify such relationships retrospectively, and analyze them through individuals’ self-reports, as was done by (Levinson, 1978), (Phillips-Jones, 1982), and (Kram, 1985). This kind of research has generated valuable insights into the subjective experiences of mentoring and being mentored, including individuals’ motivations to fill these roles. It has also helped to clarify the differences between mentoring and other helping relationships, such as tutoring or apprenticeship.

Whether informal or formal, mentoring relationships are typically analyzed according to the *mentoring functions* provided by the mentor to the protégé. While there is no standard, comprehensive set of mentoring functions in the literature, there seems to be consensus on two broad classes of mentoring functions: career and psychosocial. This division was initially proposed by (Schockett, Yoshimura, Beyard-Tyler & Haring-Hidore, 1983), and subsequent research has tended to reinforce it. Table 1 lists the career and psychosocial functions discussed by (Kram, 1985).

Table 1: Mentoring Functions discussed in Kram (1988)

Career Functions	**Psychosocial Functions**
Sponsorship	Role Modeling
Exposure-and-visibility	Acceptance-and-confirmation
Coaching	Counseling
Protection	Friendship
Challenging assignments	

As you can see, the kinds of assistance that have traditionally been classified as mentoring functions are quite broad in scope. In fact, it may be this diversity in the kinds of assistance and support provided in the relationship that best characterizes mentoring.

Despite the diversity, however, what all of the classical mentoring functions have in common is their aim to initiate the protégé into a new profession, organization or stage in life (Kram, 1985).

Some important points of contrast between traditional mentoring and other helping relationships include the overall goal of the relationship, the helper's motive, and the source of the problems that the mentor and protégé deal with together. Table 2 lays out some of the contrasts between mentoring, telementoring, and other common types of helping relationships.

Table 2: Telementoring contrasted with other helping relationships

	Tutoring	**Traditional Apprenticeship**	**Traditional Mentoring**	**Project-based Telementoring**
Goal	Expertise in solving a well-defined set of problems	Performance of a complex craft	Performance in an organization/community of practice	Understanding of a community of practice
Helper's Motive	Financial remuneration, psychosocial rewards	Apprentice's labor	Psychosocial and professional rewards	Psychosocial rewards
Method/ purpose of Problem selection	Tutor chooses problems for development of tutee's expertise	Master chooses problems to maximize both apprentice's learning and the overall productivity of the shop	Mentee brings his/her problems to the mentor, and mentor hands down challenging and/or "plum" assignments with an eye to mentee's career development	Mentee brings his/her problems to the mentor. Mentor provides advice and challenging recommendations with an eye to mentee's best possible performance against the community's norms
Length of relation-ship	Possibly days, possibly years	months or years	usually months or years	weeks or months

Though mentoring relationships are commonly described by researchers according to the functions served by the mentor, this should not be taken to imply that the protégé is the sole beneficiary in a mentoring relationship. In fact, nearly all researchers agree that mentoring is distinguished from other helping relationships by being highly reciprocal; that is, the relationship assists in the development of both the protégé *and* the mentor. In some cases these rewards will be career-related; for instance, a company may choose to officially recognize the worth of a mentor in discovering and cultivating new talent. In other cases, however, the mentor's rewards may consist almost entirely of intangibles, such as an opportunity to re-assert professional competence at a late career stage, or to re-evaluate career progress at mid-life (Kram, 1985).

In this connection, one of the most important general insights of past research on mentoring is that individuals' desires and abilities to become mentors are strongly dependent on the developmental tasks that they face, both within the organizational setting and outside it (Kram, 1985). In corporate settings, for instance, managers are most likely to dedicate significant time to mentoring if they believe they have begun to reach the limits of their personal ability to advance in the company. This brings them to seek other opportunities to grow, through aiding the growth of others. In many settings, the developmental tasks faced by particular age groups makes them much better targets for recruitment than others. In the context of my work with Wagner and Whitcomb, this finding does not have strong implications, since it is difficult to target specific age groups when recruiting via scientific listservs or Usenet newsgroups. As telementoring branches out into other subject areas, however, age-specific electronic forums will become an important recruiting tool.

One final point worth addressing here is the *length* of mentoring relationships. This is an important point to address in the context of project-based telementoring in K-12, since the length of telementoring relationships will often (though not always) be circumscribed by the length of project cycles. This being the case, is it foolish to hope that short-term, remote mentoring relationships will look anything like the longer-term, in-person mentoring relationships that have been studied in the past?

Most past researchers have tended to assert that the mentoring relationship is *ideally* long-term in nature (being measured in months or years rather than days or weeks). For example, Kram's seminal work outlines four phases of the mentoring relationship (Initiation, Cultivation, Separation, Redefinition), which presumably take some time to move through (1988, Chap. 3). However, Kram never suggests that shorter-term relationships are incapable of providing many of the functions identified with mentoring. Another definitional tactic is presented by (Phillips-Jones, 1982), who avoids setting apart mentoring from non-mentoring by naming several stereotypical roles played by mentors, including a set of more limited roles that she attributes to "secondary mentors".

In the final analysis, many of these definitional arguments may be moot. The dissensus in existing literature on mentoring makes it clear that mentoring relationships differ significantly from setting to setting. In the setting of the project-based science classroom (linked to remote sites via Internet services), mentoring relationships are bound to differ from those that have been studied in the past, despite the fact that many of the interpersonal dynamics that govern them may be similar. While most of the past research on mentoring has been conducted in very different settings than the ones that I am considering here, it nonetheless demonstrates the breadth of relationships that are possible explains many of the difficulties that they typically face.

Later in this Chapter I will present a brief example of a telementoring relationship, which reveals a few of the unique dynamics and benefits that project-based telementoring offers.

Research Participants/Co-designers

Today, in addition to our own work, a number of projects are underway to foster telementoring activity on a regular basis (Bennett, Hupert, Tsikalas & Meade, 1997; Harris, 1997; Neils, 1997). One important way in which my research differs from some of this other work is the degree to which teachers have been involved in its design. In this section, I will briefly describe my research collaborators, the schools in which they work, and their goals for our work together. The aim of this section is to provide the background necessary for readers to understand the implementation of telementoring as a response to local conditions in each school, and as a manifestation of each teacher's personal investment in new tools for innovative science teaching.

Rory Wagner

Rory Wagner has taught Earth Science at New Trier High in suburban Chicago for more than 23 years. New Trier has a strong academic reputation, both locally and nationally; however, Earth Science is considered the lowest-prestige science course taught there. In fact, because the course has no official prerequisites and is often used by students to fill a science requirement, it is often thought of as a "slum" class. This widespread perception means that Rory's clientele consists of a few very motivated students who are attracted to the subject matter, and a healthy number of others who would rather avoid studying science altogether.

I first met Rory in the summer of 1992, when I started graduate school. Months before, he had joined the CoVis project, which was to play an enormous role in changing his teaching over the next few years. For almost 20 years, Rory had taught Earth Science in the traditional mode of lectures, demonstrations and labs. Over that time he gradually lost confidence in the effectiveness of this approach in helping students learn the content of the course, or in constructing anything but a rudimentary understanding of scientific practice. At one of the early CoVis meetings, Rory and five other teachers from New Trier High and Evanston Township High were handed a book about project-based science teaching written by teachers and researchers in the LabNet Project at TERC (Ruopp et al., 1993). Rory took this book home and read it from cover to cover in the next few days, surprised to find that other teachers had the same doubts he did about the value of traditional science teaching. As the school year began, Rory set out to radically re-design the way he taught and his students learned. He never looked back.[2]

It has taken me years to get to know Rory, and these were years well spent. When I first met him, in the setting of an early CoVis teacher workshop, he seemed quiet and retiring. Only years later did I discover what a reflective and humorous conversationalist he is one-on-one. His humor is distinctively wry, and often surfaces in self-deprecating comments. While these might be taken to indicate a lack of confidence, in fact they serve as a counterweight to a rare self-assurance that is one of Rory's most indispensable assets as an educational innovator. Rory's bold experimentation, which will be discussed at length in this and other Chapters, is not merely the result of a personality trait, however, but is based on a wealth of carefully-cultivated personal experience and many hours of reflection.

In 1994/95 I heard from a fellow graduate student, Joe Polman, that Rory had begun recruiting graduate students, professors, and professionals in the geosciences to mentor his students through their independent research projects using e-mail. Rory had done this entirely on his own initiative; no CoVis staff had been involved in directly supporting his efforts. What was more, he had orchestrated telementoring consistently for several months, even as his students completed one long-term project and continued on to another. These things told me that he must be doing something very different from what I had attempted with other teachers; something which I could certainly learn from. A short while later, I paid a visit to Rory at school to ask him if he would mind me observing his work in the classroom and doing some low-impact research on his work. He opened his classroom to me without reservation, and our partnership began.

2 The continuous re-design of Rory's teaching during one school year is the subject of another dissertation by my colleague, Joseph Polman (Polman, 1997). I recommend it to all those readers who are left curious by my description of Rory and his teaching.

While Rory's commitment to his profession is obviously strong, he does not take it so seriously that he is afraid to experiment. As our partnership in this research developed, I found him open to suggestions about nearly every aspect of his work. It was clear that he would be willing to try almost any suggestion that came from a person he respected, and who shared his goal to invent a better way of teaching his students about science. At the same time, however, Rory is unflappable in his commitment to ideas which he has developed through personal experience. Nothing could better convince me of this than his calm demeanor during telephone conversations with parents who call to protest their childrens' low grades.

Aside from his confidence as an innovator, one of the things that makes Rory unique among his peers is the level of opportunity that his education has provided for direct experience of mentoring. During his first several years of teaching, he worked in his spare time to earn a master's degree in Geology. This grueling process involved substantial travel to conduct fieldwork, and long, lonely hours in the lab analyzing the mineral content and fractures in samples of rock. Much of the work seems like simple drudgery; yet throughout the lengthy process of completing his thesis, brief and important moments occurred in which Rory's thesis advisor mentored him. Years later, Rory recognizes his thesis advisor as a crucial influence on his teaching, and his interest in telementoring.

In the following interview segment, Rory begins to explain to me for the first time the nature of this influence:

> Well....it would go back to my thesis advisor. Because that's what I'm constantly going back to figure out what I am I doing [in my teaching] and why am I doing it, and is there a better way to do it, and even things like graphing and what does that mean, and analyzing data. And it's kind of funny because I appreciate [my thesis advisor] more now than I did then. Because then I was tied up in the work, and it was "why the hell do I have to make all these damn point counts? I'm getting tired of counting which mineral I see in the microscope every millimeter down a slide." Then it was a job to get done, and part of this big mountain that I had to climb, and now when I look back at it, I get it more. And again since that was scientific

> research, that really fits in more with what I'm doing with my classes now. So I'm drawing more upon that...

As Rory began to draw more upon his personal experience as a protégé, his perspective on a great deal of his past was changed. He began to realize more than ever the diverse influences on his thinking that a host of mentors and guides had provided throughout his growth into adulthood:

> ...my thesis advisor...really led me, but semi-transparently, step-by-step in all the things that I had to do, and how to put it all together. Revising the paper, and revising the research, and things like that. That was the most formal [mentoring experience I had]. And everything else has been informal. But I felt that they were mentors. And it's funny, because as I've been groping with either mentorship or work ethic over the last couple of years [in my teaching] I've been realizing that there are more and more people that have influenced my life. I've gone from my biggest mentor was my grandfather to, my father had something to do with that, and like this coach had something to do with it, and this athletic director had a lot to do with it, and this teacher over here did.... And so I started realizing that I was more diversely mentored than I ever thought. Perhaps as my perception and realization of how learning is done [changed], or what goes on in the classroom, or what mentorship is, all of those things expanded as I tried to change my style of teaching into more of a mentoring process as opposed to just giving directions.

Rory's experiences with his thesis advisor are a great asset to him in constructing and carrying out telementoring in his classroom, and may explain why he has been such an innovator in this area. In 1995/96, I interviewed a half-dozen teachers about their personal experiences of mentoring, and none of them seemed as rich as Rory's, either with regard to the number of mentoring relationships they had experienced or the depth to which these relationships had been developed. The mentoring experiences of my other counterpart in this research, Judy Whitcomb, were also not as rich as Rory's, though they were richer than those of most of my other interviewees.

Judy Whitcomb

Judy Lachance-Whitcomb is a middle school science teacher in urban Chicago. She is a 26-year veteran of the Chicago Public Schools, and has taught in environments that present all the challenges associated with urban schools. About four years ago, Judy was recruited to Jordan Community School, a new middle school being built to relieve overcrowding on Chicago's far north side. In an e-mail exchange, she vividly recounted the story of how Mr. Harvey, the principal, had come to observe her teaching and consider her for the open science position at Jordan.

> I had the worst class that I had in years in front of me. Now, I had totally sold out with this class, they were so difficult (oh, forget difficult they were downright bad) and usually I would give them seat work. However, at the time I was piloting an activity that I was developing for a New Explorer's project. I needed to know how it would fly, even with the "challenging" students. It had to do with the dissection of apples with knives (which in itself shows what a "risk-taker" I am, to even have that class and knives in the same room!). On top of all of that, a couple of days before some young students brought a young injured bird into my class because they decided a "real scientist" could help revive it. So, I had that bird in a small cage and the kids would try to give it nourishment with a medicine dropper.
>
> As soon as I had begun the lesson in the midst of all of this, I look up and see Mr. H. at my doorway and think, "So long to that job". He came in and stayed through the class. At this point all I wanted was for him to go away and leave me to my misery. Finally (mercifully), the bell rung. As I was herding the students (and Mr. H.) out of the class, a group of lingerers were gathered around the bird cage. (I don't care how bad kids are they still have a small "sense of wonder" about things remaining.) As I just about had Mr. H. in the hallway, the bird watchers yell out, "Ms. Whitcomb, the bird is DEAD!" So, I turn to Mr. H. and said, "Excuse me, I have to go and take care of the bird." It was shortly after that he told me he had found his science teacher. I asked, "Who?"

As Judy explained to a group of CoVis teachers at the 1996 annual summer conference, her new school, Jordan Community School, "could not be more different from Rory's school". To begin with, Jordan serves a different age group: Judy's students are a mixture of seventh- and eighth-graders. Jordan is also part of a much larger, more financially and organizationally challenged school district. Despite being an easy 20-minute drive apart, Jordan and New Trier serve students and parents from very different socioeconomic strata. Jordan services a high proportion of students (95%) who are on free or reduced-price meal programs, and has a high rate of transience and dropout.

Despite these challenges, Jordan Community School exudes an air of hope and possibilities. The corridors are bright and clean. Inspirational posters and students' artwork cover the walls. The school's mission statement, which occupies a prominent place in one of the entry corridors, seems to have been written recently enough to have a real and present meaning to the school staff. In part, this statement promises innovation through the use of high technology:

> State-of-the-art equipment, facilities, qualified personnel and resources will provide the environment in which to develop and implement this curriculum and support technological development into the 21st century.

Ongoing consensus about the high-tech portion of the school's mission may explain Whitcomb's positive response when I asked how her fellow teachers would react to our design experiments:

> The majority of other teachers will be curious. Supportive, most of them. Although we have a few who will still go back to that, "well, why do the kids need to do this?"....I've mentioned before that we have an exceptional school, where people will be real eager to see how this plays out.... Overall, our school is very strong that way, and very supportive.

I first met Judy in 1995 at a CoVis Project summer workshop, soon after she had joined the project. I had just defended my dissertation proposal, and was actively searching for research partners in the Chicago area. While I was enthusiastic about what Rory and I had been doing together, I knew that both my fellow researchers in academia and the career teachers whom I hoped would benefit from my work would be skeptical as to whether a teaching practice pioneered in a wealthy suburban district could succeed under less ideal conditions. Between conference sessions I explained to Judy what I was hoping to accomplish in one of the Chicago CoVis schools in the coming school year, emphasizing my belief in the importance of giving students an audience for their work beyond the school. This idea seemed to strike a chord with Judy. She responded that she would like the world to know how much her students were capable of.

Judy and one of her colleagues, Marge Rappe, attended the CoVis conference with great interest, but without much confidence that their school would be able to participate in our work very soon. At the time, Jordan Community School's only access to the Internet was through three computers connected to three relatively slow modems. Jordan did not yet have the number of computers that would be needed to participate in much of the work encouraged by the CoVis project. Both Marge and Judy were more than a little surprised when their Internet connection and computers materialized in the fall of 1995, due largely to the intervention of CoVis staff. They began their participation in CoVis curriculum activities feeling very much at sea, especially with respect to Internet applications and the administration of services for their students (such as e-mail). However, they were determined to make the most of the opportunity that had been given to them. Judy learned a tremendous amount about the Internet and project-based teaching that year.

When I found out that Jordan had its network connection in place, I contacted Judy and reminded her about my plans for research on telementoring. Was she interested in working together? Despite all the challenges she expected to face that year, she agreed to meet and discuss the possibilities. It was one of many after-school meetings in which we would work out our common goals and refine our plans for what was to be called the Balanced Community project.

One important driving force in Judy's work with me was her distaste for the system-mandated school science fairs in which she was required to involve all of her students. One might argue that the science fair, which is judged at each school by adults recruited from the local community, provides students with an audience for their work in the same way that I have argued telementoring should. In several respects, however, the science fair is the antithesis of what Judy and I attempted to achieve in our work together. It is a highly formalized, one-day event in which students are placed under great pressure to put the best face on their work for the benefit of adults whom they usually do not know, and will never see again. The hit-and-run nature of the judging (for which I volunteered twice myself) encourages students to conceal the faults in their work, rather than seeking guidance to improve it. This deception is often an adaptive strategy for success in the judging, but students who are not adept at it are made to look and feel like failures. Judy makes the best of the science fair for these students, but asks herself, is this what science learning should be like?

As my meetings with Judy continued and I got to know her better, I found that, like the other teachers I had interviewed, her personal experiences of mentoring were not as rich as Rory's. In our first formal interview, when I asked her whether she could recall having had a mentor, she immediately thought of one of the nuns who had taught English at her Catholic high school in Chicago:

> I actually view one of my teachers as a mentor. In my career. And only one! That's kind of scary, isn't it? I had a mentor my senior of year of high school. My home room teacher, who was also my English teacher, I viewed as a mentor. Because she gave me intellectual support...but she also gave me a feeling that I was really quite bright in the area...and gave me clues on how to expand what she viewed as real knowledge, and kind of pointed me in really good directions. She built a lot of self-confidence in me that I don't remember having with anybody before. But she'd be the only one, pretty much, that I felt was a mentor in my school career.

While Judy's relationship with her mentor lasted only a year, she walked away from it with a strong personal experience of how a mentor can encourage learners to stretch their capabilities:

> [We] shared...a love for literature, that I didn't know I had until she made me aware that I really did have it, and that I really was well read. The kind of equal footing she gave me, and the kind of respect she gave me...you know, for instance we'd be in class and she'd mention some character from some novel, and she'd say, "and of course you remember that one, don't you?" And even if I'd never read the book I'd lie, and say, "oh yes." And I'd run home and I'd read the book. That's what I did.

Judy's personal experience of mentoring was clearly part of the reason for her enthusiastic response to my goal of having telementors serve as a responsive audience for students' research. She had only one concern about this plan. Judy's personal experience of mentoring stood apart from other helping relationships she had experienced in the safety from unconstructive criticism that she felt. She elaborated on this sense of safety in an interview:

> [I had] the definite feeling that there would be constructive criticism, so it wasn't patronizing? You know, like, "Oh, yes, that's a good job, Judy" when it was a pile of garbage? And that when there needed to be constructive criticism, and something needed to be re-done, it was a safe environment. I knew I would get honest feedback, and I knew I would get the support necessary to help me do it better. And if she didn't have the resources, [I trusted that] what she pointed me to would be really helpful or beneficial.

While she considered it important for her volunteer telementors to serve as a critical audience for students' work, Judy knew that their criticism must be sensitively moderated if it was to be effective for her students. A few of Judy's volunteers did a particularly effective job of moderating their criticism for sensitive young men and women, and we will see some excellent examples of their efforts in Chapter 7.

Mark Ballard

Before I close this section, I would like to mention another teacher with whom I worked briefly on a plan for telementoring in 1995/96. My work with Mark Ballard (a pseudonym) was, unfortunately, not successful; but it is instructive to consider why it failed.

Mark Ballard is roughly the same age as Rory and Judy, but was a relatively new and inexperienced high school teacher in 1995. He had recently left a career in applied science which gave him a superior grasp of geology, and was teaching under an emergency certification while taking night courses to earn his credentials. In 1994/95, Mark and I had conducted a small piece of research together for the CoVis project, and had gotten along well throughout this work. So, when Mark heard that I was planning dissertation research on telementoring and asked to be involved, I set aside some time to talk with him.

After an initial e-mail exchange, Mark dedicated more than six hours of his spare time to after-school meetings with me, in which we explored possibilities for our work together. To each meeting I brought along an abbreviated version of my dissertation proposal, which explained the research design approved by my committee and my requirements for data collection. Mark surprised me by asking for a copy of the full proposal, which he took home to read. He was full of enthusiasm about the research, and full of ideas for telementored projects. Unlike Rory's or Judy's projects, however, most of Mark's ideas were driven by a concern for strict content coverage.

As time passed, it became clear that Mark felt little freedom to innovate at his school; at least not with his curriculum. He was under review for tenure at the time, and had described his nervousness about this to me. The project idea he settled upon for our telementoring work was related to geologic time. He was comfortable with the subject-matter, had taught it for the past two years, and considered it quite important to an appreciation of geology. Under the plan, teams of students would be assigned to particular periods of geologic time, which they would research in standard textbook and library sources for a period of weeks. They would produce both written group research reports and individual reports, and at the end of the project would present their results to the whole class orally.

It was unclear to me at the time how telementors would contribute to Mark's plan, and I offered some suggestions. It was clearly fruitless, however, to pressure Mark toward a design like Rory's or Judy's. Instead, I decided to treat his more traditional curriculum as an interesting point of comparison with Rory's freewheeling project-based design and see what he could make of telementoring.

As Mark and I continued to meet, my outlook on our partnership remained positive. I was confident enough in its potential, in fact, that I set to work recruiting a dozen local geologists to act as telementors in Mark's project. I continued to encourage him to produce an activity structure that would spell out how his students and their telementors should work together at each stage of his planned project, explaining how important this would be as a source of guidance for his students, his telementors and himself. He seemed to agree, but as time passed, the activity structure did not materialize.

Ultimately, despite the hours of meetings in which we discussed potential benefits of telementoring for his students, Mark could not find a way to articulate the role that telementors were to play in his project. As he explained to me in an e-mail message shortly before the planned starting date:

> Kevin,
> I'm having difficulty figuring out exactly what I want mentors to do and why I might need them. I haven't felt good lately so I'm not as energetic as I need to be to figure this out. [My] students are doing activities that are teaching them skills that may allow more sophisticated research but I'm at a loss to see exactly how mentors can help.
> ...I know that this must be maddening for you but I'm not sure that this will come together and I'm not sure that there is anything that you can do to help at this point. I'm working on it tonight and this weekend but I go home exhausted and... Well, I don't know what else to tell you.
> Mark

So it was that with a dozen geologists waiting in the wings, and with all the requisite material resources in place, including computers, a fast Internet connection and individual e-mail accounts for Mark's students, Mark and I were forced to abandon the project. I apologized to our volunteers and called it a day.

Mark's work life at this time was as complicated and stressful at the time as many other teachers' lives are. As such, it would be foolish to reduce the failure of this project to a single factor; but I believe it was more than a coincidence that in an interview with me a month earlier, Mark could not identify *anyone* who had served as a mentor to him before he began his career in teaching. Unlike Rory and Judy, he had no personal experience to draw upon in designing a telementoring activity structure to complement his project curriculum. Lacking a clear understanding of a mentor's role in assisting learning, he designed a project which was perfectly feasible in a traditional, self-contained classroom. When he realized that he had effectively designed out any constructive role for telementors, it was too late to effect a repair.

The mindset which leads to the design of clearly bounded activities for self-contained classrooms is a natural mate for traditional science curricula which, like Mark's curriculum, endlessly prepare students for work which they are never given the freedom or resources to carry out. This type of curriculum stands in sharp contrast to what we will see in the following section.

A Sample Telementoring Relationship

To understand Wagner and Whitcomb's designs for telementoring activity, it is important to know something about the on-line activity that they are meant to encourage and enable.   In Chapters 4 and 5, I will present two in-depth case studies of telementoring relationships; but as a prelude, this section will briefly discuss a telementoring relationship that occurred in Wagner's classroom in the 1995/96 school year. This example illustrates one shape that telementoring relationships can take, and how strongly these relationships are influenced by the rituals and events of the classroom.

In the last quarter of the 1995/96 school year, a team of students in Wagner’s Earth Science class decided to do a research project on earthquakes. Wagner matched them with a graduate student in Geology whom I will refer to as Mandy. The following excerpts from her e-mail exchanges with the earthquakes team illustrate some of the kinds of support, both intellectual and emotional, that a telementor can provide for students. The relationship began with a fairly typical "hello message":

> Date: Thu, 2 May 1996
> Dear Mandy,

We are juniors at New Trier High School. We are participating in a group project involving earthquakes. Your help would be greatly appreciated. Our project is due on May 17.
Yours Truly,
Marilyn and Robert

Marilyn and Robert's initial greeting received a prompt and friendly reply. In it, Mandy attempts to help Marilyn and Robert set an agenda for their work. She cautions them about the shortness of their schedule, but tries to inspire confidence as well:

Date: Sat, 4 May 1996
Dear Marilyn and Robert,
Hello and welcome! Glad to hear from you. I'm really excited about working with you on this project.
> Our project is due on May 17.
Whew! Tight timeline, but I'm sure we can make it. My help is at your disposal. What aspect of earthquakes are you interested in? We first need to define the question/info that best grabs your interest, and then we can formulate a "research attack" plan for the project.
Draft a few ideas down on paper, then e-mail me back with the info. Once we have a good topic, we can hit the ground running.
If you're short on ideas, grab the local paper or the Tribune, or news magazines like Time, Newsweek, or even Discovery. With the recent earthquake in the Pacific Northwest, I'm sure the media has cooked up a few articles with cool graphics.

After this message, five days elapsed in which Robert and Marilyn brainstormed ideas for their project. This can be a very time-intensive process, requiring iterative reasoning, book research and consultation with the teacher. Students must consider not only what they are curious about, but which of their curiosities can most likely be addressed to their teacher's satisfaction using available data.

At the end of the five days, Robert broke the silence with Mandy by reporting the question that he and Marilyn had come up with:

Date: Thu, 9 May 1996
Dear Mandy,
I'm sorry about not really corresponding with you as much as I should... I'm starting to get nervous about not completing much on our project so far. The following is the exact question we are researching: Where and why do the largest earthquakes occur? Please write back. Thanx.
Your friend,
Robert

At this point in their exchange, Mandy sent Robert and Marilyn a long message suggesting a four-step process to completing their project. The steps, as she worded them, were:

1) Learn about earthquakes: what causes them and the three types of faults

2) What causes earthquakes: this is due to plate tectonics and you need to learn about the three plate boundary types: convergent, divergent, and strike slip...find out which one causes the deepest and strongest earthquakes

3) Where do the strongest EQ occur: find a world-wide map with dots showing the distribution of EQ the last decade or so. There are a few on the net but any intro Earth Science textbook should have such a map. Your local library has to have a text with it (school or city public libarary).

4) Match plate boundary location with the location of the strongest EQ: in doing this, you have defined the cause for the strongest EQ.

Robert was so impressed with this plan that in his next message, he expressed some concern about the amount of time that Mandy might be taking away from her job to help with his project. He also informed Mandy that the deadline for his final report had been extended somewhat. Note that in her response Mandy shares his relief, but stresses the importance of making good use of the additional time. She also requests a summary of the work he and Marilyn have done so that she can continue to offer informed advice:

Date: Tue, 14 May 1996
> It's me, Robert. I want you to know that I did get your rather large message sent
> on Friday. It will be very helpful.
> Thank you very much. Our new due-date is Monday, May 20, instead of Friday.

Alright! Deadline extensions are always a great feeling. Together we'll make sure to make the best of it!

As to the "four step plan", the approach is really that simple. And if you hit a stumbling block, just e-mail (or in last ditch effort as the deadline nears and you don't have computer access....call) because I have a small confession to make...I already know the answer to your thesis question. The steps I outlined last week are the exact same steps I put my undergraduates through to answer the same question within a 50 minute lab. They have it easier since I provide all the necessary references; you have to find them on your own.

E-mail a quick research summary the next time you get on the computer; that way I know where you are and can drop suggestions to make sure your time isn't lost on unimportant sidetracks.

Another confession....it doesn't take me that long to write these letters, so please don't worry about that. After being face to face with a comptuer since I was

6, I've been typing at 90+ words per minute since junior high. And also please don't worry about my finals and job because it's also my "job" to help you though as much of the research snarls that I can for your project. I'm a teacher here at the university, and I make myself available to my students anytime during the day, except after Letterman has read the Top Ten :-)

If you want me to read your paper before you turn it in, just attach it to an e-mail message and I'll review it and e-mail back suggestions.

Talk to you tomorrow, Robert -- Mandy

Two things are important to note in this message and the dialogue as a whole. First, this dialogue between Mandy and her mentees is driven forward by the project requirements and deadlines that the teacher, in this case Wagner, has put in place. These classroom events both stimulate needs for conversation and provide a common frame of reference in which the participants use dialogue to accomplish joint activity. A second observation relates to Mandy's comment about her role in helping Robert and Marilyn over "snarls" in their work. This is a fruitful way of distinguishing the kind of assistance that telementors should provide, which I will revisit and expand upon considerably in Chapter 4.

Finally, let me be clear that the kind of personal attention which Mandy provides in this case does not guarantee that students’ projects will be successful. Their project ideas can often come closer to realizing their potential with a telementor helping them handle the snarls, but the work itself is still up to the students, and is influenced by many factors over which a telementor can have no control. Students have great difficulty grasping what it means to do research, to analyze data, to write a formal report. They get sick, and miss school; they bicker with their teammates; they fritter away class time. Computers crash, and work is lost. It remains the teacher's responsibility to mediate these factors and help bring students' projects to the best possible conclusion. But with telementors sharing the burden of providing advice and guidance to their students, a teacher can encourage her students to pursue ambitious project ideas with greater confidence.

Building the Audience: Orchestrating Telementoring in Classrooms

As I mentioned earlier, my experience with telementoring began in 1994 as CoVis teachers and I were experimenting with uses of the Collaboratory Notebook software in freshman Earth Science classrooms. On the whole, these experiments were not particularly successful. My early failures to make telementoring more than a brief adjunct to classroom activity helped me to appreciate what Rory Wagner had been able to accomplish in his classroom in 1993/94. In my early experiments, students had seemed unconvinced of the worth of communicating with a distant adult as part of a project, even if that adult was reputed to be an "expert" on the subject they were studying. The few conversations that took place between students and their telementors seemed perfunctory, and trailed off quickly from disinterest. By contrast, Wagner had had roughly 60 students in three sections of his class working with telementors on a daily or weekly basis throughout most of the school year. What was he doing so differently?

Design Parameters for Telementoring

Curricular Occasion for Telementoring

My observations of Wagner's scheme for telementoring made it clear to me that the single most important design element in curriculum-based telementoring is the curriculum itself. Students did not participate enthusiastically in my early experiments with telementoring largely because it was clear to them that their work, and the standards that their teachers assessed it by, did not *necessitate* working with anyone outside the classroom. Because the curriculum goals were relatively uniform and pre-planned by the teacher, all the appropriate intellectual resources could be gathered conveniently at arm's length. At most, students might need to take a trip to the public library. Far from providing necessary assistance or additional interest-value to their projects, working with distant experts over computers merely added a needless complication for students who were still learning to use computers and were often slow typists.

In contrast, Wagner's implementation of telementoring had evolved as a response to the challenges he faced in teaching his class in a radical project-based fashion. His students' research projects covered such a wide spectrum of content and posed such a range of questions and problems that he could not hope to keep up with their needs for advice about new on-line data sources and methods of researching obscure phenomena. Twice his daily allotment of planning time would not be enough to meet this challenge. He and his students needed the kind of help that only other people, knowledgeable in these fields, could provide them with. Volunteer telementors provided the intellectual capital they needed to make an ambitious curriculum feasible. Wagner never viewed telementoring as a way to spice up the curriculum with technology use, but as a tool to enable pedagogical changes undertaken for their own sake.

Telementor : Student ratio

Teachers and researchers who are worried about the possible scarcity of volunteers to support curriculum-based telementoring often turn their minds to this issue first. While this issue did occupy our thoughts as Wagner, Whitcomb and I proceeded in our work, it was not for the reasons that might be expected.

Both Wagner and Whitcomb's classrooms contain a small number of Internet-capable computers. Having computers in the classroom itself (rather than a central lab) was an important enabling factor for telementoring in both cases, since it meant that project work in the classroom does not need to be interrupted for students to communicate with their telementors. Equally important was the fact that the teachers were not required to make special arrangements for staff supervision to, and in a lab space. On the other hand, because fewer computers fit into a normally-architected classroom than into a lab, each student's computer time is limited. In this arrangement, a ratio of one telementor per student would mean that practically nothing would get accomplished in a standard-length period besides reading and writing e-mail.

In order to accommodate these variables, Wagner and Whitcomb each adopted a scheme in which students worked in teams of two to five, each guided by one telementor. This arrangement served both to reduce the number of computers needed to make telementoring a practical reality, and brought the number of telementors needed to a more sustainable level. For deeper discussion of the potential size of the volunteer workforce for telementoring, see Chapter 8.

Length of Project

It is important for teachers, students and telementors alike to develop reasonable expectations about what can be accomplished through telementoring in a given time frame. Because the work schedules and routines of schools and adult workplaces differ so greatly, there will often be lags of a day or two between the receipt of a message by a telementor and the return of a reply. From time to time, when telementors' paid work takes them away from the office (for example, to a conference), these delays can stretch to several days.

This being the case, it is important for telementored projects to be planned with some opportunities to make up lost time. During the 1995/96 school year, this was more practicable in Wagner's class than in Whitcomb's. Given the seven-week period of communication that Wagner's students had with their telementors, they could miss a mid-term milestone or two and still manage to catch up if they were eager enough. Attempts to catch up sometimes prompted what I refer to as "crisis" messages, in which students would urgently appeal for aid in getting back on schedule. On more than one occasion students did get back on track, forming a stronger bond with their telementors in the process.

In contrast to Wagner's experience, Whitcomb's much shorter Balanced Community project fell victim to a hectic end-of-year school schedule. This prevented the students' experience with telementoring from having much of the closure hoped for. In particular, none of the students' final reports were sent to their telementors for review, despite Whitcomb's good intentions. This disappointing outcome was largely the fault of a series of previously-unannounced school assemblies; there was simply no buffer time in the activity structure to accommodate slips or delays.

Activity Structure

After the curriculum itself, the activity structure is the second most important design element to consider when orchestrating telementoring. What I will refer to as an activity structure in the chapters that follow is, essentially, a set of roles and responsibilities for students, telementors, and the teacher, connected to a schedule of deliverables. Taking a leaf from Wagner, I refer to these as "milestones". Rather than attempt to explain activity structures further here, I will offer one I produced with Whitcomb for her Balanced Community project. This is shown in Table 3.

Table 3: Activity structure for the Balanced Community project

Stage of Project Cycle	Students	Mentor	Teacher
Introduction	Introduce themselves to the mentor	Introduce him/herself to the mentees	- explain the role of the mentor in the project - distribute guidelines for telementoring - explain the role of the students as they interact with the mentor
Set the Scenario	- describe the project to the mentor - describe the task of their group in the project	Ask any questions necessary to clarify the nature and purpose of the project in a way that helps the student focus on the problem	- aid the student in answering the mentor's questions, if they are having difficulty with interpretation or explanation - review communication to make sure that the students are on the right track
Project Proposal	Explain the "plan of attack": - how they will go about investigating the problem - how the information will be presented to the town council (peers) and mayor (teacher)	- review the plan for investigation and presentation - point out logical procedure for investigation - comment on the elements for the presentation that are professionally acceptable	- review mentors' comments. - bridge the comments with realistic expectations in respect to students' developmental and experiential abilities - discuss with the students those suggestions which are feasible and "doable"
Drafts of Milestones	- provide the mentor with all the drafts or milestones submitted to the teacher - provide the mentor with plans for the model	- provide critical commentary and positive reinforcement to students and teacher - provide critical comments on the value and construction of the model	- review mentor's feedback with each group
Between Milestones	Request help in locating resources, collecting and/or interpreting data, reformulating questions, etc.	Make all reasonable efforts in helping students in understanding data and other resources, pointing them to other sources, clarifying questions, analyzing results and drawing conclusions	
Final Project	Provide mentor with final paper and photo of model	Make recommendations to the teacher with respect to students' evaluation, including but not limited to: effort, quality, logical progression from problem to final project	Consider mentor's recommendation, consult with students if necessary, determine grade as seems fit

Note that the activity structure in Figure 3 is richer from a typical set of deadlines. It spells out the participants' responsibilities not only to their work, but to each other as that work is being completed. Especially important, it describes what the teacher expects to do to support the students and telementors in their work together. In these ways, the activity structure serves both as a curriculum planning document for teachers, and as a tool for communicating their expectations to students and volunteers.

Monitoring of Telementoring Dialogues

A healthy majority of the teachers and researchers with whom I have discussed telementoring over the years (but who have not experienced it themselves) feel it absolutely necessary to monitor the e-mail that passes between telementors and students. Their concerns over monitoring may arise from a variety of perceived needs, including the need to assuage parents' or students' concerns about the volunteers in an atmosphere of media hype about "net sex", the need to protect telementors from unreasonable requests by students, or the need to protect students from impolite or overly-demanding telementors. Each of the teachers I have worked with has adopted a different approach to the monitoring issue, these are worth discussing at some length.

Wagner's monitoring strategy. Wagner has never considered it practical to directly monitor the e-mail exchanges that take place between his students and their telementors. His 60 students and their telementors simply produce too great a volume of e-mail for him to read, in addition to the regular barrage of work-related e-mail he receives. Because he administers his students' e-mail accounts himself, Wagner has always had the technical capability to read his students' e-mail whenever he likes, and in conversations with his students I found that many assumed that he did this periodically. For the most part, however, Wagner relies on his students and their telementors to contact him with any concerns that arise. In practice, this does not occur often enough to create an unreasonable burden for him. In fact, he enjoys his periodic e-mail exchanges with telementors, which serve to remind him that scientific professionals do, in fact, appreciate his work.

While Wagner does not choose to monitor telementoring exchanges from his own computer, he does conduct over-the-shoulder spot checks as part of his regular teaching routine. While he circulates through his classroom, checking in with student teams about their progress, he will ask how their work with their telementors is going. If students suggest that their telementors are not being helpful, he may ask to see some of their messages. Sometimes this over-the-shoulder review results in teams being assigned to new volunteers. On other occasions, Wagner is able to help his students to see the value in their telementors' messages. In focus groups, a few of Wagner's students expressed amazement at what he had been able to "pull out" of telementors' messages — in particular, advice which they had not understood or appreciated on first reading.

Whitcomb's monitoring strategy. In her first telementored project, Whitcomb took quite a different approach to monitoring exchanges between her volunteers and students. Perhaps because she wanted to learn everything she could from her first attempt to orchestrate these relationships, and perhaps because she was concerned that her volunteers might expect too much from her students, she elected to review each and every e-mail message her students exchanged with her 6 volunteers. Because of her busy school schedule, this task had to be done on her own time at home, where she happened to have dial-up Internet access. In practice, she could only afford the time to review the e-mail exchanges every two or three days.

While there were few occasions on which Whitcomb needed to step in and remediate on the basis of her reading, she did derive an unexpected benefit from it. She had previously told me about the "breakdowns" she had experienced in project work with her students. It would seem as though they understood their assigned tasks very well, along the way to completion something would get lost. She had wondered about this a great deal, but simply did not have the knowledge she needed to understand how and why these breakdowns occurred. She believes that listening in on her students' conversations with their telementors allowed her to "step back" from her position as a teacher, and observe more closely where the breakdowns were occurring:

> ...one of the things that we've talked about already was my ability to step back from being immersed in the project itself. So that I have gotten a lot of good information as far as where there's breakdowns when I ask the kids to do something. On my part, or something that isn't clear. By being able to read the communication between the kids and the mentors, that was very helpful for me, and gave me a lot of insights that I'm going to try to specifically address when I set up a project like this again.

This issue of "stepping back" will be re-visited at the end of Chapter 7.

Products Produced by Students

As the case studies of telementoring in Chapters 4 and 5 will illustrate, it is difficult for a telementor to effectively advise students on their work without regular progress reports as fodder. In the best case, telementors should have access not only to reports from students about how their work is progressing, but also drafts or portions of the final products that they will be submitting to their teacher. Of course, this scheme necessitates a curriculum in which students are regularly producing such artifacts in a form that can be shared electronically.

In the design experiments discussed here, both Wagner and Whitcomb adopted a system of deadlines for their students structured around what we called "milestones". Milestones are submissions required from students at regular intervals in a project cycle, which demonstrate their progress toward the final goal. The types of products may vary with the type and purpose of the project, but the objectives are the same. First, milestone products should combat procrastination by pushing students to tackle small pieces of the project in a sensible order. Second, they should providing an opportunity for the teacher to provide feedback to students and help them make mid-course corrections on their projects while they can.

Wagner began to implement milestones in his classes years ago, and his scheme has undergone constant refinement since that time (some of which is discussed in (Polman, 1997)). Currently, Wagner's milestones include a broad project topic (e.g. "Earthquakes"), followed by a more specific research question (e.g. "Do more earthquakes always occur at plate boundaries with higher velocity?"), and a specific data set and analysis plan. Finally, students incorporate the milestones into a final research article.

When I described Wagner's scheme of milestones to Whitcomb in one of our planning meetings, she immediately saw it as a possible solution to some of her own problems in implementing project-based science with her students. She incorporated this idea into the Balanced Community project immediately.

Stumbling-blocks to Telementoring

In addition to the design parameters mentioned above, it is important for teachers who orchestrate telementoring to consider two important stumbling-blocks: the complexity of organizing telementoring and students' naive conceptions of expertise and "help".

Organizational Complexity

The single greatest stumbling-block to routine, curriculum-based telementoring is the organizational effort it demands from teachers. This effort includes the tasks of recruiting volunteer telementors, matching them with teams of students, and managing and monitoring communications mentors and mentees. I will not elaborate on these demands here, but in Chapter 9, I will discuss a technological tool called the CoVis Mentor Database which I designed to lessen the weight of these demands on the teacher.

Students' Naive Conceptions of Expertise and "Help"

Telementoring is such a new experience for most students that it strains their conceptions of the nature of expertise and their abilities to recognize the value of the advice that telementors offer to them. Wagner continues to struggle with these issues on a weekly basis. In an interview, he and I discussed how he copes with them:

> What I do sometimes, I guess, is when kids say the [telementor] is not being helpful, I say, "what are they saying? What should you be doing? What do they suggest?" Usually when I see mail messages, what [the telementors are] saying is really great stuff! And you have a lot of that stuff, I mean, it hasn't changed that much from last year to this year. And yet the kids don't interpret them as being good stuff. They think, "he's leading us down a garden path," or "he doesn't know what he's talking about." Why is that? Something they have set in their head, I think, about the way the whole process of doing science works.

In Chapters 4 and 5, I will discuss specific cases that illuminate the challenges associated with students' developing conceptions of expertise. In addition, Chapter 7 will discuss longitudinal data from surveys conducted in Wagner's classroom which suggest that students' conceptions of expertise are enriched through repeated experiences of telementored projects.

Summary of the Wagner Design for Telementoring

Wagner's design for telementoring is summarized in Table 4. As discussed by Polman (Polman, 1997), Wagner employs a largely reactive teaching strategy in his work with students. He will invest a great deal of time with student teams to refine and enhance their research projects, but only if and when they ask him to. This teaching strategy grows out of Wagner's personal experiences with his master's thesis advisor, and a deep-seated belief that students need to "find their own motivation" in order to succeed.

Table 4: Summary of Wagner's design for telementoring

Wagner design for telementoring	
Curricular Occasion	Research projects, planned and executed by students in a largely independent fashion. Students choose the phenomena they would like to study within the domain of the course (Earth Science). They are required to provide some form of numerical data analysis to address the research questions they raise.
Ratio of Students to Telementors	3:1 to 1:1
Length of Project	~10 weeks

Products Produced	Research Article, milestone documents (broad topic, research question, data and analysis plan, research article)
Monitoring	periodic over-the-shoulder spot checks

Wagner's orchestration of telementoring is complementary to this largely reactive teaching style, and in part is motivated by it. Because Wagner usually does not intrude on students' work unless they explicitly ask for his help, students have a strong incentive to seek the aid of their telementors and to "bond" with them, despite their distance. As one student remarked to me, with some exaggeration, "It's like you're on your own with your mentor."

I mentioned earlier that to help ensure that students make good use of their independence, Wagner has developed a system of deadlines structured around "milestones". These milestones, which are listed in Table 4, are of great use to him in his own monitoring and guidance of students' work; but unfortunately he has yet to settle on a practical way of ensuring that students share these milestone documents with their telementors. Thus, while the due dates for various milestones often drive students' e-mail discussions with their telementors, the telementors do not always have the chance to examine them and offer advice for their improvement. The practical implications of this and other features of Wagner's design are vividly illustrated in my case studies in Chapters 4 and 5.

Summary of the Whitcomb Design for Telementoring

When Whitcomb and I set out to design and implement telementoring together in her classroom, we were fortunate to have Wagner's example to follow. Nonetheless, the question remained whether Rory's brand of telementoring could be tailored to fit a radically different, urban school setting. The occasion for our first attempt at this adaptation was a project which Judy created as a wrap-up for the 1995/96 school year. The project, titled "A

Community in Balance", engaged Whitcomb's students in a fictional scenario in which they played environmental consultants. It was largely intended to integrate themes and subject-matter which she had worked on with her students earlier in the year, to give her students a chance to pull loose strands together.

The scenario was described as follows in the brochure that Whitcomb prepared for her students and distributed to their telementors:

> You are a member of a team of environmental engineers. Each team is comprised of people who have specialized in explorations of the following areas: soil, water, and health. A small community, Nadroj, has asked you to use your expertise as they determine whether or not a paper mill should be built in their community.
>
> Nadroj is a community that has experienced major economic problems in recent years. Once a steel mill provided a vast number of jobs in the community. But in the past ten years, the mill had to cut back on employment and now it has closed down....
>
> Recently, a proposal was made to construct a paper mill near the town. While the immediate reaction of the town council was to accept the proposal, there was strong opposition by government environmental agencies who feel that the paper mill will severely and negatively impact on the environmental health of the community. The debate in the city council has centered around the construction proposal. Each side has provided valid arguments for and against the construction of the paper mill. Tempers began to flare.
>
> In order to resolve the problem, you and the other environmental engineers have been asked by the community to examine the issues of possible soil and water damage and the related human health issues in order to provide a plan that will allow the construction to take place without major damage to the community's environment.

Whitcomb's students were asked to work with their volunteer telementors to develop knowledge of how paper mills work and the kinds of pollution they can create. At the end of the project, each team was to deliver a position paper on the issues related to their particular specialty (air, water or human health) and deliver a briefing to the "city council" (other teams in the class) and the "mayor" (Whitcomb) based on the paper. The principal challenge of the project, as planned, lay in the need to research the potential solutions and costs and associated with pollution from paper mills, and determine a course of action which would balance the community's economic needs with its environmental health. In addition, students were asked to produce a physical model of a paper mill which stressed the processes they had studied in detail.

As one might expect, a number of Whitcomb's students were tempted to oversimplify the problem by rejecting the paper company's proposal out of hand. In fact, one team's ultimate "solution" to the problem was "to build a crayon factory instead, because crayons are non-toxic." The other five groups appeared to engage the problem much more seriously, drawing upon the expertise of their telementors to construct more complex understandings of the problem. This was no small feat, since by Whitcomb's own description her students were:

> ...quite opinionated (typical of the junior high student).... We have spent much of the year trying to direct that energy into constructive research (What is your evidence?) and open minded listening. They rotate to three other teachers in the morning for other core subjects and the teachers often find my class to be a little overwhelming with their expressions of independence.

Table 5: Summary of Whitcomb's design for telementoring

Whitcomb Design for Telementoring	
Curricular Occasion	"Community in Balance" Project, in which students play the role of environmental consultants to a city council considering a construction proposal from a paper company.
Ratio of Students to Telementors	5:1
Length of Project	1 month
Products Produced	Physical model of a paper mill, position paper for "city council", oral presentation
Monitoring	Thorough reading every 2 days

Table 5 summarizes Whitcomb's design for telementoring, which in several respects was quite successful. Though the project was implemented at the very end of the 1995/96 school year, the students were surprisingly engaged in their work and enthusiastic about working with their telementors. In part, their high engagement may have resulted from the fact that this project was the students' first opportunity to use e-mail. In fact, when I asked the students in focus groups why they thought their teacher had chosen to run the project, a majority seemed to believe that technology training was a key objective of the project. In retrospect, Whitcomb did not find this surprising:

> I think the newness [of e-mail] certainly was a factor. You know, it was a promise that I held all year to them, "oh, you're going to get to use e-mail." ...You know, I'm sure that I used it as a carrot.

Unfortunately, after a promising start, the Balanced Community project failed to reach closure. The most notable reasons for this were a somewhat over-ambitious plan (a product of simple inexperience on both Whitcomb's part and mine), and an end-of-year school schedule filled with unscheduled assemblies and extracurricular activities. As an example, one group of students was even pulled out of a research focus group with me to participate in a sporting event!

I will leave further discussion of Whitcomb's implementation of telementoring and its results for Chapter 7.

Chapter 3: Research and Evaluation Methods

Having introduced the motivations for my telementoring design experiments in Chapter 1 and explored some of the challenges of this work in Chapter 2, this Chapter will provide an overview of the questions that this dissertation was designed to answer, and how they have been approached.

Research Questions

It was clear to everyone involved in my research that its main purpose should be formative. Telementoring is a very new area of research and practice in which there is a strong need for careful empirical work. While a one-year study involving just over 100 students could not hope to produce a general theory of telementoring, it could certainly produce detailed accounts of telementoring activity and its outcomes which would have diagnostic value. By diagnostic, I mean that the research measures and analysis should make it possible to judge why some number of telementoring relationships succeeded or failed. One could generalize cautiously from these cases to inform future designs for telementoring.

With the goal of diagnostic value in mind, I set out to document successful and unsuccessful telementoring relationships well enough to yield working hypotheses about how the orchestration of telementoring might be improved. Listed below are the major questions that my collaborators and I had in mind as we undertook our design experiments, and the Chapters in which I have attempted to address them.

Table 6: Research questions and chapters in which they are addressed

How does each teacher implement telementoring?	Chapter 2
How effective is each model of telementoring?	Chapters 4, 5, 6, 7
What varieties of mentoring activity occur?	Chapters 4, 5, 7
Does telementoring influence how students argue about their work in writing? How?	Chapter 6
How do scientists evaluate students' written work?	Chapter 6
How sustainable is each model of telementoring?	Chapter 7
What do teachers and volunteer telementors want and expect from telementoring?	Chapter 7
How often do they get what they want and expect?	Chapter 7

The questions listed above originated both from a belief in the importance of understanding how telementoring can be tailored to suit particular circumstances, and from a concern to inform the efforts of educators and researchers following in our footsteps. Accordingly, our questions fell into two groups: those related to the *effectiveness* of a telementoring strategy with respect to our own goals, and those related to the *sustainability* of telementoring as a strategy for supporting wider reform. Figure 4 illustrates in greater detail the relationships of these questions to each other and to the data I collected.

Methodological Challenges

Challenges in the Study of Mentoring Relationships

While telementoring is a new phenomenon, requiring new approaches to research design and analysis, a considerable amount can be learned about how best to approach the study of telementoring by examining the methodological concerns of researchers of traditional mentoring. In their reviews of the literature on traditional mentoring in various work and educational settings, (Healy & Welchert, 1990) and (Jacobi, 1991) identified a number of methodological flaws. To summarize, the chief ones are:

- **A tautological definition of mentoring**
  It is assumed by the investigators that whomever is assigned the role called “mentor” actually fulfills the role. Whatever desirable things the “mentors” do are (sometimes mistakenly) assumed to be a necessary part of a more general mentoring role that appears throughout society.

- **Definitions of the mentor’s role and the relationship between mentors and protégés vary widely among studies**
  Largely as a consequence of the mistaken assumption described above, studies of traditional mentoring have historically produced very different definitions of the mentoring role. This makes it very difficult to compare studies, and near impossible to build a generalized knowledge base about mentoring.

- **Use of research methods that can’t capture the development of mentoring relationships**
  Often, researchers have used only retrospective survey instruments or interviews to gather data on mentoring. Other studies have employed a simple pre and post survey design. Both of these approaches have serious drawbacks. Besides being plagued by all the problems of self report (Nisbett, 1977), retrospective surveys and interviews often cannot be administered more than a few times during the intervention due to their invasiveness. Thus, this research strategy yields too few data points to shed much light on how relationships develop (or don't develop) between mentors and protégés.

Considering this set of criticisms, I constructed the following “wish list” for a research design aimed at producing practical advice to teachers and researchers attempting to orchestrate telementoring. I believed that such a study should:

a) Develop clear inclusion and exclusion criteria to identify where mentoring relationships have developed and where, in contrast, the assigned “mentor” is merely performing a question-answering or data-discovering service for the students.

b) Employ non-invasive measures wherever possible. Because the teachers and students with whom I was working were participants in the CoVis Project and active in its ongoing research and development activities, they were heavily enough researched to begin with. Invasive measures such as lengthy surveys were therefore unlikely to produce useful results.

c) Provide diagnoses of successful and unsuccessful mentoring relationships which might inform the redesign of activity structures and technological supports to support telementoring.

Challenges of Classroom Research

As my readership is most likely aware, the challenges of conducting research in classrooms are formidable. Of special concern to me in the design of this research was the difficulty of collecting sufficiently rich data about the influences of telementoring on students' work without alienating my research participants by stealing time and attention away from their customary activities. In the section below, I will explain how I attempted to cope with this challenge by employing a stratified sampling methodology, and developing an instrument to use some of the students' usual classroom work as primary data.

Data Collection Strategies and Rationale

Using my "wish list" for mentoring research and my need for a non-invasive approach as a starting place, I began to define the data requirements for an evaluation of the telementoring design experiments I ultimately carried out with Wagner and Whitcomb. In this section, I will discuss each type of data gathered for this research and the purposes it served. For quick reference, Figure 4 provides a summary of the data sources, and their relationships to the research questions.

Mentor-Mentee Correspondence

The Mentor Database service that I constructed as part of this research (see Chapter 8) enabled me to collect a large sample of the e-mail exchanged by telementors and mentees throughout their work together. Since the students' relationships with their telementors were mediated almost entirely by e-mail, this scheme allowed me to address some of the most important faults in past research on mentoring. First, the e-mail capturing mechanism provided a means to non-intrusively collect data on the development of the mentoring relationships without relying on self-report. These data also supported a more detailed analysis of the mentoring functions provided in each relationship than has been presented in much previous research (see Chapters 4, 5 and 7).

Despite these advantages, the e-mail logging and routing mechanism that I constructed for this research did have its flaws and limitations. One of these is its reliance on both students and telementors to pay heed to, understand, and follow instructions. In order for the logging mechanism to work correctly, both students and their telementors must address their messages to a central routing address ("mentor@covis.nwu.edu"), rather than directly to each other. Message headers are modified while passing through the router so that replies automatically return there. Students and mentors participating in my research were told that mailing to "mentor@covis.nwu.edu" would not only provide me with a record of their correspondence, but would have the added benefit of ensuring that each of the participants in the relationship (sometimes as many as six) received a copy of every e-mail message sent by any of the others.

Students' and mentors' confusion with the necessary instructions resulted in a number of e-mail logs which were clearly incomplete. As a sample, however, I believe that the logs are fairly representative of the correspondence that took place. None of the focus group data give me reason to suspect that students or telementors deliberately circumvented the e-mail logging mechanism to avoid my scrutiny, or that the people who failed to follow my instructions were, as a group, systematically different from the others with respect to their development of telementoring relationships.

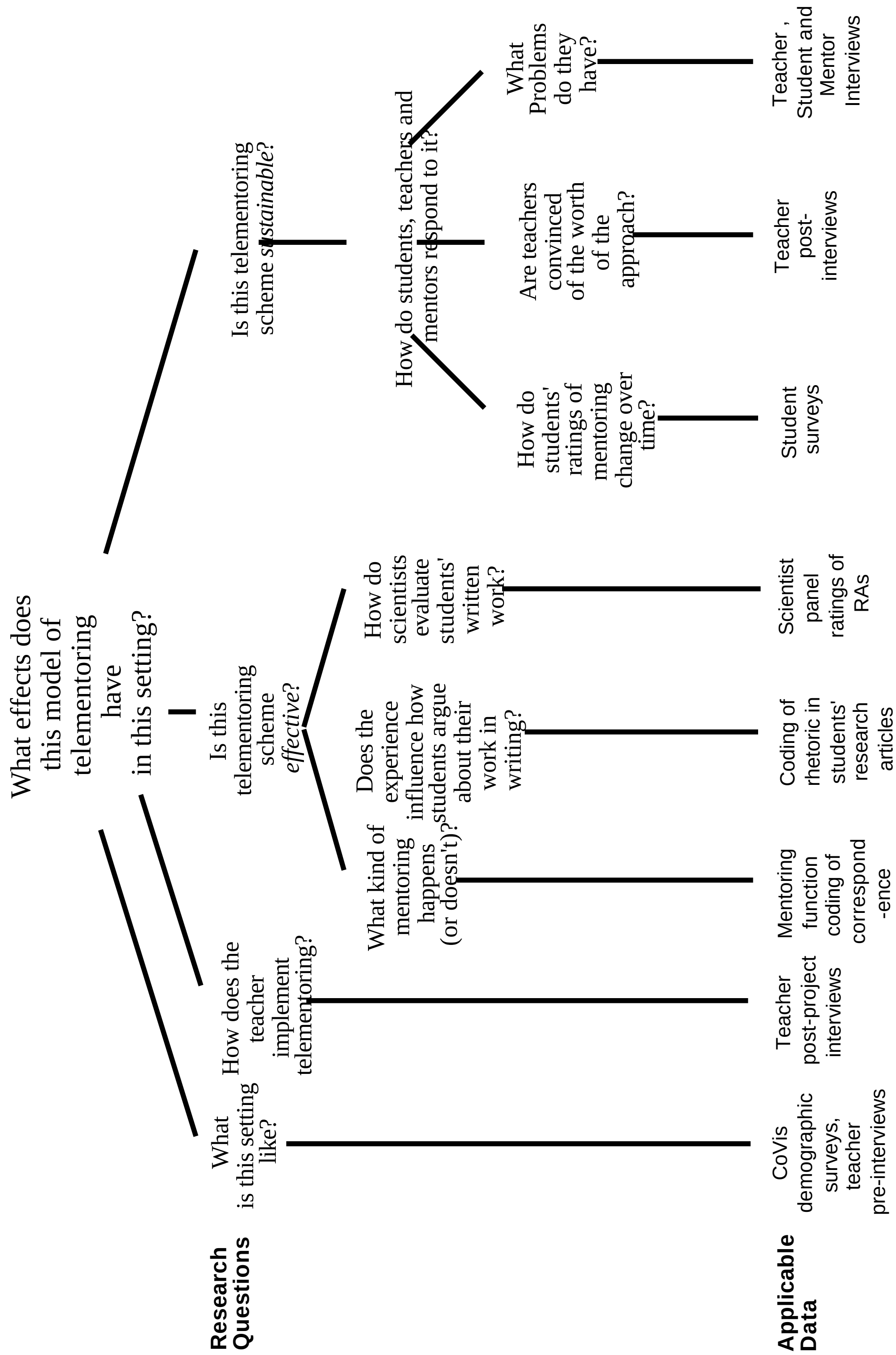


Figure 4: Relationship of research questions to data collected

Student Surveys

While very useful, records of electronic correspondence are not enough by themselves to provide a diagnostic account of a telementoring relationship. These records can tell the researcher what words passed between a group of students and a telementor, but cannot reveal what motivated the dialogue or what it meant to the participants themselves. Both of these factors are important to an understanding of how to replicate successes and avoid repeating failures; therefore, a truly diagnostic account of telementoring relationships needs to employ richer data

Interviewing the participants in a relationship is the best way to learn about its dynamics. Unfortunately, given how time- and labor-intensive a process interviewing is, I could not gather detailed data on all of the telementoring relationships taking place in Wagner's classroom at any given time. I needed some principled way to focus my efforts on a few relationships at a time, and surveys served this purpose.

I had personally administered enough paper surveys to be wary of their invasiveness. Often students, not understanding what use the data are put to, consider them a meaningless exercise and complete the Likert or multiple-choice items randomly. Worse yet, the students most resistant to surveys are usually the ones most dissatisfied with school, whom the designer has the most to learn from. For these reasons, I kept my survey instrument very brief.

Appendix A is a version of this survey form, which the teachers and I administered to all students in the participating classes at the end of each telementored project. An early version of this survey form was created by Rory Wagner before our partnership began, for the purpose of informing his own teaching practice. Over the course of several administrations, I made substantial changes and additions to his design, both to facilitate data analysis and to satisfy more of our curiosities as we developed our research agenda together. Among the most useful of the survey items is one which asks students to rate their level of agreement or disagreement with the statement, "overall, the mentoring was a success for me." Using each team's average response to this item as a criterion, I constructed a stratified sample of telementoring relationships to examine in greater depth.

Student Focus Groups

By far the richest data I collected were from focus groups with student research teams. These were intended to aid my interpretation of students' e-mail exchanges with their telementors, and to give the students a voice in explaining why particular relationships had succeeded or failed. They also provided students with an opportunity to suggest what might be done to improve the design of the activity structures for telementoring, the technologies used, or both.

At the end of each project cycle, I used students' responses to the telementoring survey to construct a list of project teams with whom I might conduct focus groups. In Whitcomb's class there were few enough research teams that I was able to schedule meetings with them all (though one meeting was cut short). In Wagner's class, I tried to schedule meetings with six teams per project: two whose average satisfaction rating for telementoring was very low, two whose rating was very high, and two whose rating was close to the overall average for the class.

Getting all the students in a research team together outside of class was often difficult, for reasons ranging from simple forgetfulness on the part of the students to absenteeism. In response to these problems, I began to present my list of potential focus groups to Wagner for an up-front assessment of the likelihood of arranging a meeting. On some occasions I was forced to replace one team with another whose average satisfaction with telementoring was similar. At other times, I had to be satisfied with only five focus groups per project cycle.

Each of the focus group meetings, which ran from 45 minutes to more than an hour in length, was conducted in a quiet room in the school building, and was videotaped. The final version of the focus group guide used in these meetings is provided in Appendix B, but I will summarize the contents of the guide here. The focus group questions spanned six broad themes:

- Students' general impressions of telementoring
  At the very start of the focus group, the team was given five minutes or more to sound off about telementoring any way they liked. Students would usually either rave or gripe about their telementors, setting the tone for the rest of the interview.

- What students in the class can get out of telementoring
  If the first question did not garner much of a response, this set of questions usually separated teams with a poor opinion of telementoring from those who saw some promise in it.

- How and at what points in a project telementors can be useful
  I was surprised at how little the responses to this question varied within each classroom.

- The teacher's reasons for orchestrating telementoring
  This was a very informative set of questions from a design standpoint. In the worst case, students saw telementoring as an attempt by their teacher to avoid work or to force students to use e-mail.

- Telementors' reasons for volunteering
  Students' responses to questions on this theme were usually quite revealing. Most students who had been involved in successful telementoring relationships had more than one theory about what motivated their mentors, though they might not be confident about them. Students in failed mentoring relationships either had never considered the issue or insisted that they had "no idea" what might induce an adult to become a telementor for no pay.

- Teacher's reasons for asking students to write reports in the Research Article (RA) genre.
  This question probably brought the most intriguing variety of responses. All things considered, students in Wagner's class seemed less likely to doubt the worth of writing papers than any other aspect of their project work. In Whitcomb's class it seemed to be almost the reverse.

While the focus questions were not about specific telementoring relationships, students were usually best able to frame their answers using stories about particular situations which had arisen between them and their telementors. These stories provided ample opportunities for me to probe for fuller explanations.

Telementor Interviews

Often after conducting a focus group with a team of students, I arranged to interview their telementor by telephone. These interviews, which lasted between a half hour and an hour, revolved around the volunteers' expectations of telementoring, the nature of the relationships they had experienced with students and their teachers, how telementoring fit into their work routines and their organization, and their desires to continue telementoring (the interview guide is provided in Appendix C).

The telementor interviews were most valuable to me in constructing the case studies of telementoring presented in Chapters 4 and 5; however, they also helped a great deal in refining my perspective on what motivates people to volunteer as telementors, and what types of experiences are most likely to bring them back. For example, the particular characteristics of each volunteer's work setting have a larger influence in this regard than I had expected. In some work settings, telementoring did not need to be formally sanctioned or formally recognized in order to take place. Most of the graduate student volunteers I spoke to, for instance, had not even mentioned to their advisors that they were working as telementors. They felt no need to do this, since they could easily fulfill their commitments to their mentees during breaks between classes or in spare moments in the lab. However, in work environments where the volunteers' paid work time was tracked closely and billed to accounts (environmental consulting firms, for instance), volunteers found official sanction from their supervisors a necessity.

Teacher Interviews (Pre and Post)

While I learned a great deal from the informal conversations that Wagner, Whitcomb and I had throughout our partnerships, I felt it necessary to set aside time for formal interviews with them as well. These interviews gave us space to discuss issues requiring lengthier, more thoughtful, or more sensitive treatment than time stolen before and after classes would permit. I refer to the two sets of interviews I conducted with each teacher as "pre" and "post", but only because they took place before and after telementored projects. They were not designed as part of a traditional change study, and each used an entirely different interview guide.

For the pre-interview, my objective was to find out more about each teacher's past experiences of mentoring in other settings and create a record of each teacher's opinion on what I expected, from pilot work, to be pivotal issues for implementing telementoring successfully. The post interview was based on an entirely different set of prepared questions and was meant largely as a retrospective. Having set out to implement telementoring with certain ideas in mind, how satisfactory did the teachers find their experience? What did they find surprising about this experience, and what aspects of it (technological, organizational, etc.) would they like to change the next time around?

Unlike most of my other data, the teacher interviews were not intended to shed light on the dynamics of specific telementoring relationships. While it was sometimes useful to approach my questions by discussing how telementoring was involved in the work of particular students, the main focus of our attention was on the design decisions that had been made, either by the teachers or myself, and how these seemed to have worked.

Pre-telementoring Interview

The first few minutes of my pre-telementoring interview focused on the teachers' experiences of mentoring in their own personal, professional and academic lives (these data are discussed in Chapter 2). I suspected that these experiences would be one of the teachers' most valuable resources in their efforts to explain the nature and potential of mentoring relationships to their students. As the teachers' experiences varied, so might their abilities to explain the "help" that a telementor might provide besides information or answers to questions.

Another set of interview questions revolved around the teachers' pedagogical goals for their telementored projects, and how they expected telementoring to contribute to the satisfaction of these goals. This set of questions provided the teachers and I with an opportunity to step back and carefully consider what value telementoring should add to their students' projects, before the projects began. It also provided an opportunity to discuss the unique concerns of each teacher about how telementoring would work with their students. This set of issues is discussed at the openings of Chapters 6 and 7.

My final set of questions for the pre-telementoring interview revolved around the teachers' past experiences in helping students to write research articles about their science projects. How often had they required this type of writing? How satisfied had they been with their students' work? What techniques and approaches did they use when teaching students to write research articles? It was not only important for me to know the answers to these questions; it was important for the teachers and I to have a focused opportunity to discuss the challenges of this aspect of our work.

Post-telementoring Interview

At the end of the 1995/96 school year, I conducted structured interviews with Wagner and with Whitcomb to discuss what had most satisfied and disappointed them about their implementations of telementoring. These interviews are best understood as a kind of debriefing, aimed at determining what complications had arisen in each implementation of telementoring, and how these might be addressed. Some of the questions I asked in these interviews included:

- How happy were you with the contribution that telementoring had made to their teaching?
- What surprised you most about telementoring?

- What aspects of telementoring took up the most time for you? Could this be reduced in any way?

The complete guide for the post-telementoring interview is provided in Appendix E. The data from these interviews are drawn upon most extensively in Chapter 7.

Students' Research Reports

As one might expect, students' research reports were the simplest data to collect, but the most difficult to analyze. The motivations and methods for my analysis deserve some lengthy discussion, which I will provide under the heading "Genre Analysis" in the next section.

Analytical Approaches

Exploiting Natural Variation

One of the most important features of the research design presented here is its use of natural variation, rather than specially-crafted experimental conditions, to explore the relationships among the variables under study. At an early stage of my research planning I considered a more experimental design, but my committee and I rejected this idea in the end. The most important arguments against an experimental design were that:

- It would defy my objective of conducting non-invasive research.
- Getting buy-in from teachers and students for such a research design would be more difficult. Who, after all, would want to carry out a "lame duck" condition which we hypothesized to be inferior?
- There was no single hypothesis crying out to be tested which was more compelling than other research opportunities related to how telementoring is carried out and what the relationships are like.

These considerations together made it clear that the practice of telementoring was in too formative a stage for research in the traditional paradigms of Psychology to be useful. Much more could be learned by committing our best efforts to all participants, and strategically sampling from them afterward, than by dedicating half of them to test a single hypothesis.

Instrumental Case Studies

Much of the work I will discuss in Chapters 4, 5 and 7 is based on what (Stake, 1995) refers to as "instrumental" case studies. Using the student survey data, I constructed a diagnostic sample of successful and unsuccessful telementoring relationships. The focus group, interview and e-mail data surrounding this sample then informed my view of the characteristics that were most likely to benefit a particular design for telementoring. This data analysis was instrumental in the sense that both the selection of the cases and the analysis of the data were directed toward yielding design advice, rather than the deepest possible understanding of each case.

My data analysis was conducted with the knowledge that in some respects, telementoring relationships *cannot* develop in the same ways that traditional mentoring relationships do. Unlike many work-oriented mentoring relationships, such as those discussed by (Kram, 1985), the telementoring relationships that I studied were not developed in the context of a single work setting that creates and perpetuates interdependence between the participants (mentors and mentees). In traditional work settings, mentoring relationships can arise spontaneously between workers and their supervisors; but in telementoring, this cannot occur. For this and other reasons, the students who participated in my research were in a position of greater control than mentees in a company. As we will see in Chapters 4 and 5, this difference has strong consequences.

Notwithstanding the differences between traditional mentoring and telementoring, I believed that a detailed coding of the dialogues between telementors and mentees would enable me to judge when and where students and telementors had developed relationships approximating mentoring. Ultimately, this analysis of telementoring dialogues, along with the participants' own diagnoses of the relationships, might afford explanations for the success and failure of the telementoring relationships on which I had chosen to focus. These explanations, in turn, would provide practical guidance for the orchestration of telementoring. See the end of Chapters 4 and 5 for some of this guidance.

E-mail Coding

Using a piece of software for qualitative research called QSR NUD*IST (QSR, 1997), I developed a coding scheme to represent the topics of conversation and types of conversational moves I observed in the e-mail exchanges between students and their telementors. The coding categories were developed through the typical inductive process of reading and coding each message, proceeding to the next one, attempting to apply the existing categories, and where necessary, creating new ones which could be applied on the next pass through the data. Later, some categories were collapsed and re-arranged to create a scheme which was more parsimonious and which better assisted the retrieval of pertinent quotations used in case studies and elsewhere.

The scheme includes three main sets of coding categories for e-mail dialogues between students and their telementors. Many of these categories are not mutually-exclusive, but can applied in an overlapping fashion. Some of the most useful categories represent the speakers (telementors or students), topics discussed, and types of conversational moves being made. The "moves" performed in each message relate to the apparent function of messages and message fragments in the dialogue as a whole. These categories include:

- Hello
  Students introduce themselves to their telementor, explain their ideas or objectives for their project

- Goodbye
  Students or mentors send what they believe will be their last message to each other

- Question

Students or mentors ask a question

• Request
Students or mentors make a request

• Advice
Students or mentors (usually mentors) offer advice

• Complaint
Students or mentors complain to each other (usually about a lapse in correspondence or overly vague requests by students)

• Apology
Students or mentors apologize (usually for a lapse in correspondence)

• Compliment
Students or mentors compliment each other

• Paper or draft of paper for review
Students send all or a portion of their report for their telementor's review

In addition to these conversational move categories, a number of topical categories were also developed and applied to the messages in an overlapping fashion. Some of the sub-categories in this portion of the coding scheme include:

• The students' project idea
This may be mentioned in several different contexts during a telementoring dialogue. In each context it might be expressed as a question ("Where are the strongest earthquakes, and why are they there?"), a thesis ("X704 is a black hole"), or a topic ("We have decided to do our project on dinosaurs").

• Constraints on students' work
Some of the constraints mentioned include the teacher's due dates for particular artifacts, the knowledge students' bring to the investigation, and technological or information resources available in the school or nearby.

• Students' needs in completing the project
Students or telementors may discuss students' needs for references to literature, advice on formulating a research question, locating data appropriate to the investigation, etc.

• Domain phenomena
This may take the form of a summary of what the students have learned through their reading, or a mini-lecture from the telementor about important concepts or distinctions

• Status of work
This takes in both students' reports of their progress and mentors' requests for progress reports

One of the benefits of this scheme of overlapping categories was that it enabled the source data to be examined at the intersections of conversational topics and moves. Thus, I could not only determine the relative frequency of conversations which revolved around domain phenomena versus references to literature, but also search instances of mentors giving advice on various aspects of the project, students making particular sorts of requests, and so on.

Genre Analysis

In Chapter 1, I argued that the lack of a critical audience for students' work, other than their teacher, distorts their appropriation of genres of scientific writing. The absence of a reading audience to consume students' research places them in a rhetorical situation which orients them toward persuasive goals quite different from those of professional scientists. This leads them to misappropriate the genres of science and renders the imitation of professional rhetorical forms from the sciences worse than useless as a teaching tool. Rather than pursuing a greater familiarity with scientific practice through the task of reporting their research, students may simply become more comfortable with caricatures of that practice.

I entered my design work with Wagner and Whitcomb with the hypothesis that telementors could provide students with a supportive and critical audience which might change the rhetorical situations in which they saw themselves enough to make their appropriation of scientific genres more faithful. Accordingly, my analysis of the final project reports produced by Wagner and Whitcomb's students was partly intended to capture any systematic variations in the rhetoric used by students in presenting their work so that its relationship to the writers' telementoring relationships could be examined. The approach is based on a simple premise which is put well by Cope and Kalantzis:

> Texts are patterned in reasonably predictable ways according to patterns of social interaction in a particular culture. Social patterning and textual patterning meet as genres. (Cope and Kalantzis 1993, p. 7)

While there were principled reasons for studying students' written arguments about their research, there were even more compelling pragmatic reasons to take this approach. I knew that rich data would be needed to evaluate my design experiments and their influence on students' classroom research, but collecting such data would be a challenge. One option was to observe the classes I was working with first hand, to make audio or video recordings of students' responses to the intervention. Unfortunately, given other demands on my time, I could not afford to observe classes full time. This left me wondering if I could find some way to take the work that students were producing for class as an important outcome variable.

While these considerations were coming into focus for me, I paid several visits to Rory Wagner and his classes. I began to observe how much of the activity and conversation in Wagner's classroom revolved around the preparation of a formally-structured final project report. Through my previous work on the Collaboratory Notebook software (O'Neill et al., 1994) (O'Neill & Gomez, 1994) I was beginning to develop an interest in genres of scientific writing at the time. Between classes, Wagner and I discussed this aspect of his work with his students at length. Over the following months, through readings in the sociology of science (Bazerman, 1988; Myers, 1990), I discovered that genres of professional scientific writing had been studied extensively, and I began to see the potential of conducting a genre-based analysis of the research papers that Wagner's students wrote about their projects. This might provide me with the data I needed without souring the goodwill of my research participants.

How is Genre Analysis Done?

Genre analysis can be done in many different ways, depending upon the objectives of the researcher and the nature of the genre or genres being studied. To illuminate the origins of a genre, one can take historically-oriented approach such as Bazerman's in Shaping Written Knowledge (1988), which took 135 years of the earliest experimental reports ever written as its dataset. If the objective is to understand in a finer-grained way what the conventions of a genre are, one can code and analyze particular sections of articles, as was done in much of the linguistically-oriented research reviewed by (Swales, 1990). In my research, the objective is to observe how students appropriate a generic form, and whether there is a systematic relationship between this appropriation and a set of experiences designed to alter the rhetorical situation (telementoring). In other words, I will be treating students' use of and accommodation to a customary form of writing as a dependent variable.

Those not familiar with the notion of a genre may ask whether it is any different from a style of writing. The answer is yes. Genre is *not* primarily about sentence structure, grammar or vocabulary choice, but about the customary form that specific arguments, observations, and so on, are adapted to when they are put into writing. This is an important difference because as (Brand, 1994) puts it in a different context, “style is time’s fool; form is time’s student”. Genres have a social history that is usually quite deep, while style is ephemeral. There is also little reason to expect that a person's writing style will be influenced by a change in the rhetorical situation, like the introduction of a new audience such as a telementor.

By analyzing samples of research papers written by students with successful, unsuccessful and average telementoring relationships, I hoped to be able to isolate the influences that telementoring was having over students' understandings of the nature of the persuasion they were doing in their writing. What kind of persuasion (if any) do students believe they are doing when they write papers for their science classes? Is this impression influenced in a measurable way by the involvement of telementors in their work? If so, how and in what ways does this influence vary? Since I wanted to use statistical tests for significance to aid me in answering these questions, I needed a coding scheme to help me observe students' science rhetoric.

The Student Science Rhetoric Coding Scheme

The current version of my coding scheme synthesizes observations about the professional genre of the Research Article (RA) from literature in the sociology of science (Bazerman, 1988); (Myers, 1990) and Linguistics (Swales, 1990) with observations made through close reading of a corpus of roughly 150 research articles written by middle and high school students in two project science classrooms over a period of two years. Despite having taken much inspiration from researchers who have studied the research and writing of professional scientists, the development of this coding scheme was largely inductive. That is, no behaviors are included in the scheme that I did not observe in students' writing, or that aren't logical complements to behaviors I observed. Thus, I have not sought to unfairly apply the standards of professional science to the work of middle and high school students, but to view the work of middle and high school students through the lens of professional science.

In its current form, the scheme contains codes for many of the customary rhetorical functions of the sections of IMRD (Introduction, Method, Results, Discussion) Research Articles, as well as other trappings of argument in this genre, such as:

- Treatment of perspectives and opinions (e.g. anticipating objections to the research done and attempting to address them)
- Use of hedges and qualifications on arguments
- The text types employed (narration, expository prose, overt persuasion)

• Ways in which sources and authorities are used to reinforce argument (e.g. precise citation of supportive research, or vague references to straw men)

The version of the coding instrument used to produce the results reported here is included in Appendix E. Developing this instrument involved the typical process of repeatedly coding the same corpus of data, judging which differences it captured and did not capture among the papers in the corpus, then changing the scheme to try to capture more differences. The papers in the corpus vary in length from 1 to 20 pages and took between 5 and 30 minutes each to code. Results from coding 31 project reports produced by teams in Wagner's 1995/96 class are presented in Chapter 7.

Validation of the Student Science Rhetoric coding scheme

In time, the Student Science Rhetoric coding scheme might be developed into a reliable measure suitable for use on large corpora of student work; at present, however, I consider it to be in an early stage of development. To mature, the instrument should be revised on the basis of observations of a larger corpus of work by students in a variety of school and curricular settings. To determine the worth of this effort, however, it seemed sensible in the near term to explore the relationship between the results of my own coding of a sample of papers, and the judgments of practicing scientists about the same work.

For this purpose, I developed a more holistic, less time-intensive paper rating scheme than the Student Science Rhetoric coding scheme, for use by volunteer scientists. This one-page scheme solicits holistic judgments on the quality of students' research reports, the research they represent, and the strength of their arguments. It also solicits ratings of quality for each of the individual sections of the students' reports. The form used to solicit these ratings is included in Appendix G.

The collection of the scientists' rating data took place as follows. Volunteer raters were solicited among scientists who had previously registered themselves as volunteers in the CoVis Mentor Database. Paper rating packages were sent to 9 respondents who indicated their willingness to participate in the study; 6 packages were completed and returned in time to be included here.

Each rating package contained a set of six paper rating forms, a short survey about the volunteer's experience in writing, publishing and reviewing papers in the IMRD genre, and two envelopes each containing three student research reports, labeled A and B. Raters were instructed to read and rate the papers in the following way:

> Included in this package are two envelopes of student research papers, labeled A and B. The set of papers in Package A was selected to familiarize you with the range in the quality of work produced by the students under study. All raters will read and rate these same papers as a form of "calibration". To this end, please open, read, and rate the papers in Package A **before** Package B. This will help ensure that any inconsistency of results between you and other raters is due to genuine differences of opinion rather than differences in your exposure to students' work.
>
> You will note that the rating form asks you to focus your attention on certain *aspects* of students' work, but does not provide exact criteria. This is because the issue under study is whether the criteria most important to you are similar to those applied by the teacher and by me. Simply report your judgments as they occur to you, and if you like, make a note of the criteria you apply or other thoughts that occur to you beneath each rating scale.

Together, the 6 volunteers provided ratings for 18 papers, in addition to the 3 common "calibration" papers. These data, and their relationship to my results from the Student Science Rhetoric coding on a sample of research articles from Wagner's class, will be discussed in Chapter 6.

Chapter 4: Case studies of telementoring

In the last Chapter, I detailed some of the thinking and planning that guided my research with Rory Wagner and Judy Whitcomb from 1995 through 1997. Here I will bring some of the fruits of this thinking and work together to paint two detailed portraits of telementoring relationships experienced by students and volunteer scientists in Wagner's classroom. While interesting in themselves, these stories are most useful for the opportunities they provide to explore design issues associated with the orchestration of telementoring as part of a larger curriculum. Because they raise these design issues in a way that involves real personalities and the contingencies and constraints of classroom life, I hope that they will be of particular use and interest to K-12 teachers and other would-be facilitators of telementoring in school settings.

Selection of the Cases

As Chapter 3 explained, my data-gathering for this dissertation was guided by careful consideration of sampling issues. Of the of the 60 students working in Wagner's classroom, I had time and energy to gather data from only a few at once. Likewise here, I have reserved enough space to examine just two telementoring relationships in depth. Since this analysis is so selective, my first matter of business is to explain how the two relationships were selected, and how they relate to the body of the data I collected.

I chose the two telementoring relationships explored here, first, because the data available to understand them was comparatively rich. For each of the chosen relationships I had a relatively complete log of the e-mail exchanged by the student team and its telementor, had conducted a focus group with the students which helped me to interpret this log, and had conducted either a telephone interview with the telementor and/or had an explicit discussion of the relationship with Wagner. These criteria still left me with significant choice, so I focused my attention on two cases which had been of particular concern to Wagner and me as designers of activity structures and technological supports for telementoring.

For example, the relationship discussed in Chapter 5, "You can lead the kids to mentors...", was important to consider because of its implications for the sustainability of telementoring as a strategy to support curricular reform. It illustrates how and why students can actively resist telementoring as part of a larger curricular innovation. How teachers respond to that resistance, and how volunteer telementors respond to disappointing interactions with students will determine, in large measure, how sustainable telementoring is at the level of daily classroom practice.

In this chapter, the case of Andy, Cori, Bill and Dan provides a view of the potential that can be realized when students engage with their telementors in ambitious work and take them seriously as a critical audience for the results.

Case 1: Exploring Black Holes with a Distant Guiding Light

The first of the telementoring relationships that I will consider here developed in Rory Wagner's first project cycle of 1995/96. This is an example of a particularly friendly and reciprocal telementoring relationship, in which both the students and their telementor experienced rewards for their effort. This relationship enabled three students to pursue a unique project idea which would otherwise have been beyond their capabilities, and those of their teacher. It is somewhat unique in the degree of maturity that the students, chiefly Andy, displayed in their dealings with their telementor, and in the amount of time that their telementor, Dan, dedicated to their work. It is, however, an example that I believe could be broadly emulated, under the right conditions. The case provides an opportunity to examine these conditions in depth.

Based on comparisons with other telementoring relationships from Wagner's class (which will be overviewed in Chapter 7), I believe that the key elements in the success of this relationship were:

- The students were convinced of their need for help and advice from outside the classroom to carry out their plans for the project

- The telementor was able to simplify the students' work significantly, while still expecting a great deal of agency on the students' part

- The telementor acted as an advisor, but not a boss; in particular, he never usurped the teacher's authority to veto or accept the students' project proposal

Design issues illustrated by this case include the following:

- Telementors may find part of their reward through using their commitments to students as a legitimate opportunity to pursue curiosities which are related to, but outside the realm of their paid work

- Regular status reports from students play an indispensable role in allowing telementors to carry out their work. Without these, they may be left in a "black box"

- Students' and telementors' conceptions of what constitutes "too much help" can be an important driving force in the development of a telementoring relationship. This is a complex issue and outcomes are vitally dependent on the level of shared understanding between students and telementors of the teacher's pedagogical goals

The Story

As I suggested in Chapter 2, the first project that students carry out in Wagner's class is a more challenging undertaking than many of them expect it to be. By the time they complete it, most of them are just beginning to understand the important differences between what Mr. Wagner expects from a project and what their teachers have required in the past. The greatest difference, as many of Rory's students have told me, is that he expects them to provide *proof* for the knowledge-claims they make in their reports, rather than simply citing published authorities.

The reports that Mr. Wagner is most pleased with are those that pose a question he finds interesting and develop and argue for a claim or set of claims using some form of original data analysis. The data analysis can amount to something as simple as making a set of graphs of relevant data and comparing them to one another by eye; even at this level of simplicity, it is quite different from the topical reports that his students are most experienced in writing. In those reports, students simply summarize what they have read about a scientific phenomenon in the popular press, textbooks or library books, and assume that it is true. The key challenges in this task are to avoid plagiarism by paraphrasing sources, and to understand their content just well enough not to distort it in process of paraphrasing. As I argued in Chapter 1, this kind of activity does not lead students to engage the problems of data analysis, interpretation and persuasion which are central to scientific practice. Students' difficulty in understanding Mr. Wagner's project requirements shows that as the school year begins, many of them have little understanding of the difference between data interpretation and other forms of knowledge-building.

For their first project of the 1995/96 school year, Andy, Cori and Bill were interested in studying black holes. This was certainly a unique project idea. It is far more common for projects in Wagner's class to focus on natural disasters like hurricanes, floods, avalanches, and volcanoes, which students have seen and heard a lot about in the media. Andy, Cori and Bill's relationship with their telementor, a Physics Ph.D. student named Dan Jeffries, is worth close attention because, while not ideal, it developed into a friendly partnership that both Dan and his mentees seem to have enjoyed. All were satisfied with the rewards that the relationship offered them for their investment of time and effort, and in this respect it can be taken as a model of what telementoring should be.

Dan Jeffries was a 24-year-old graduate student in Applied Physics. Like a number of our telementors, Dan had worked with children before, as a tutor. He had not been involved in any telementoring prior to 1995/96, but took to it enthusiastically, volunteering to advise three different astronomy-related projects in Rory's class over the 1995/96 school year. Part of Dan's interest in telementoring seems to have arisen from the fact that his own advisor was on sabbatical in Hong Kong in 1995/96, supervising his work entirely through weekly e-mail exchanges. Dan's unique experience made him sympathetic to the needs of Rory's students. Along with his previous teaching and tutoring experience, it inspired his view that telementoring can offer an intimacy with students somewhere between classroom teaching and face-to-face tutoring:

> ...I guess you're asking did I get fulfillment out of it? Yeah. I liked the opportunity to work with just a few people who I could talk with about one specific issue, rather than having some set list of topics that I had to get through with 30 people.
>
> I had done some tutoring a few years back, and I really enjoyed being able to work with students in a more one-on-one relationship, rather than in a classroom. And I was hoping that, and I did get that I feel [from telementoring], but not as much so as when I used to work with one individual student, two nights a week at a regular set time, and really got to know them a lot better.

In another connection, Dan emphasized that telementoring was not the kind of relationship he would *ideally* like to have with students, but that he found it sensible and satisfactory under the circumstances:

> It seems to me it *can* be done if it *has* to be done. An actual relationship where you could sit down and talk to the people would be better. But if it's the only option, it is possible to do things this way. So I think the idea of, OK, let's get these [students] talking to someone who actually has a bit more knowledge in the field that they want to look at a specific project on, rather than having to limit themselves just to what a high school teacher who's, certainly knowledgeable but not as knowledgeable in that specific area, I think that's good....

While Dan clearly viewed telementoring as an inferior substitute for face-to-face tutoring, it served a worthwhile purpose for him within the circumstances of his work life, which prohibited much travel:

> I really enjoyed it, and for me it was great. I'd be sitting down, coding all day, writing [computer] programs, and I'd be able to take, you know, a half hour, an hour break every couple of days to answer this e-mail and look up something that I wanted to learn about. So from my point of view, I really enjoyed it.
>
> ...the main thing was that it was something that I could use when I needed a break. I mean, that's really the way I looked at it. It was, you know, great! I'm really sick of my work, I can go to the library and look up a couple of papers on what they're doing so I can answer their question. You know, I can go spend a half an hour learning about something else I enjoy.

The logs of e-mail correspondence show that Andy, a senior student in Wagner's class, took on the role of managing most of his team's correspondence with Dan. It was also Andy who became my primary informant about the relationship later on, since his other teammates were unable to find time together to participate in a focus group with me. From the other data I was able to gather, it appears that the success of the relationship between Andy's team and Dan may largely be accountable to the maturity of Andy's attitude toward it. One indication of this maturity is the response that Andy gave when I asked him why he thought Mr. Wagner went to the effort to set up telementoring for his students. This was one of my standard focus group questions, and was partly intended to assess how thoughtful students were about how telementoring fit into the overall structure of Wagner's class. Whereas some students seemed to think that telementoring was a way for Mr. Wagner to avoid work, or to force them to learn to use e-mail (which some students strongly disliked), Andy's answer focused on the practical challenges of teaching and learning in a large, project-based class:

> I think one reason is the class runs very freeform almost. Actually, it's a great deal of responsibility put on you. It's almost like going to college, where you're on your own for the projects. And I think as a teacher, Rory doesn't have the time, or probably wouldn't want to as a teacher, have to spend all this time having checkpoints on people, knowing exactly where they are in their project. By assigning a mentor and seeing if people are using them, it shows that these people ARE getting guidance. That they're not completely off on their own making something up. So I think it's a tool for him and it's also a tool for us.

Andy's characterization is a good one. Mr. Wagner does in fact consider his volunteer telementors an important part of his tool kit for project-based teaching. As such, he encourages his students to treat their telementors as active members of their project teams, and to keep them informed about their progress, setbacks, and developing curiosities. This doesn't always happen; but as we will see, in Andy, Cori and Bill's case it did. Their friendly consideration of Dan as a more experienced team member who needed to be regularly informed of their progress was motivated by a justified belief that they needed his help to carry off their project idea successfully.

The partnership that developed between Andy's team and Dan Jeffries may have been missing at least one common attribute of mentoring relationships: a clear sense of imbalanced authority. As the quotations below suggest, Andy, Cori and Bill were in full command of their project and their relationship with Dan from start to finish. Their project idea, in particular, did not change much from its first clear formulation to the submission of the final paper, a period of several weeks. To be sure, they *consulted* with Dan about implementing their idea; but they did not defer to his judgment in any overt way or follow up on any of his suggestions which would have substantially altered their course or complicated their work. In other cases, students did in fact defer to their telementors, resulting in quite different kinds of relationships, though not necessarily superior ones.

The "Hello" Stage

Because first impressions are as important in telementoring as elsewhere, the way that students handle the first couple of messages to their telementors can have a large influence on the potential these relationships are able to realize. If a telementoring exchange begins badly, with students behaving in a demanding or disrespectful way, it can be very difficult to recover. Andy, Cori and Bill's exchange with Dan began favorably but not exceptionally, with the following message:

> Dear Dan Jeffries,
> Greetings from Chicago, Il. We are currently working on a project on black holes. If possible we would like to periodically ask you questions on the subject. The questions will require short answers. Any information would be greatly appreciated. Please contact us regarding any interest.
> Sincerly,
> Cori "expert librarian" and Andy

It is important to note that by the time this message was sent, Dan had already exchanged more than one e-mail message with Rory, who explained his expectations with regard to the role that Dan and the other volunteers would play in telementoring students' projects. For their part, the students seem to have assumed that Dan's role would primarily be that of a subject-matter resource. Not having experienced telementoring before, they may not have known what else to expect from telementoring besides an "expert" who responds to questions with on-line lectures. They try to reassure Dan that they will not demand very much of his time, and that anything he has to say will be welcome.

Dan's reply to this first message was prompt and friendly:

> Cori and Andy,
> Sure, I'd be happy to. I have a quick question for you that will help me to answer your questions in the future. What's your math and science background? Which of the following have you had? (algebra, geometry, trigonometry, calculus, chemistry, physics)
> I suppose I should say a little about myself, so you'll know who is answering your questions. I am currently a graduate student in my third year, getting my M.S. and Ph.D. in physics. My Bachelor's degree is also in physics. I am studying theoretical astrophysics, mostly dealing with radiative transfer in interstellar dust, so hopefully I'll be able to answer any questions that you have.

Feel free to let me know if my answers are helping you. If I assume you know more or less than you actually do, tell me.

Good luck on your project. I look forward to hearing from you.

Dan Jeffries

Perhaps without knowing it, Dan does something very important in this message. Not only does he ask specific questions about the students' academic backgrounds, but he explains *why* he wants to know these things. Likewise, before telling the students anything about himself, he explains why these details are relevant. This may not seem important, but experience has shown that it can be quite important with high school aged students. On a few occasions, students in Rory's class expressed concern over telementors' innocent self-disclosures (such as their spouses' names, or the number of children they had), or over questions telementors had asked about students' lives outside of class. This will be discussed at length in Chapter 7. Whatever motivates this concern, it is important to deal with it sensitively, as Dan does.

After responding to Dan's question about their science and math background (they each have had some Algebra, Geometry, Trigonometry, and Chemistry), Andy, Cori and Bill take the time to provide Dan with an uncommonly detailed explanation of what they are hoping to do with their project, and how they believe he can help them. At this point, Andy seems to have taken over as the team's primary correspondent. One thing that is uncommon about the message below is its candor. The students not only summarize the work they have done so far and offer a reasonably detailed plan for the rest of their project, but they mention the challenges and setbacks they have faced so far in getting a proposal passed by Rory. This helps Dan to better understand Rory's grading requirements:

Dear Dan Jeffries,

I'm glad to Know yould be interested in helping us. I hope you got our information on our educational past. We need to come up with a thesis proposal. We submitted several proposals which weren't accepted because they didn't fully meet the thesis requirments. Here's the bind: We must have a topic question which will not turn our project into an infomercial. However, we need specific data (however much data on Black Holes is complex Physics which we can't

> use/understand) We're thinking of the following type of project proposal. Finding several reports on Black Holes which may exist. Using the data we know (in simplified terms) we will evaluate the data known on this these supposed black Holes. We will then conclude whether any of these can truly be black holes (dependant on whether they meet our "requirments for black holes"). This case study will require transferring a great deal of complex material into simplified, workable terms. Perhaps this is an area that you may be helpful in. Please write us and tell us if such information we're looking for exists and is workable, or if you have any ideas for our project. Your help is greatly appreciated. Keep in touch.
> thank You,
> Andy, Cori and Bill

Note that at the tail end of this message, Andy proposes a specific role for Dan: to help his team render "complex material into simplified, workable terms". Later, in our interview, Andy likened this role to that of a "translator":

> One of the most important things that I think the mentor has done for me...is I can get a lot of information, but it's way above my head. And I almost need like a translator to tell me, what does this mean? What are all these units and signs? So it was very useful that I could send him [e-mail], look I found this on the Internet, I know it's something very important, I know what it deals with, but what are all these numbers? And he could try his best to send me back, saying, well this means this, to simplify this you can say this. That helped a great deal. Especially on my first project dealing with black holes, because there are some pretty bizarre physics involved with that.

Mentoring in a Black Box

Though Andy, Cori and Bill were quite forthcoming about their plans for their project, and shared a little of their educational past with Dan, he had some justified concerns about their ability to carry off a project on as advanced a subject as black holes. In order to do a responsible job of advising the students, Dan needed to be confident that his advice would not lead them to pursue a path which Rory will consider trivial (an "infomercial"), or that they would be incapable of doing justice to. Like all the telementors who will be discussed here, Dan had entered into an unusual kind of team-teaching arrangement with Mr. Wagner. He has agreed to help Rory achieve his goals for students' project work, despite having only a small window through which to view classroom activity: students' own accounts of their work. While Dan can choose to send e-mail to Rory at any time to clarify his objectives or ask about his mentees, Rory's activity structure for telementoring provides for very little pre-planned interaction between him and the telementors. This is necessary in Rory's case, because he can already barely handle the volume of work-related e-mail he receives daily.

In the case of Andy's team, Dan handled his concerns over their project plan judiciously, and without contacting Rory. His response to the students' plan was quick and enthusiastic. It came in the form of three relatively long messages, all sent on the same day. The first was a short, friendly note, not specifically related to the project, but intended to encourage their general interest in Astronomy. This signals to the students that they are free to explore other project ideas with him if they like:

> Dec 5, 95 10:45 am
> Andy et. al.
> Just saw something from the Hubble. Press release pictures are on the web at http://www.stsci.edu/pubinfo/PR/95/47.html
> Might give you a few ideas, might not. Still a cool picture.
> Dan

Later on that day, Dan sent the students a second message recommending a few amateur-level periodicals that the they could read to inform themselves about black holes. To do this quickly he had used a professional on-line resource unknown to the students or Mr. Wagner, called the ADS Abstracting Service. While this service saved Dan time up-front, however, it delivered a wealth of references which he needed to filter down for the students' consumption. As Dan later explained to me in our interview, he found it more difficult than he had expected to choose articles that Andy, Cori and Bill would be likely to learn something from. To be confident about his recommendations, he needed to consult some of his peers in the Physics department about what high school students might find accessible:

> Jeffries: The thing that I always had to remind myself was that I was working with high school students, and I had to scale back a lot of the things that I would want to say about the topic. For instance...I wanted to recommend what types of

> periodicals they would be able to understand. And I'd go out and look at them the first time and go, "Oh wow, this one doesn't have a lot of math." And then I'd go, "OK, I guess you really have to understand what Doppler shifting is in order to understand this article." OK, this periodical's out. So, that's the hardest part for me in this is, having to sit down and realize what they should know at that level. That's hard to do over e-mail. And it depends a lot on how much feedback I get from them. I always tried to tell them that if I was suggesting things that were either below them or above them, let me know. And they never really said much of that, so I assumed that whatever I was giving them was helping.

In addition to recommending readings for the students, Dan also provided them with a few heuristic questions to guide the formulation of their research agenda on black holes. These seem designed to help the students "play scientist" by considering the sources of evidence that they would need to examine for each potential black hole. Part of Dan's second message for the day read:

> The basic questions you would want to ask are: What is a black hole? If it exists, where would we expect to look for it? What would we see? Has anyone looked for this, and what did they find?

The last, and most lengthy of Dan's three replies on the same day read as follows:

> Tue Dec 5 1995
> Andy et. al.
> Sorry, I wasn't able to get all of my thoughts out in one e-mail ;-)
> I don't think I gave you the month on that Physics Today article, I'm not sure of the month but it's number 8. I would assume that's August but I'm not sure if PhT puts out 12 issues a year. Once again, I'd look at Sky and Telescope or Astronomy first. I talked it over with a few of my colleagues, and they suggested that Physics Today might be too advanced.
> As I understand it, your problem is that you cannot just say "This is what a black hole is, isn't it cool", but you have to come up with some verifiable, answerable question. The process used by astronomers to determine if a source is a black hole isn't all that trivial. If you do not have to go into how they measure the velocity of the surrounding material, that might be do-able. Still, there are only three sources that have been conclusively identified as black holes. (And one of them was just announced days ago.)
> In addition to looking at the idea of how the existance of black holes are determined, you might also ask yourself if there are any other astronomical questions that you are interested in. You might look through a few back issues of Sky and Telescope, and see what interests you.
> Let me know what you think.
> Dan

Dan's message exemplifies a reasonable strategy for mentoring in a situation where one has limited knowledge — a situation that another telementor, Lauren, will describe in Chapter 5 as "a black box". He is honest in sharing his misgivings about the difficulty of what the students have proposed, but does not tell them outright not to pursue their idea. He realizes that he cannot confidently dismiss a project idea without knowing more about what the students are capable of, the effort they are willing to put forward, and the precise criteria that will be applied in the evaluation of their work. He therefore relies on Mr. Wagner to veto the project idea if necessary, and does what he can in the mean time to help the students' exercise their own judgment.

As it turned out, the students could not be dissuaded from studying black holes. They continued their research, and Dan continued to be supportive despite lingering doubts about the length of the rope they seem to have been given to hang themselves with. As he later explained in our interview:

> The students had a rather broad range of topics they could look at, you know; the students I was helping were looking at black holes, in basically as I understand it an Earth Science class. I kind of feel that...while I understand that one of the whole points is to get the students a greater range of things that they could look at, some limitations might be in order in the sense that, even myself I thought, sure, explaining black holes and understanding, no problem. You can do that without a lot of the complex math. But then I realize, there are a lot of important physical concepts that do need to be explained there that I didn't think about the first time. A lot having to do with, realizing that OK, I guess they would have to know about Doppler shifting. Things like just what is the nature of light itself that, on my first initial time thinking through this, I thought, OK this isn't going to be a huge hurdle to overcome. And as I get further into it I start realizing, wow, there is a lot of knowledge that you have to build up over time in that.

It's clear that if Dan were teaching this class himself, he would teach it differently from Mr. Wagner. Still, he respects the choices that Wagner has made, knowing, like the other volunteers, that he is involved in a teaching experiment. In due time, Dan's concerns were addressed:

> Really a lot of my concern — and from what I understand with the grades received, this was definitely taken into account — my concern is a lot over how you evaluate

> it. If they come up with a conclusion which you look at and go, "no way, that's completely wrong! They missed this concept right here!" Do you say, "oh, you've messed up this concept, you fail!" Or do you say, "wow, you've got a lot of interesting information in the background here. You have some unanswered questions here"? ...So I guess my concern is, if you give them a lot of credit for effort, and the time to spend on the background, I could see that as being something really good. If it's harshly graded, I could see that as being very damaging.

How Much Help is Too Much? The Epistemology of Exploration

A recurring theme in my conversations with both telementors and students is the question of what constitutes "help", and how much of it is too much. This turns out to be quite a complex issue, and a lack of consensus about it on the part of teachers, students and telementors has led to frustration on more than one occasion. In some instances, telementors' concern over offering too much help leads to what I call a "teasing" dynamic, in which students make what they believe are reasonable requests of their telementors, only to be rebuffed with the assertion that "I know the answer to your question, but I don't think I should tell you." More often than not, this creates some animosity. Students sometimes suspect their telementors of egotism or simple mean-spiritedness, wondering aloud: "if he didn't want to help us, why did he volunteer in the first place?" In Chapter 5, I will consider one such case.

In the case of Dan, Andy, Cori and Bill, this kind of animosity did not arise; but it was clear that at particular junctures, their conversation was strongly influenced a by concern over what might be "too much help". In the following message, Andy sharpens his team's research plan for Dan, as a prelude to a series of requests for research pointers or information:

> Thu 7 Dec 1995
> Dear Dan,
> Thanks a great deal for your continual responses and input. Your help is much appreciated. We think we've found a nifty idea for our project.
> First we'll breifly explain the features and dynamics of a Black Hole, talking about simple physics, formation of etc. Next we'll research the three known Black Holes and find information about how and why these areas were positivly identified

as a black hole. Next we'll do a "case study" on the areas which scientists think may be Black Holes. By comparing observations between the Black Holes and the "possible Black Holes" we can conclude which of these "possible Black Holes" are most likely to exist.
Some of the following information may help.
1. What are the names of the three Known Black Holes, where might information be found on them (we'll find it).
2.Where might information be found on the unknown Black Holes.
3. What "traits" in these Black Holes and supposed Black Holes would be the most simplistic and beneficial to helping us compare.
Once again Thank You Greatly,
Andy, Cori and Bill

I would like to draw the reader's attention to two small portions of this message. The first is Andy's statement that "we've found a nifty idea for our project." Note that Andy does not say that they have "come up with" the idea, or "had" the idea, but that they have "found" it, as if it had been lying out in the world, waiting to be tripped over. In a similar way, students often explain their telementors' helpfulness using metaphors of navigation and exploration. They say that telementors can "point you in the right direction", or "help you get on track", or "point out things you overlooked". Without their help, you might just wind up "lost". All this vocabulary suggests that there is just one right way to proceed with any project.

In this vein, it is a small but significant gesture when the students ask "What are the names of the three Known Black Holes, where might information be found on them?", then add parenthetically, "we'll find it" . This small addition alludes to an important perceived difference between asking for information (which they believe would be too much help) and asking how to find it (which the students believe would be just enough). This distinction shows up so often in my data that I began to seriously question what it means. If a telementor sends students an Internet address to look up, how different is this from simply sending them the text of a web page? Does one course of action constitute good teaching practice, the other bad?

There is an essentially non-constructivist epistemology at work, I believe, in this way of distinguishing kinds of help. This epistemology posits that knowledge lies out in the world (in books, computer databases, or experts' heads), waiting to be found in a more-or-less usable form. When the "right" information is found, it needs no construction or refinement. The right information speaks for itself. This folk epistemology, which Wagner and I both object to, has specific implications that need to be dealt with in the orchestration of telementoring. Particularly because telementoring involves the exchange of messages over computers, it can easily be viewed as a straightforward exchange of "information". This can play into an impoverished model of teaching and learning which reduces it to a process of asking for information, receiving it from some source, then storing it away or massaging it into a report.

Unfortunately, students are not the only ones who are victims of this impoverished epistemology. For a moment, let's consider Dan's perspective on what is "too much help". In our interview, Dan informed me of an instance in which he believed that someone on Andy's team had asked for too much help:

> O'Neill: ...were you ever asked by the students or Mr. Wagner to do things or to answer questions that you thought were unreasonable?
> Dan: Mmmm...no. I will say this though. I originally heard about this, there was a period there where my work was really slow, so I was spending a lot of time reading the newsgroups. And I came across, in the sci.astro newsgroup, I came across the original [request for volunteers] from Rory.
> O'Neill: Yeah?
> Dan: Over the course of the projects, while the things they asked me I thought were completely in line — they never really said, OK we need JUST one source, or we need JUST to know this — it was always general background questions, can you recommend areas to look at for this.... But I did notice one of the students — and I won't mention which one — posting a much more specific question that I did think was way out of line on the sci.astro newsgroup. That was more specific, we're looking at this, can you tell us this answer? Can you say exactly what this is? As opposed to, you know, where can we look for this?

What's the essential difference for Dan between too much help and just enough? What precisely about the student's posting to the sci.astro newsgroup did he consider out of line?

In the last paragraph of the quotation, Dan suggests that the student's question was too specific; but is it simply the specificity of the question that he found troublesome? He implies otherwise by contrasting the question with an alternative which he favors: "where can we look for this?" This is the epistemology of exploration at work. The implication of Dan's statement is that it is OK for students to ask for directions, so long as they find their own way to the goal.

The thinking behind this belief seems to be is that if students are given all the right information, they need merely need to cut-and-paste a final report together; there is nothing more to be learned. Under this model, the telementor's job is to make the students' work for their information, to coach and guide their search for it (and if necessary, to tease), rather than to coach and guide their thinking about scientific phenomena, or data sources, or methods, or the defense of knowledge-claims. It implies that what students need to learn from their projects is how to use library indexes or Internet search engines. While this may be one small objective of project-based science, it is far from the most important one.

I do not mean to suggest that Dan did a sub-par job of telementoring Andy's team, or that his expectations of the students was low. On the contrary, Dan demonstrated a generally high set of standards for students' work when I asked him to rate a number of papers as part of the validation study for the science rhetoric coding scheme (discussed in Chapters 3 and 6), and in the case considered here, he provided Andy, Cori and Bill with a detailed and helpful critique of their paper, part of which will be discussed below. I suspect that there may be a disjunction at work between the explicit model of teaching and learning that Dan revealed in our interview, and the richer implicit one that guided his work with the students.

An Epistemology of Construction

In place of the epistemology of exploration that I have been discussing, telementors, students and teachers need a more thoughtful epistemology which asks what effort a particular answer or piece of advice would save a student or students, what learning opportunities this would forfeit, and what further opportunities for learning it would open to them. What *could* be learned if students expended the effort to answer a particular question themselves (*if* they could), and what other prospects for learning would this effort sacrifice, given the constraints on the project work (deadlines, available resources, background knowledge, etc.)? This is precisely the set of considerations that Wendy, the telementor discussed in Chapter 2, seems to have had in mind when she suggested that her job was to help the students over "snags" in their research. The implication was that it is OK to answer students' questions when you believe that it will help them reach a greater challenge more quickly—that it will essentially achieve an efficiency gain. In this case, you are helping the students to get over the foothills more quickly so that they can reach the mountains beyond. The mountains are the real objective.[3]

With his next message, Dan shows us that in fact he has his eyes on the mountains:

> Thu, 7 Dec 95
> Andy et. al.
> (One of the many signs that you are a graduate student is you use et. al. whenever refering to more than two people, i.e. Snow White et. al. :-)
> The three "known" black holes are:
> 1. Core of M87
> 2. Core of NGC 4258
> 3. Core of NGC 4261 (very new, released news of discovery 12-4-95)
> You should be able to find articles in either Sky and Telescope or Astronomy on both of the first two. The last will probably not be released for a while, but there was an article in the New York Times on the fourth, and there is a website at http://www.stsci.edu/pubinfo/PR/95/47.html If I see anything with more quantitative information on the newest black hole, I'll let you know.
> Also, Nature has many articles on these black holes which are more technical than the ones you will find in S&T or Astronomy, but these articles will be much

3 Mountain-climbing is a persistent metaphor in Rory Wagner's teaching. It is discussed in (Wagner, 1996) and in (Polman, 1997)

more difficult for you to read, as Nature is written at the level of a professional scientist. I'll look at a few of these and let you know whether or not the level is appropriate, or if the information is necessary. I looked at that Physics Today article, it did not have any complex mathematics, but it did assume knowledge of some fundamental physical concepts concerning the nature of light.

I suspect you will start coming across a few phrases which may be new to you, most of which will deal primarily with light, and how we observe it. Since that is all that astronomers have to deal with, the light from distant stars, it is extremely important in our field to know as much as possible about light. As you come across phrases which are new to you, feel free to ask for explanations of those which you do not understand.

Dan's message pushes the students to learn more about the nature of light, and offers help with any terms they find difficult to understand. By making the suggestion that they learn more about light, he assumes a great deal of agency on the students' part. Dan also assumed a great deal of agency in his next message, the last before the students submitted their final report to Rory. This is by far the longest message that Dan sent during his exchange with Andy, Cori and Bill, and more than any has the feeling of an on-line lecture. However, it is clearly conversational in its tone, showing some of Dan's experience with tutoring.

Just prior to this message, Andy's teammate Bill had interjected to ask what evidence the scientific community considered conclusive of M87's status as a black hole:

Thu 14 Dec 95
OK, fair warning, this is a little long.

First, Bill, I took a quick look at what I could find on M87, in an article by Van der Marel, R.P., in the Monthly Notices of the Royal Astronomical Society, Vol. 270, pp.271-279, 1994. Just to give an example of how you could go about finding black hole masses from velocities, this had velocity dispersion profiles of 270 km/s at 15 arcseconds from the center, 305 km/s at 5 arcseconds from the center, and 400 km/s at 0.5 arcseconds from the center. By velocity dispersion I mean the difference in velocity from one point at an angular distance of x arcseconds on one side and the velocity measured at a point an equal distance on the other side. This allows us to not worry about any other velocity (i.e. how fast and in what direction is the whole galaxy moving).

How they actually get a mass is to compare the velocity dispersion profiles with respect to angular separation to theoretical models. (They get 5*10^9 solar masses by the way.)

I wouldn't reccomend doing it their way. What they do is more accurate than a straightforward application of Newton's laws, but it is also EXTREMELY difficult.

> What you can do, if you know the distance to the galaxy, is the following. (You should be able to find references to this in any high school level physics book. I highly reccomend looking at a high school physics book and checking my equations, since I'm going off of the top of my head on this.)
>
> The accelaration due to gravity is going to be G*M/(r*r). G is Newton's gravitational constant, M is the mass of the central object, r is the distance between the two objects.
>
> The centripital acceleration required to keep an object moving in a circle is v*v/r, where v is the tangential velocity of the circling object. Since the only force that is acting on the stuff is gravity, set the centripital acceleration equal to the gravitational acceleration.
>
> If you need to find the distance r from the angular separation of the rotating object and the central object, then r=D*sin(theta), where D is the distance to the source, and theta is the anglular separation of the central and rotationg objects. (theta is a greek letter, it looks like an 0 with a line horizontally through the middle.)
>
> I was not able to quickly find the distance to M87, so I'll leave that to you. If you can find velocity dispersion profiles and distances for your sources, you should be able to use this method to get a rough estimate of the mass of the central source.
>
> Well, that answers a couple of questions at least.

Next, Dan responds to a question that Andy had asked about a particular astronomical term he had seen in many of his readings, "event horizon":

> Next question, what is the "event horizon" of which you speak?
>
> What exactly is a black hole? It is a source so massive that not even light, leaving from the surface of the black hole, could escape the gravitational pull of the stuff. (According to General Relativity, despite being massless, light still feels the pull of gravity.) What if, however, the light did not attempt to leave from the black hole, but from a little bit away from the black hole. Obviously, since we do see light, there must be some distance away fromthe black hole at which light does not get trapped, and instead escapes. This critical radius is the event horizon. Anything which falls within this event horizon will not ever escape from the black hole.

To ensure that the students are not working in ignorance of crucial concepts, Dan also offers a lengthy explanation of some concepts concerning light. This is certainly not the best way for students to be introduced to such material, and if Andy's team had given Dan a clear indication of having followed up on his suggestion to learn more about light, he most likely would not have included it. But again, since he is operating in a black box, he feels it necessary, as a responsible advisor, to explain these concepts:

> Finally, how do scientists measure the velocity of light?

> (there is a little bit of extra information here, I'm not trying to bog you down with useless stuff, I just want to make sure all of this has been explained to you in case you come across it in one of your sources.)
>
> This one is a bit tricky, and I don't reccomend trying to duplicate any work you see on this. What is needed here is a bit of knowledge on the basic nature of light. My reccomendation is to trust the measurements you find on the velocities.
>
> First, what is light? Light is a wave of fluctuations in Electric and Magnetic fields. If it is a wave, then there must be some distance between two wave tops. This distance is called a wavelength, often represented by greek letter lambda (a \ with a line from the center down to the bottom left corner). If you stand in one place and let the wave pass you, the number of waves that pass in one second is the frequency, represented by a nu, which looks sort of like a funky lower case v. These are related by c = lambda * nu, where c is the speed of light.
>
> So why am I bothering you with all of this? This wavelength of light is also known to you as the color of the light. This "color" however, extends even to light which is not visible to the human eye, infrared, microwave, ultraviolet, and all that fun stuff. This phenomenon is known as "doppler shifting", and it also happens with sound. When a police car or ambulance drives by, notice how the sound is different in pitch when the car is approaching you than from when it is going away from you.

Finally, also like a good advisor, Dan checks the team's progress and makes them aware of his own schedule. This behavior may have been modeled by his own distant advisor in Hong Kong:

> Well, that's it for today, Good luck on finding information on your sources.
>
> Since you all seem to be moving full steam ahead on this, I assume you have had your thesis proposal accepted?
>
> How are you coming with the other phases of your project, Is your data collection going to be done for tommorrow, will your data analysis be done by next week? I will be out of town and will not have computer access from the 21st of december to the 2nd of january. Be sure to get any last minute questions on your data analysis section of your paper by that wednesday, so I can answer you before I leave.
>
> Later,
> Dan.

The Final Report

It was considered standard procedure in Mr. Wagner's class for students to share their final papers with their telementors. This informal procedure was set by Rory in response to extensive feedback from telementors in previous years, who quite naturally wanted to see how students had implemented their advice. Unfortunately, this informal policy was not carried out as frequently or as fully as Wagner hoped. In several of my focus groups, student teams who had been unsatisfied with their telementoring relationships suggested that, "Sending the paper is a good idea, but it shouldn't be required. Why should we HAVE to share our paper with someone if they didn't really help us?" Student resistance notwithstanding, Rory tried to satisfy telementors' desire for closure in one project cycle of 1995/96 by docking marks from students who neglected to share their papers with their mentors via e-mail. Implementing this scheme in a fair way turned out to be both labor-intensive and problematic, however, and it was quickly abandoned. This continues to be an ongoing issue for Rory in refining activity structures and technological supports for telementoring.

In the case of Andy, Cori and Bill, there was no noticeable friction over sharing the final report with Dan. During our interview I asked Andy my standard question about how he felt about sharing his report. His answer reflected some nervousness, counterbalanced with consideration of Dan's motives and desires as an advisor:

> I think...it can be almost scary, almost embarrassing. Because I'm sending a pretty amateur paper to a physics professor, asking him to put comments on it! I don't know, it might be quite laughable to him. But on another level, they're probably anxious to see your paper. They want to see...you know they put some element of work into this whole mentoring deal, they want to see what the student has got out of it, and how successful their mentoring was.

As it turns out, Andy and his team had little reason to be insecure about Dan's response to their paper. His reaction was friendly and enthusiastic. He provided extensive, paragraph-by-paragraph comments on the work, ranging from collegial asides to fine points of clarification regarding the theory of black holes and the interpretation of data sources. Below is one of Dan's friendly asides on part of the team's Introduction (the students' text is the top portion, Dan's comments are preceded by dashes). This excerpt illustrates how telementoring conversations can help cultivate students' curiosities in a very natural, incidental fashion:

> Black holes can vary greatly in size. Scientists have noticed compacted mass resembling black holes which span several galaxies. Thus, the mass of many galaxies may have imploded into one massive "hole". Single stars have imploded to create miniature black holes. Some of these miniature black holes contain the mass of earth in a space the size of a sand grain. it is believed that one of these miniature black holes may have encountered Earth in 1908 and caused a 50 mile stretch of forrest to "disappear" in seconds.
>
> -- Sounds like the Tungaska incident in Siberia. This has been suggested to be
> -- many things. My favorite explanation (though not the one I actually believe) is
> -- the idea that it was an anti-matter asteroid. Tungaska is fun to speculate about.

In addition to more lighthearted comments like this, Dan offered minute reactions to the team's Data Analysis section. Here is one example:

> Cygnus X-1 however cannot be conclusively proven a black hole. Few common traits could be found between Cygnus X-1 and NGC4261/M 87. Although thought for years to be a black hole because it's density outmatched a neutron star's maximum capability, it clearly is not. However, Cygnus's density may have been miscalculated slightly. Assuming Cygnus X- is actually 20 percent less dense (this is quite possible given it's distance), then it is low enough in density to be a neutron star yet too large to be classified as anything else. Therefore, Cygnus is most likely not a black hole, but a neutron star instead.
>
> -- Given its distance, or unceartainty in the determination of its distance?

Along with these paragraph-by-paragraph comments, Dan provided summary comments on the entire paper which emphasize how well the students limited and defended their knowledge-claims. As you recall, I argued in Chapter 1 that this should be one of the primary goals of telementoring:

> Interesting paper. You did a good job of making what conclusions you can from a limited data set. This is a must for anyone in astronomy. In the field, since there is almost always limited data, error analysis is crucial, as well as a healthy sense of scepticism. I think you did a good job of showing why the nature of Cygnus X-1 is in doubt. More information on what you would expect to observe from typical neutron stars would help to strengthen your claim that the Cygnus X-1 source is a neutron star. Good Work! I hope you had fun with this.

Implications for Design

In illustrating telementoring's potential (both realized and unrealized), this case has important implications for the design of activity structures and preparation materials for telementoring. Some of the most important of these implications are associated with how telementors are prepared for their role.

The reader will most likely agree that Dan showed considerable aptitude as a telementor, despite the fact that he was given no formal preparation for the role other than a brief (though carefully-crafted) e-mail description of Wagner's students and the types of projects they do. These facts belie the suggestion that telementors must be given extensive up-front "training" in order to successfully do this job. If they are sensitive to students' needs and capabilities, comfortable with e-mail correspondence, and restrict their advice to their areas of professional competence (attempting to assist the teacher, rather than usurping his or her role) they can do an effective job with motivated students.

What seems to have been far more important than training in Dan's case were Andy, Cori and Bill's regular status reports. While the students deserve considerable credit for being such regular correspondents, it should not pass notice that their status reports were often spurred by the due dates of "milestone" deliverables which Wagner had put in place (such as the proposal and data analysis plan), as well as ongoing events in the classroom. This raises the critical importance of putting activity structures in place which indirectly encourage regular exchanges (simply ordering students to send e-mail is not the answer).

This case and others discussed in Chapters 5 and 7 also point to the importance of addressing the dynamics generated by the issue of "too much help". In a project-based classroom like Wagner's, successful telementors should have a grasp of what I referred to as the "epistemology of construction" — meaning simply that when decision-making is required over what level of guidance to provide students, what to say or not to say, telementors should reflect on the trade-offs at issue between helpful efficiency gains in students' work and learning opportunities that may be available through more independent effort. In a world in which both students and their teachers must adhere to schedules, project work can benefit greatly from telementors' assistance with "snarls"; but the telementors' eyes should remain open to opportunities for independent learning. If they have strong doubts as to where the teacher's priorities lie, they should be free to consult directly with them.

As a final note, I will point out an important limitation in Dan's relationship with Andy, Cori and Bill. While this relationship was productive and enjoyable on both ends, it was able to be so in part because Dan did not attempt to problematize the students' work, or recommend extra work. If he had seen a need to do this, it is unclear whether the relationship would have survived. In the next Chapter, we will see an instance in which a telementoring relationship was unable to withstand this strain.

Chapter 5

Case 2: You can Lead the Kids to Mentors, but you Can't Make Them Think

The relationship I examined in Chapter 4, between Dan Jeffries and his mentees Andy, Cori and Bill, approached the ideal of a telementoring relationship in many respects. That case was worth close study because it brings greater clarity to what teachers, telementors and students can hope to achieve through telementoring, and how. In contrast, the second relationship that I will examine was much less successful, and it is worth study for different reasons. Because it barely had an opportunity to get started before it was over, I refer to it as a stillborn relationship. In it, we see how and why students sometimes resist telementoring as part of a larger teaching strategy. The details of this case, including why it failed and how each of the participants felt about this failure, reveal important limitations on the role that telementoring can play in routine classroom activity.

Design issues illustrated by this case include the following:

- Students cannot be expected to respond positively to telementoring if they are set against the pedagogy it is used to enable. Students who dislike doing long-term projects to begin with probably won't enjoy project-based telementoring, or invest much effort in making it successful.

- In a reciprocal telementoring relationship, the telementor sometimes needs to problematize students' work, rather than simplify it. Examples of this may include attempts to redirect students' curiosities and effort, adding work in the process. Students with a naive view of the "help" that telementors can or should provide may find this form of help difficult to appreciate.

- Giving students a choice to work with a telementor or not may make it substantially easier to retain volunteer telementors over the course of several projects.

The Story

Lynn and Charlotte were a pair of Rory Wagner's senior Earth Science students during 1995/96 school year. They belonged to the most challenging segment of his clientele: students with little interest in science. For their first project of the year, they had proposed to study the extinction of the dinosaurs. This idea was probably inspired by media events such as the film "Jurassic Park" and television documentaries about the asteroid-collision theory of dinosaur extinction. Here is how the pair of students explained their project idea in their first message to their telementor, Lauren:

> Dear Lauren,
> We are 2 students looking for any information on the extintion of dinosaurs. We are in Mr. Wagner's Earth Science class and he told us to write to you as a mentor. We have a basic idea about 4 theories about the extinction, and our question is about the analysis of dinosaur extinction theories. Our 4 basic theories are; 1-an astroid hit the planet and created a huge dust cloud that blocked the sun and therefore killed off the vegitation causing the dinosaurs to slowly die off, 2- the uplift of the land wipped out the swamps where dinosaurs lived, 3-dinosaurs are warm-blooded and the change in climate wiped out the dinosaurs, 4-the dinosaurs did not become extinct they evolved into some species of today. What do you think?
> We would apriciate any help you can offer.
> Thanks,
> Lynn and Charlotte

As the message begins, Lynn and Charlotte say they are looking for "any information" they can get on the extinction of the dinosaurs. It looks for a moment as though they might be making the sort of overly-general request that often frustrates telementors (e.g. "We would appreciate it if you could send us any materials you have about the giant red spot on Jupiter. Thanks."). These sorts of requests reveal an expectation on the students' part that a telementor's contribution to their project will be analogous to that of a librarian who provides them with pieces of text to summarize and include in their final report. Volunteer telementors are generally not eager to play this librarian role.

Lynn and Charlotte seem to show a more sophisticated set of expectations, however, when they take the trouble to explain to Lauren in at least a rough way what they plan to do in their project. They say they want to compare the merits of four particular theories of dinosaur extinction. They are vague about what "the analysis of dinosaur extinction theories" means to them, but that is something that could clearly be discussed and refined in future messages, if they are open to Lauren's advice. Finally, the students end their message by asking Lauren's opinion of their project idea ("What do you think?"). This offers her an opening to provide whatever feedback she sees fit.

All in all, relative to many other "hello" messages I have read, this is not a bad starting-place for a telementoring relationship. Lynn and Charlotte's statement that "[Mr. Wagner] told us to write to you as a mentor" is a sign that they may not be the most willing correspondents, but they have been forthcoming enough about their plans that Lauren can begin to frame some useful questions to them and make some helpful suggestions. So far, so good.

Unfortunately, when Lynn and Charlotte handed in their telementoring surveys to me at the end of their project, several weeks later, both rated their telementoring relationship as completely unhelpful. On one set of items, they also claimed not to trust or respect Lauren in the least. By way of explanation, they offered only the short comment, "Did not communicate with her much."

What Went Wrong?

This outcome seemed strange, since one might argue that Lauren was uniquely qualified to telementor Lynn and Charlotte in their project. She was a graduate student in Geology who had just finished teaching a university-level course on the fossil record. She also held a master's degree in Education, so her understanding of high school students' capabilities and limits in pursuing independent projects was probably superior to that of many of our other volunteers. As we will see in the next few pages, she was eager to help her new mentees, and even had a small amount of previous experience in supporting K-12 students' work on-line. If Wagner was aware of all this at the time, he could hardly have felt more secure in making the match he did. In fact, he routinely makes matches on the basis of less knowledge about mentors and their qualifications, and a substantial number of these matches result in productive telementoring relationships.

Given all this, it is natural to wonder what could have gone wrong with this relationship. Had there been some kind of personality conflict between Lauren, Lynn and Charlotte? Had time pressures or limited access to e-mail simply prevented them from corresponding, or was their lack of communication the result of absent-mindedness or lack of interest? In any case, I wanted to know what the consequences of this failed relationship had been for the students, their mentor, and their teacher, and whether this type of failure was likely to be repeated if the project requirements, activity structures, or technological setup in use were not changed.

In the e-mail quotation below, Wagner briefly explained his requirements for project work to would-be volunteer telementors as his students began their first project. This explanation, similar to what Wagner offers to his students in class, was part of a larger message that volunteers received prior to committing to work with a team of students:

> The students do background research on their broad topics, which can be anything covered by the term "Earth Science." They choose any topic of interest to them. We have just started this. They then must come up with a much more specific research proposal, due Dec. 1. Then they use the appropriate "tools" to collect data relevant to their research (experiments, libraries, internet), analyze the data, come to some conclusion, then write a formal paper and make a 15 min. presentation to the class.

Measured against these requirements, Lynn and Charlotte's project idea was clearly ambitious. To compare four rival theories of dinosaur extinction *and* evaluate the weight of their supporting evidence in the space of seven weeks would challenge the very brightest students in their class. However, Mr. Wagner allowed the two young women to proceed with their plan, knowing from years of experience that students' project ideas often change dramatically in the first few weeks of their work (sometimes, in response to their telementors' advice). To help them develop their idea, Wagner offered the support of Lauren.

I scheduled a focus group with Lynn and Charlotte to find out why Lauren had been of so little help to them. Our conversation took about 45 minutes, and they were both quite willing interviewees. They were also quite free with their opinions, though the inconsistency of their stories did reveal some attempts at deception, as I will explain.

Our conversation began with the two students offering a very condensed account of their relationship with Lauren:

> Charlotte : Well, it was good as far as, like, we told the lady...should I say her name?
> O'Neill: Sure.
> Charlotte : Okay, Lauren. We told her, you know, what our project idea was and what we had gotten so far. And it was okay, she told us to narrow it down, to maybe two things [theories of dinosaur extinction] or something. And that was fine. But she didn't help us, like...
> Lynn: She just told us to narrow it down.
> Charlotte : That's like all she told us.
> O'Neill: Oh, really.
> Lynn : That's it. Period. End of the conversation.

Despite Lynn's confident assessment, the story was not quite as simple as that. Charlotte and Lynn did not know at the moment that I had already spoken to Lauren and gotten her side of the story, which was quite different:

> Well, I think it started off very well. They sent me an e-mail with 4 hypotheses on a very broad question, which was the extinction of the dinosaurs. And, thinking back on it now, I think maybe they should have worked through their broad question maybe a little on their own and had something more specific when they first got in contact. Because I think maybe they thought they had gotten what they were supposed to from me [in my first reply]. But anyway I sent them back ideas on the four hypotheses and told them the one that I thought that they would find the most material for, and suggested a few articles that they could look into for a beginning understanding, beginning research. I think I referred them to a Newsweek article on asteroid impact and the extinction of the dinosaurs, and another article....I think they contacted me *maybe* once more, and said yes they had decided to pursue *this* hypothesis, and that was it!

My conversation with Lynn and Charlotte supports Lauren's suspicion that they got what they thought they were supposed to get from her early on. At the very end of our conversation, I asked Charlotte why she and Lynn had not sent a copy of their final project report to Lauren. This was standard practice in the class, and in the second project, a grade was even assigned for this specifically. Charlotte's response to my question was, "We kind of blew our mentor off towards the end, because we didn't like it.... She was really only there to narrow our topic down, and that was about it."

One may wonder, as Lauren did, whether she had done anything to leave the two young women with such a limited impression of her role as a telementor or her willingness to work with the students. Had Lauren's messages been brusque, dismissive or intimidating? This position is hard to support on the basis of the e-mail records. Lauren's first reply to Lynn and Charlotte, which they described as "just telling us to narrow it down", read as follows:

> Hi Lynn and Charlotte,
> Your four ideas are good hypotheses and you should be able to find information on all of them - perhaps too much. You might want to focus on one of the topics. There is plenty of material on the asteroid impact hypothesis. In terms of changes in swamp environments and "land uplift" there might be very little material, and not much new work. The warm-blooded issue is very interesting and can be compared to other extinctions of warm-blooded animals due to climate change to cooler conditions, such as Mammals in the Oligocene. Your fourth idea, extinction vs. evolution, is well documented by fossils and could be tested as a hypothesis of "Birds are dinosaurs." Talk to Mr. Wagner about the broadness of your hypotheses and if he thinks you should have a more restricted focus. I guess I'm not sure because I don't know how long you have to work on this project and what library resources you have available.
> I'm looking forward to working with you!
> Lauren

In my reading of this message, one could hardly characterize it as unhelpful or dismissive, though it is businesslike. Note that Lauren compliments the students on the ideas they're starting with before expressing her concern about the breadth of their plan. To help them choose between their four theories and sharpen their focus, she then offers her own assessment of the interest-value of each hypothesis and how much background material they are likely to find on it. Finally, not wanting to be too dismissive of the prospect of Lynn and Charlotte working with all four theories, she advises them to consult with Mr. Wagner before making a final decision. She then signs off by saying "I'm looking forward to working with you!", clearly indicating that she believes their work has just begun.

If this was not a clear enough indication of Lauren's interest in Lynn and Charlotte's project, a few days later she took the unusual step of writing to offer them further help. Most telementors do not take this proactive an approach, choosing instead to wait for their mentees to contact them. Unfortunately, Lauren's initiative did not meet with any reward:

> ...after a while I wrote back to them, saying how are you doing, what do you need, can I help you with anything, and I never heard back from them. And then the next thing I got was an e-mail from Rory saying they were going on vacation, you know, Christmas break, so you wouldn't hear from them for quite some time. But when they got back their reports were going to be due, and I expected a flurry of activity. I wrote them another e-mail when I got back, and received no response.

While none of the messages Lauren is referring to have been preserved, Lynn and Charlotte do offer reasons to believe that they were received, and dropped some hints in our focus group of what they thought of them. Both Lynn and Charlotte took a cynical attitude when I asked them why they thought telementors in general volunteered to take part in their project work:

> Lynn: I don't see why they would want to. I mean personally, it's not like you're going to make a new friend. I have some weird feeling that our mentor expected us to be friendly.
> Charlotte: Buddy-buddy.
> Lynn: Yeah, 'cause we were fairly businesslike. Just basically straightforward. They were like, "give a brief description of yourself." And we were like, "students, this school, this age. Anyway, back to what we really need." We weren't, like...
> Charlotte: (Reading from her written answer to my question in a saccharine voice) I said, maybe mentors help other students because they take joy in knowing (thinking) that they are helping someone else. But see, what they really don't know is, they're not helping.
> Lynn: Well, okay, actually, she helped a little bit.
> (long silence)
> Charlotte: A real little bit.

About mid-way through our conversation, when I informed Lynn and Charlotte that I had already spoken with Lauren about their project, Charlotte made clear how little interest she had in either their project or their relationship with Lauren:

O'Neill: Actually, I talked to her.
Lynn: (laughing)
Charlotte: What did she say about us?
O'Neill: She just didn't have such a great time, that's all.
Charlotte: What, is it supposed to be exciting? Are you supposed to be ecstatic when you get the answer [from your telementor], like "Oh! Our mentor wrote us, stop everything!"
Lynn: (laughing)
Charlotte: It's like, it's not supposed to be a fun thing here. It's like, boring! I don't know....

What Telementors Don't Know

As we continued our conversation, Lynn and Charlotte began to back away from personally blaming Lauren for the failure of their experience with telementoring:

Charlotte: But, like, I mean, it wasn't her fault., you know. I didn't expect her to, like...
Lynn: But talking to other people, like, their mentors were a little more helpful.
Charlotte: So I don't know if it's just like the people, or...I don't know.
Lynn: But I think it's also partially us. We didn't really care for [a mentor] in the first place.
Charlotte: Yeah. I don't think we like...(mumbles).
Lynn: We didn't exactly clue her in on anything.

Lynn's remark that she and Charlotte didn't "clue Lauren in" set the stage for some general criticisms of telementoring which are worth discussing here. Realizing that it made little sense to blame Lauren personally for failing them (which she clearly didn't), Lynn and Charlotte began to argue that telementoring was simply a flawed idea — that telementors could not be helpful to students:

Charlotte: They can't help you. They don't know what resources you have, they don't know what's available to you. They don't even know what, really, you want to do with your paper. You know? And you can't really specifically tell them.

There are two separate complaints here which should be considered individually. The first, that telementors don't know what resources students have available to them, is often true. In stating this, Charlotte is simply echoing Lauren's first message, in which she had said, "I guess I'm not sure because I don't know how long you have to work on this project and what library resources you have available." To the extent that this gap in a telementor's knowledge is considered critical, however, it reflects the telementor-as-resource-librarian view. It suggests, "if you can't point me to a specific book to find an answer, what good are you?"

Turning Away

Charlotte's last remark is more difficult to interpret, and more revealing. Why can't students tell a telementor specifically what they want to do with their paper? Perhaps she means that it's too difficult: that she and other students just can't find the words to explain themselves. This is possible, but I suspect that Charlotte meant what another of my focus students had in mind when he remarked that "You're not going to openly tell [your mentor], 'Well, I'm really a slacker and I could almost not give a damn about what you're telling me', you know?" This interpretation is reinforced by Lynn's later remark that:

> Lynn: Basically the way I see it is that mentoring is just a pain in the butt. Because like, you've got other things to do. Like this report [her second project] has gone a lot smoother, a lot quicker. Possibly because it's like the second one, but also the fact that I wasn't even wasting my time with a mentor, trying to get their information, trying to send stuff to them.

There is no question that a significant minority of the students in Wagner's class feel precisely the way Lynn does about their telementors. This is not surprising, given that when a telementor's advice is taken seriously, it can complicate students' work substantially. Project ideas that seemed viable suddenly need to be abandoned or reformulated; data sources that seemed appropriate are discovered not to be; and the team must return to the drawing board at a time when they are not certain they can afford to do so. Meanwhile, deadlines loom.

In a sense, problematizing the students' work is Wagner's key objective for telementoring. He doesn't want his students investing several weeks in a naively-conceived research project, as he has seen in the past. The "naive" project is an attractive option for some students, since it requires less thought and less risk. They may design a project to confirm something they already feel they know, or have on good authority, for instance. If students have access to knowledgeable telementors, Wagner reasons, they will have fewer legitimate excuses for taking the path of least resistance. In Lynn and Charlotte's case, it was clear that they had taken little advantage of their telementor's advice, so he could feel justified in refusing them leniency in his assessment of their project.

Wagner made the following remarks to me after Lynn and Charlotte presented their project to the class. In the presentation (and in their final paper) they claimed that the asteroid theory of dinosaur extinction was the most strongly supported, though they provided little reason to believe so:

> They made no case for their conclusion. It's like [they said]...there's more stuff written about this, so it must be right. I don't think so! We have two theories that are both doing the same thing; changing the atmosphere, changing the climate. We know the dinosaurs died, so we know what the end result of all that is, but now which theory is best? The one that has the most stuff written about it? Why? What's the evidence for that? Maybe they both work equally. I mean, there's no denying that a meteorite hit the earth then, but did that cause the end of the dinosaurs? One meteor? Was it big enough? What percent of the change [in the climate] was brought on by that particular event as opposed to being brought on by all the other events that were going on? Over what time frames? What evidence do you have to prove that? Now, this may not be a provable question because this is the exact kind of thing that geologists are constantly working on themselves. But you can at least analyze the arguments, which is what I thought they were going to do, and then present them in opposing fashion, to say, "okay, because of this, this and this we believe this." And it didn't come out that way.

One difficulty with telementoring as a strategy to encourage and support deeper thinking by students on their projects is that students quickly recognize it as an attempt to problematize their work. Sometimes, as in Lynn and Charlotte's case, they resist this effort actively. Lynn and Charlotte were not especially resistant to telementoring as such; they were resistant to project-based teaching as a way to problematize science learning, and telementoring as an attempt to reinforce this teaching strategy. As it happens, neither Lynn nor Charlotte agreed to work with a telementor for their second project. According to Wagner's official class policy, they could not do this; but unofficially, he recognized that they would simply have denied a motivated telementor like Lauren to another group of students.

Frustration With E-mail Lag

Another set of Lynn and Charlotte's complaints, which I heard from several of their classmates (though not at all from Andy), arose from their frustration with the delays that are a built-in feature of e-mail based telementoring. These are also worth considering here.

One of the reasons that e-mail is well suited to telementoring is that the students and volunteers do not need to be beside their telephones or computers at the same, pre-arranged moment in time. This would put a heavy strain on a professional's schedule, or even, in many cases, a graduate student's. With e-mail, telementors check in on their students first thing in the morning, or at lunch, or whenever they can find time. The drawback of e-mail, of course, is that students do not get the kind of instant gratification that they can get from a classroom teacher. For Lynn and Charlotte, this seemed to be unbearable:

> Lynn: It's like one thing if you've got like a teacher, but it's another thing if you're trying to talk to someone...
> Charlotte: Over the computer. And it's like you wait for the response. And by that time you did something else! And then you know, it's like writing about what you did in the past, and when you get the response it's already done.

When I asked Lynn why she thought a telementor could not be helpful to students in her class, she expanded:

> Because they have no idea what you're doing, what you've been doing, what you've gone through, what you haven't gone through. They've got no clue. The person is not, like.... Well, personally I just don't like help very much? But like, personally the way I see it is if they're not stepping through the project with you,

> they've got no idea what you've already done, and I don't like repeating myself very much.

While these students were clearly looking for excuses, all the same they had a point. As I hinted in Chapter 4, and as is more clear here, e-mail telementors are in a fairly helpless position if their mentees are not motivated to work with them. Unless the teacher dedicates time to sending each telementor a regular update on the progress of his or her mentees (something which Wagner has *never* done because the workload would be prohibitive), the telementor must rely on the students themselves for this intelligence. Lauren's case exemplifies what can happen when students are not reliable correspondents.

Frustration With Non-participation

I asked Lauren in our interview what the most difficult or frustrating part of her experience with Lynn and Charlotte was. She responded:

> Most frustrating was not getting the interaction from the students that I expected to get. I don’t know if it’s because they aren’t interested in science, or because they’re not interested in their topic or what. Maybe if he [Wagner] knew that this particular group had a problem, and were getting stuck on their project, maybe he should also have contacted me more directly and said, well these two girls are having problems X, Y and Z, and then I would have known what to *address* if I sent them another message. You know? Because I would have had a little inside information. It’s very much working in a black box.

If we compare the set of conditions under which a telementor offers guidance to those under which traditional mentoring occurs, the costs of doing mentoring over e-mail become evident. In the workplace mentoring which Kram (1988) has documented, for instance, relationships often develop between superiors and their subordinates. In this context, would-be mentors have unique assets to support and strengthen their roles. In particular, they can often rely on informal contact with co-workers or formal evaluative procedures to learn how their mentees are progressing with an assignment or settling into a role. Where this is not the case, they may be able to subtly or forcefully compel their mentees to make reports. As Lynn and Charlotte's case demonstrates, the volunteer telementors in our design experiments were in a quite different, and much more vulnerable position. In the toughest cases, they had only one informant on which they could rely if their mentees failed them: the teacher. Unfortunately, the teacher's time is likely to be at a premium at just those junctures (project deadlines) when a telementors concern is piqued.

Implications for Design

The most important implications of this case revolve around the issue of preparing students for the experience of telementoring. Lauren, Lynn and Charlotte show us that when telementoring is implemented on a class-wide basis for average students, rather than as a boutique program, some number of failed relationships will be inevitable. We should hardly be surprised by this, given that in traditional settings and in the most favorable circumstances, too, mentoring relationships can fail to realize their full potential. In the project-based science classroom, telementoring relationships may fail for several reasons: because a volunteer faces unexpected schedule conflicts; because unforeseeable events (such as technical failures) conspire against the development of the relationship; because students turn out to be resistant to the curriculum that telementoring is meant to strengthen (as in this case); or because the participants miscommunicate or just don't get along. The key to sustaining telementoring in any setting is not to rely on avoiding such difficulties, but to learn to cope with them when they occur, and keep their frequency within reasonable limits.

An important part of preparing students for telementoring is disabusing them of the naive notion that telementors can instantly gratify their curiosities or needs for resources. As knowledgeable as telementors may be, they are not mind readers; thus, they cannot respond helpfully to requests as vague as "We are working in Lightning and don't know what to look for! Please help!" Believe it or not, such requests do occur. An important part of the teacher's role in fostering telementoring relationships is to help students understand the kinds of knowledge that a telementor requires to understand their problems and offer useful advice. A small amount of explicit instruction about what it means to be a "good mentee" is called for, such as, "begin every message with a sentence explaining what you have been up to since your last message and what you are thinking of doing next." However, teachers should avoid the temptation to routinize telementoring to the point at which students are simply following steps thoughtlessly. A better strategy is for teachers to conduct in-class "walk-throughs" of successful and unsuccessful telementoring relationships, with appropriate discussion around them.

One last strategy for teachers to keep in mind is to ensure that cases of exemplary telementoring which occur in their classes are made known to all of their students. A few of the most resistant students with whom I spoke in Wagner's class insisted that they did not know of a single "good" experience of telementoring among their classmates, despite the fact that I had spoken with several satisfied classmates. If telementoring appears not to work, it is understandable for students to resist investing effort in it. Here again, walk-throughs or whole-class discussions of "good" telementoring experiences may go a long way. Finally, for students who continue to resist, it seems best to follow Wagner's strategy and allow them to opt out of telementoring altogether. In the end, this will save telementors considerable frustration and better ensure their willingness to participate year after year.

Chapter 6: Influences of Telementoring on Students' Written Arguments

In Chapter 1, I argued that today's educators should be able to provide students in middle and high school with the opportunity to construct more authentic understandings of scientific practice and argumentation. Science projects are a traditional strategy for achieving this goal, but often fall short because students lack an audience which takes knowledge-claims, rather than invested time and effort, as its first concern. Not only should students have the opportunity to pursue their personal curiosities and interests through lengthy science projects, but they should ideally have routine contact with a critical and supportive audience other than their teachers. Students' relationship with this audience should be far deeper than a one-day science fair judging which merely serves to put them on the defensive: It should involve them in a reciprocal learning partnership that challenges and informs their ideas about how science is accomplished and why.

The design experiments that I conducted with Wagner and Whitcomb were aimed at developing practical ways to provide students with this sort of participant-audience, in the guise of volunteer telementors. Some of the promises and pitfalls of students' relationships with this audience were explored through in-depth case studies in Chapters 4 and 5; but two cases cannot not tell the whole story that needs to be told about these relationships. We must also consider what effects our design experiments had on students' work and thinking at the level of an entire class. This chapter does just that, by exploring the empirical relationship between the effort students invested in telementoring relationships and the quality of the written arguments they produced about their science projects.

As I will show, the argument strategies adopted by students in their formal reports appeared to vary as a function of the effort they invested in their relationships with telementors. More specifically, student teams in Wagner's class that invested greater effort in telementoring were significantly more likely to produce sophisticated, authentically-structured arguments which took account of possible objections to their work and fulfilled the customary persuasive functions of scientific research articles. What is more, the teams with the most sophisticated rhetoric were not merely "carried" by traditionally high-achieving students. Performance on the argument measures described below was unrelated to performance on a traditional science content test.

Before discussing these measures and results in greater depth, I would like to return briefly to Wagner and Whitcomb's stated objectives for telementoring, to point out the affinity between these objectives and the aspects of students' writing on which I will focus my attention.

The Teachers' Objectives for Telementoring

At the start of the 1995/96 school year, Wagner expressed to me some ambitious aims for telementoring, associated with the development of his students' scientific thinking and the communication of that thinking. For instance, he suggested that one purpose telementoring should serve for his students was:

> ...that the kids can see how scientists think, how they work. Not only get the information, because they're going to get that, because they could get that from anybody who's knowledgeable, but also the process of doing it. So, when mentors write to me and they say, "what are we supposed to do? I've never mentored before," [I say] yeah, but you do science. And that's what it's all about. You're just helping the kids to do science. How do you think about it? How do you attack a problem? How do you look for data? You know how to do that; you do it all the time. So just help the kids think in the same way. So I'm just asking the mentors to get kids to think like scientists think in dealing with them.

Wagner's statement places special emphasis on having students encounter new ways to approach scientific problems — new methods. In a similar vein, Whitcomb talked with me about her hopes that telementoring would help her students to think critically about their project work by attracting their attention to a variety of perspectives on the issues they encountered in it:

> The critical thinking part is still a loose piece for me, or from what I saw [in my students' last set of project presentations], it's a loose piece. They still are, instead of taking the data that was available, and looking at them...they did a lot of talking about it with me, but when it came to putting their presentation together with their evidence, invariably they'd say, "and this book said...." I would hope that by working with the mentor they actually get to be a little bit more critical, and not use them as just, here's a source.

These instructional goals are as relevant as one could want to helping students understand scientific practice and argumentation, but they present a formidable problem for evaluation. As I mentioned in Chapter 3, a large part of this problem lies in gathering data that is sufficiently rich to address the issue of "thinking like scientists" without intruding too much upon students' and teachers' work (with a series of lengthy interviews, for example). What other data might one examine, though, to test whether students thought critically about their project work? In Chapters 1 and 3, I argued that students' appropriation of the Research Article genre could shed light on their understandings of scientific practice. Inevitably, students' use of the tools and trappings of scientific reporting are shaped by their understandings of the persuasive task of reporting. Thus, students' appropriation of scientific genres is one window on their understandings of scientific argument and the practices those arguments refer to.

Assessing Influences on Science Rhetoric

The Data and Coding

The results presented below are based on an analysis of 31 research reports, composed by teams of students in Wagner's 1995/96 Earth Science class over the course of three research projects. These reports, and the guidelines presented to students for composing them, were modeled on the most widely studied genre of reporting in professional science, the Research Article (RA) (Swales, 1990). The sample of articles analyzed here, including slightly fewer than half of the total reports composed that year, includes all of the articles which could be obtained in a reasonably complete form, and for which matching survey data describing the teams' telementoring relationships were collected. All but one of the six research reports written by Whitcomb's students were also obtained for analysis, as were survey data; but due to their small number, these will not be included in the statistical analysis below. These will be considered in Chapter 7, along with other data relevant to that class.

The 31 research articles from Wagner's class were coded using the Student Science Rhetoric coding scheme described in Chapter 3 (the instrument itself appears in Appendix F). As I explained there, the purpose of the coding scheme was to capture differences in students' use of common tools of argument in research articles, and to represent these as a small set of numerical scores. Each report took between 15 and 45 minutes to code, and I was the sole coder. To the extent possible, coding was conducted "blind" of students' telementoring experiences. That is to say, I did not consult the results of the telementoring surveys or student focus group during the coding. In a few cases, students' reports specifically cited their telementors, but did not describe the depth of their relationships.

Working Hypotheses

In analyzing the coded papers, I considered two rival hypotheses. The first follows from my suspicion (explained at length in Chapter 1) that the lack of an audience concerned chiefly with knowledge-claims distorts the opportunities that projects provide for students to learn how science is done and reported. If this suspicion is true, one would expect that teams engaging their telementors seriously as a participant-audience would be more apt to write about what they thought they knew on the basis of their research than about the effort they invested or the grades they deserved. Their engagement with practitioners of science while carrying out their projects would enable them to build more sophisticated models of the rhetorical situation (Bitzer, 1968) surrounding the reporting task, and this should be evident in their writing. We might call this the "rhetorical situation" hypothesis.

A second possibility, equally important to consider, is that telementoring would have a relatively small influence on students' approach to the reporting task. Variation in the sophistication of students' arguments would more likely be a function of general academic ability or interest in science. Under this hypothesis, traditional high-achievers would be expected to write the best reports, regardless of the depth of their telementoring relationships. We might call the "good students are good students" hypothesis. The best data that could be obtained to test this possibility were students' scores on an open-book Earth Science content test administered in the first quarter of 1995/96. These scores are taken here as a reasonable indicator of the students' academic ability and/or dedication to Wagner's course.

Hypothesis Testing

The primary analytical tool used to assess the relationship between the sophistication of the rhetoric used in students' reports and their experiences of telementoring was correlation. Given that the data from the rhetoric coding are non-continuous, and that the sample sizes concerned are sometimes small, Spearman's rank correlation was used to minimize the influence of outliers.

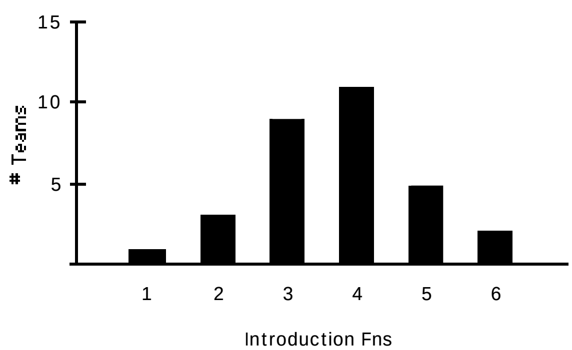
The Customary Elements (IMRD) Scores

Following Swales (Swales, 1990), I refer to the genre in which Wagner's students wrote their reports as the Research Article (RA) or IMRD genre. The name "IMRD" refers to the customary names of the major sections in such articles: Introduction, Methods, Results and Discussion. Chapters 1 and 3 discussed the long history of this genre of writing and the approach I took in developing an instrument to study students' appropriation of it in school settings.

In pilot work with Wagner during the 1994/95 school year, I identified a small set of rhetorical functions performed by his students in each section of their IMRD reports.

Several of these functions roughly parallel those discussed by Bazerman (Bazerman, 1988) and Swales (Swales, 1990) in their discussion of IMRD reports written by scientific professionals. For each of the 31 reports in my sample from 1995/96, I coded the presence or absence of these customary rhetorical functions. I then made a simple count of the number of customary rhetorical functions performed by the student research teams in each section of their reports. The functions coded for, and the sections in which they usually appear, are described below. Beside each list of rhetorical functions is a bar chart showing the distribution of scores on this variable for the 31 reports coded. A quotation from a high-scoring report is also provided, by way of illustration.

Introduction



- States a purpose in the form of a problem, question, or issue to be resolved
- Explains the significance of this purpose to the audience (i.e. why do we care?)
- Summarizes Method
- Summarizes Results
- Provides background research into the broad topic area
- Summarizes important findings from earlier work on the problem by others (names names and gives citations)

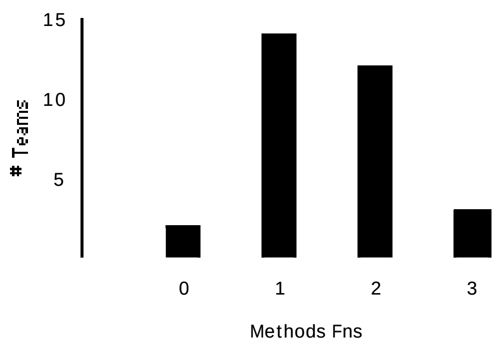
Below is a brief quotation from a report on Black Holes composed by the team whose telementoring experience was discussed at length in Chapter 4. It scored a 6 on its Introduction:

> A black hole is a region in space with such gravitational pull that light and all other matter are compacted. No amount of energy could ever remove such matter from the black hole. It is as if an entire galaxies have disappeared into an unidentifiable region. Only three black holes have been conclusively identified; NGC4261, ceter of M87 and NGC 4258 (discovered just weeks after our project began). Nonetheless, several regions of space have been theorized as being black hole regions. We decided to select two of these "non proven" black holes, Cygnus X-1 and Sagittarius A, and compare their characteristics to that of the two proven black holes, NGC 4261 and M87. We would then predict which of these two "unidentified" regions of space ar most likely black holes. By looking for similarities between the two proven and "unproven" black hole regions we were

> able to conclude that Sagittarius A is most likely a black hole yet Cygnus X-1 is beyond a reasonable doubt not.

Here we see students doing an admirable job of contextualizing their work by stating a clear problem (identifying black holes), mentioning previous findings ("proven" black holes), and summarizing their investigative methods and results. In other paragraphs, they also provide a reasonable overview of the theory of black hole formation and the significance of black holes as a phenomenon.

Methods



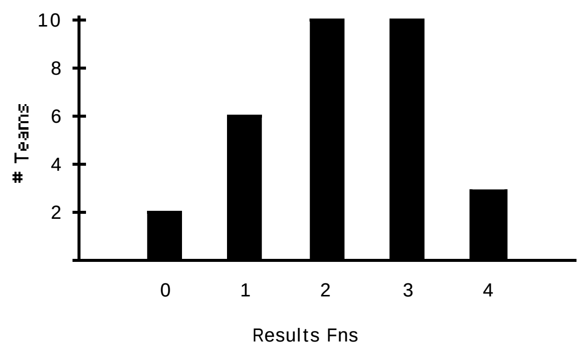
- Describes what was done by the investigators (built a physical model, collected samples, gathered sources from libraries or electronic archives, etc.)
- Does this description with precision appropriate for others to reproduce the results
- Explains why the method followed could be expected to lead to a resolution of the problem, or an answer to the question

Below is a quotation from a report which investigated the empirical relationship between the volume of snowfall in mountainous areas and the number of avalanches that occur there. The method used essentially amounted to plotting the two variables together on a graph and visually inspecting them; but the research is described with uncommon precision and care to explain its significance. Since the students did not fully explain the rationale behind their research methods (point three), they scored a 2 for Methods functions:

> At the start of our project we planned to find out whether there is a pattern of avalanches in North America but we ran into some roadblocks along the way. There is not an organization that documents the time and date of each avalanche along with its location.... We began by calling different ski areas to find if they published there own information about avalanche records and snowfall. We found that all of the Colorado ski areas report their data to the Colorado Avalanche Information Center. In calling the center we met Dan Altman, who turned out to be an incredible help. Dan provided is with the information we needed for analyzing,

> annual snowfall and number of avalanches.... We immediately produced spreadsheets and graphs to analyze the data received (see spreadsheet 1 graph 1) We examined the line graph and found that there was definitely not a direct parallel between annual snowfall and total avalanches....

Results

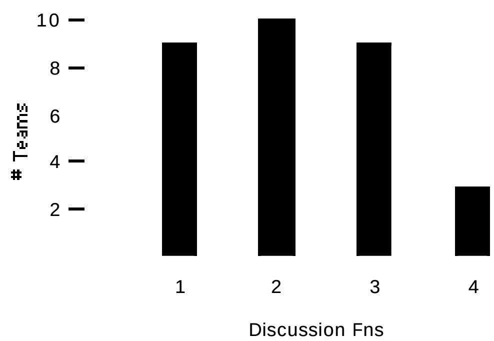


- Foreshadows results briefly (in a sentence or two)
- Presents the data collected or found (in tabular or graphical form, a set of images, etc.)
- Characterizes or "glosses" the data for the non-specialist
- Provides an interpretation of the data with respect to the original question or problem (in the form of calculations and/or prose that refers specifically to the data)

Below is a quotation from a report on volcanic activity in the Pacific region which scored a 4 for Results functions. This section serves its purpose well because it foreshadows the research results, presents and glosses the data, and provides interpretation of these data in a very concise manner :

> The amount of volcanic activity directly corresponds to the rate of [continental plate] movement as suspected. Of the three island arcs studied, Japan had the greatest incidence of volcanic activity; at that location, the Pacific Plate has the greatest measured velocity: 9.29 centimeter per year. The Aleutian Islands had the second greatest incident of volcanic activity; at that location, the velocity of the Pacific Plate measured 8.02 centimeters per year. The Philippines had the least incident of volcanic activity; at that point, the velocity of the Pacific Plate measured 7.27 centimeters per year. See graph #3.

Discussion



- States the conclusions that can be made about the original question or problem from the data or information collected
- Attempts to explain how the data support, refute, or are unrelated to hypotheses about the question or problem mentioned earlier
- Discusses the importance of the results with reference to the significance of the original question or problem
- Makes suggestions for further study

Finally, below is a quotation from a report which investigated why the coastal waters in California are so much colder than the surrounding land and ocean. The authors attributed this phenomenon, in part, to the upwelling of cold water from the ocean depths. This report scored a 4 in the Discussion dimension because it offers an explanation of the phenomenon (point 1) and the lack of available data (point 2). In later paragraphs, the authors also describe the importance of the results and offer suggestions for further study:

> The data on upwelling is indirect. This is because it is really hard to measure vertical velocities (up and down flow) in the ocean, because they are very small. We infer that upwelling occurs from a combination of theory and measurements. From theory, we know that wind blowing toward the Equator along a coast will tend to cause upwelling. The upwelled water comes from about 200 meters depth, so it is colder than the surrounding [sea surface temperatures] when it reaches the surface. From measurements of wind direction and SST we can say that cold coastal SSTs during periods of upwelling favorable winds (i.e., equator ward along the coast) are consistent with the theory of upwelling.

Relationship of Customary Elements (IMRD) Scores to Frequency of Correspondence with Telementors

The working hypothesis I stated at the top of the chapter would suggest that through extended discussions with telementors about their research, student research teams would become more concerned and/or informed about the difficulty of supporting knowledge-claims based on their research. Given this increased awareness or concern, their persuasive goals would shift away from a focus on the time and effort they invested in their projects, toward the defense of knowledge-claims. In the next sections, I will consider what my coding of students' research reports reveals about this hypothesis.

Estimates of e-mail correspondence

As was mentioned in Chapter 3, direct logs of the e-mail correspondence between Wagner's students and their telementors were available only for the third project of 1995/96, and some of these logs were apparently incomplete. For the analysis conducted here, the quantity of correspondence between each student team and its telementor was estimated on the basis of survey data collected at the end of each project.

In the post-project survey (Appendix A), the members of each student research team filled a six-cell table with estimates of the number of messages sent to and received from their telementors at the beginning, middle, and end of the project. The variable used in the analysis reported here represents the mean of the estimates of message traffic provided by the members of each team. Students' estimates were generally quite consistent: in fact, just 5 teams (8.3%) had standard deviations in their estimates higher than 3.5 messages. Figure 5 shows the distribution of the estimated message traffic for the 31 project teams.

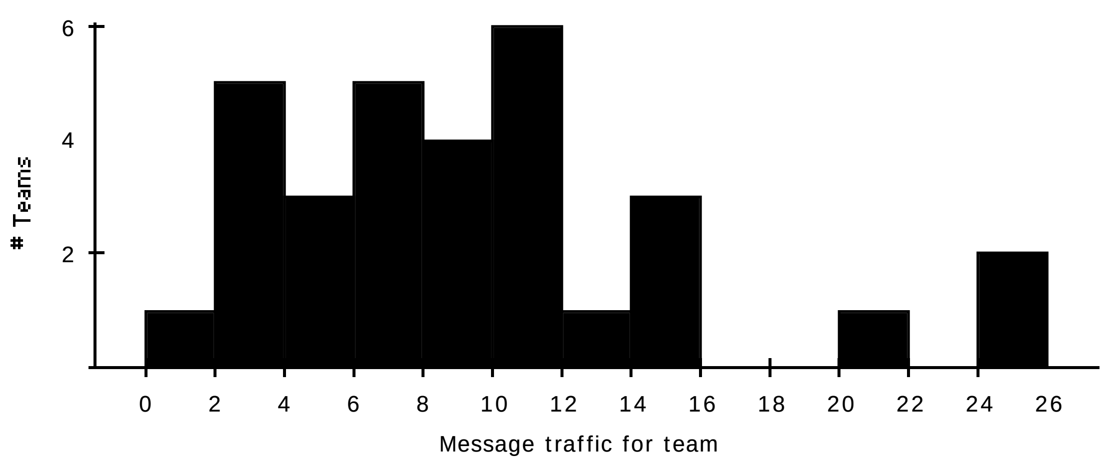


Figure 5: Students' estimates of total messages exchanged with their telementors, averaged by team

As is clear from Figure 5, the volume of correspondence between student teams and their telementors over the course of a project varied widely, from no correspondence at all in one case to virtually one message per day in another. The majority of the teams, however, exchanged between four and sixteen messages with their telementors over the course of each project. To some, this number may seem small; but note that the Black Holes project discussed in Chapter 4 involved a total of just fifteen messages.

Since my sample of 31 coded papers were written at the conclusion of different projects, one might wonder how the volume of messages between student teams and their telementors varied between projects. In fact, it was surprisingly consistent. While the total volume of correspondence students reported having with their telementors dipped somewhat from project 1 to project 2 (see Figure 6), this change did not approach statistical significance. Thus, we can safely compare the relationship between volume of e-mail and the results of the paper coding across project cycles.

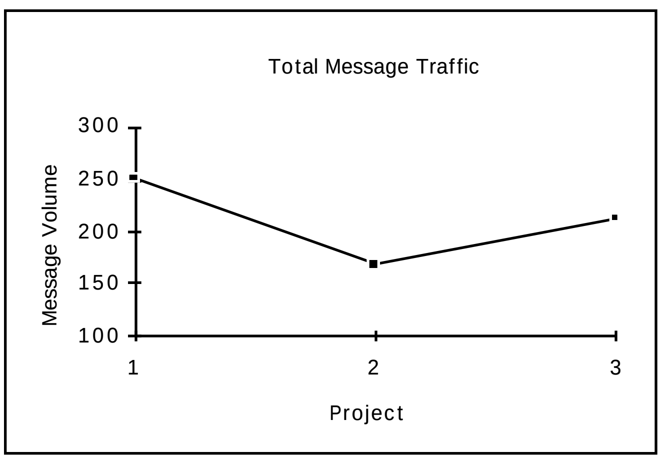


Figure 6: Change in total volume of message traffic over three projects

In Chapter 7, I will provide a topical overview of students on-line dialogues with their telementors. Here I will simply ask: did teams which sustained lengthier conversations with their telementors write more rhetorically sophisticated research articles?

Relationship to Customary Rhetorical Functions

When the 31 coded reports from projects 1, 2 and 3 are considered together, there are no significant correlations between the research teams' volume of correspondence with their telementors and the individual rhetorical function scores for the Introduction, Methods, Results and Discussion sections. However, when the rhetorical function scores for the Introduction, Methods, Results and Discussion sections are added to produce an overall score for each paper (see Figure 7), a significant correlation appears.

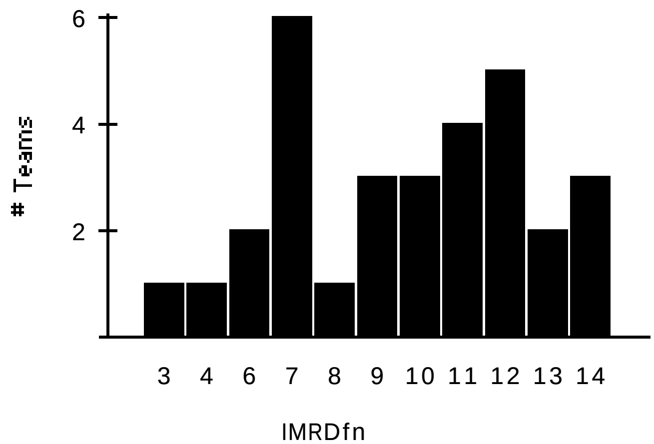


Figure 7: Distribution of total IMRD function scores for the 31 papers sampled

The correlation between the 31 teams' frequency of correspondence with their telementors and their total IMRD function scores (Figure 7) is significant and positive (ρ=.357, $p<.05$). These results are consistent with my hypothesis that more extensive correspondence with telementors would lead to more sophisticated rhetoric in students' research articles. Furthermore, there is no significant correlation between the IMRD function scores and the team members' top score or average score on the first-quarter content test. It is arguable, then, that students' telementoring experiences had an influence on their written arguments which would not have been predicted from their performance on a traditional academic task.

Interestingly, inspection of the relationship between the IMRD scores and frequency of correspondence by project (see table 7) revealed that project 3 was the only one for which the correlation was individually significant (ρ=.552, p<.05). This finding is noteworthy from the standpoint of implementation, since it suggests that the influence of telementoring activity on IMRD function scores did not take effect, or was not measurable, until the students had developed a substantial collective experience with telementoring. The small number of papers available for coding from projects 1 and 2 leave some doubt, however, as to how early the apparent effect began.

Table 7: Correlations between IMRD scores and message traffic, by project

	Projects 1-3	**Project 1**	**Project 2**	**Project 3**
Research Articles Coded	31	9	8	14
Spearman rank correlation between Message Traffic and IMRD Score	.357*	.230	.118	.552*

The Perspectives and Hedging Scores

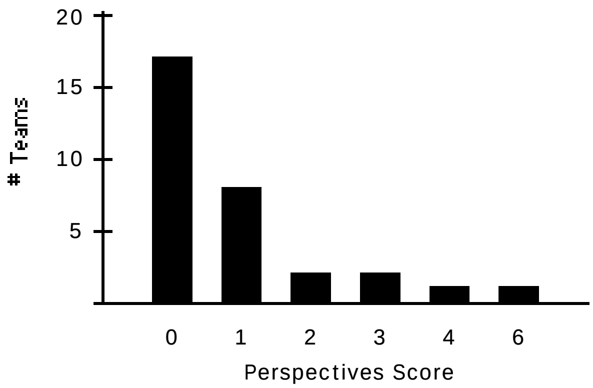
Students' attempts to account for alternative perspectives on their research findings and strategically weaken their claims are captured in the Perspectives and Hedging scores. As I discussed at length in Chapter 1, it is common for students to overstate the case for their preferred interpretations of their results, perhaps under the assumption that stronger arguments are more persuasive. It was hoped that ongoing conversations with telementors would teach students a more even-handed approach, helping them to avoid the pitfall of one-sided or overly bold arguments.

The components of the Perspectives and Hedging scores are listed below. The distribution of scores on these dimensions are provided, along with illustrative examples of the behaviors coded for. It should be pointed out that *unlike* the IMRD function scores

* Indicates p<.05

discussed above, the Perspectives and Hedging scores have no predetermined upper limits. Whereas a paper can earn only one point on the IMRD scales by performing each of the previously-identified rhetorical functions, a research article can earn multiple points on the Perspectives and Hedging scales by accounting for a number of different perspectives or acknowledging a number of different weaknesses.

The Perspectives Score

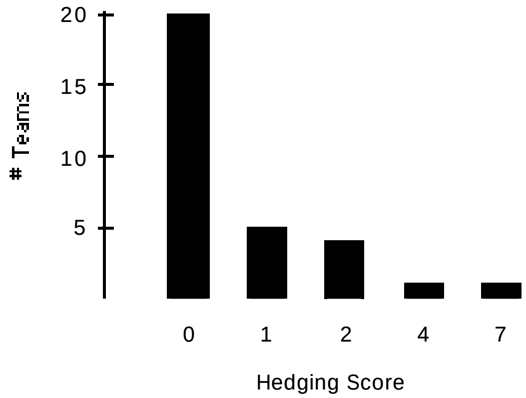


- Anticipates possible objections and attempts to address them (e.g. "It could be said that...but on the other hand...")
- Summarizes and weighs several perspectives on a point (i.e.. evaluates more than two possibilities for their relative merit)
- Draws attention to a point of general contention in the field (e.g. "There seems to be little consensus over how to interpret the ice core data...")

Below is a quotation from a paper which investigated the relationship between lightning strikes and forest fires using data from all 50 United States. The hypothesis tested (that states with larger forested areas would have more lightning-related fires) was relatively trivial, and the argument not well carried. However, to their credit, the students do attempt to account for possible objections to their conclusion:

> ...the states with very little forested area mostly followed our original hypothesis. The three states Delaware, North Dakota, and Rhode Island did not have any lightning related forest fires. So, for the most part, our theory held true. There are some sources of error, however. There are always a lot of instances in which lightning might have started a chain reaction which set off a bigger fire than would have been normally. Another error is that are data is only on that of 1995. We would have been better off if we did a data analysis of around ten years. That would have given us a more solid data presentation.

The Hedging Score



• Acknowledges possible flaws in the method or calculations performed by the writers
• Acknowledges the limits of the writers' own experience or data
• Emphasizes the provisional nature of the conclusion or argument put forward (e.g. "More data are needed for a definite answer to this question")

Below is a quotation from the Conclusion section of a paper which evaluated the supporting evidence for two rival theories about the locomotion of an aquatic dinosaur known as the Plesiosaur. This paper was not only unique in the question it chose to address, but in the care with which the evidence was considered. It could not be considered in the correlations reported in the next section due to inadequate survey data on the team's telementoring experience; however, this passage from the Discussion section shows some of the thoughtful provisos that earned its authors a Hedging score of 6:

> Alexander [a researcher in the field] argues that underwater flight is a more efficient means of propelling large reptiles in water, but there is no hard data to support this conclusion.... Given the paucity of fossil evidence regarding the Plesiosaur it is currently impossible to reach a firm conclusion regarding its method of locomotion. There is a significant amount of circumstantial evidence that seems to favor the underwater flight hypothesis, but other forms of locomotion cannot be ruled out at the present time. Until further fossil data is found or a living Plesiosaur is located (perhaps at Loch Ness since "Nessie" is thought to be a Plesiosaur-like creature) the true mode of locomotion of this extinct reptile must remain unproved.

Relationship of Perspectives and Hedging Scores to Frequency of Correspondence with Telementors

The data from the Perspectives and Hedging coding also support my hypothesis that more extended dialogue with telementors would tend to increase the sophistication of students' written arguments. When the articles from all three projects are considered together, the correlation between the Perspectives scores and teams' estimated frequency of correspondence with their telementors is significant; but once again, repeated experience with telementoring seems to play an important role. As with the IMRD function scores discussed above, project-by-project inspection of the data shows that the expected correlations are significant only in the third project of the year (see Table 8). The Perspectives scores, in particular, have a highly significant correlation with the number of messages exchanged in the third project ($\rho=.803$, $p<.01$), while the Hedging scores have a smaller, but still significant correlation ($\rho=.627$, $p<.05$).

Table 8: Correlations between Perspectives and Hedging scores and message traffic, by project

	Projects 1-3	**Project 1**	**Project 2**	**Project 3**
Research Articles Coded	31	9	8	14
Spearman rank correlation between Message Traffic and Perspectives Score	.385*	-.044	-.049	.803**
Spearman rank correlation between Message Traffic and Hedging Score	.332	.120	.195	.627*
Spearman rank correlation between Message Traffic and Perspectives+Hedging	.409**	.044	.127	.771**

Giving the "good students are good students" hypothesis its due consideration once again, I found that neither the teams' Perspectives scores nor their Hedging scores correlate significantly with their high or average scores on the Earth Science content test. Thus, the apparent influence of telementoring activity on students' written arguments cannot be explained away as the product of differing levels of ability between teams.

Discussion

This analysis of the 31 available research articles from Wagner's 1995/96 class reveals that teams of students who carried on relatively frequent correspondence with their

** Indicates p<.01
* Indicates p<.05

telementors were significantly more likely than their classmates to strategically soften their arguments and take multiple perspectives into account. This more cautious and mature argument strategy was particularly evident in the final project of the year, when the class had accumulated substantial collective experience with telementoring. As the large-scale topical analysis of telementoring dialogues will show in the next Chapter, the differences between shorter and lengthier telementoring dialogues are not simply quantitative, but qualitative. Lengthier dialogues typically offer telementors more grist for advice-giving and greater opportunity to subtly inform a team of possible objections to its work.

The most likely alternative explanation of these results, which I termed the "good students are good students" hypothesis, finds no support in my analysis. Under this hypothesis, "good" students would be expected both to produce thoughtful reports *and* maintain rich telementoring relationships, simply because these are expected of them. However, the lack of any significant correlation between the IMRD, Perspectives, or Hedging scores and teams' average or *maximum* grades on the first-quarter content test gives the lie to this hypothesis. One would have expected the most dedicated or compliant students to score high on a traditional academic task like a content test; but these high scorers clearly did not "carry" their teams when it came time to put together written arguments about their project work.

To be fair, there is a third explanation of these findings which I do not have the data to refute here. One may speculate that both the best research articles and the richest telementoring relationships were produced by teams whose members possessed the strongest writing ability. This ability would be beneficial to both the composition of research articles and the maintenance of telementoring relationships, but would not necessarily correlate with high scores on a content test. Unfortunately, test data to address this hypothesis were not collected from the participants in this research, so this hypothesis must be left open.

Relationship of Rhetoric Coding to Scientists' Holistic Ratings

To put the results of the Student Science Rhetoric coding in perspective, I solicited holistic ratings of a sample of the 31 coded papers from a small group of graduate students, professionals, and university faculty in the sciences who had volunteered as telementors. These volunteers were asked to rate a random sample of 18 student research articles with respect to their overall quality, the quality of the arguments they presented, and six other attributes. This set of holistic ratings was intended not as a thorough validation of the Student Science Rhetoric coding scheme, but as a preliminary test to inform its future development.

As I described more thoroughly in Chapter 3, the six raters were recruited using volunteer records from the CoVis Mentor Database. As shown in Table 9, these volunteers had varying levels of experience in publishing and reviewing research articles at a professional level. Each volunteer used a prepared form (Appendix G) to rate articles chosen at random from the 31 which I had previously coded using the Student Science Rhetoric Coding Scheme. As an introduction, all volunteers read and rated an identical set of three papers chosen to familiarize them with the range of quality in the students' work. This "calibration" or "training" set included papers with relatively high and relatively low IMRD and Perspectives scores.

Table 9: Experience of volunteer raters in publishing and reviewing research articles

Rater	Number of Research Articles Published	Number of Research Articles Reviewed
1	2	15
2	7	6
3	3	0
4	0	0
5	2	0
6	1	0

After rating the three articles in the training set, each volunteer coded three unique articles, resulting in a total of 18 sets of holistic ratings for the 18 "unique" articles, in addition to the three articles in the training set. All articles in both the training set and the unique set were presented in a uniform word-processing format to minimize the influence of surface attributes (such as page layout or font size and style) on raters' judgments. Spelling, grammar and paragraph structure were, however, left unchanged from the original submissions.

Rating Scales Presented to Volunteer Scientists

The paper rating form in Appendix G prompted volunteer raters for judgments of quality concerning several different aspects and portions of each paper. These were:

- The quality of the paper as a **whole**
- The quality of the **question** or problem posed
- The quality of the **research** presented
- The quality of the **argument** presented about the research
- The quality of each of the individual sections of the paper (**Introduction**, **Methods**, **Results**, and **Discussion**)

These judgments were registered on scales from 1 to 7, where 1 represented the worst possible rating and 7 represented the best possible rating. As noted in the instructions enclosed with the rating forms, no explicit criteria were given for any of the scales. Rather, the purpose of the study was to determine the extent to which the raters' criteria agreed with my own. Volunteer raters were provided ample space on the rating form to describe the criteria they applied in making their judgments, and the majority of raters made full use of this space.

Findings

In general, the correlations between raters' holistic judgments and the scores generated using the Student Science Rhetoric coding scheme were positive, but non significant (see Table 10). The one case in which the scientists' ratings correlated significantly with my own rhetorical function scores was, however, a particularly important case: the Methods sections.

Table 10: Spearman rank correlations between rhetoric coding scores and scientists' ratings for individual sections of students' research articles

Introduction	Method	Results	Discussion
.248	.640*	.368	.264

The differences between the scientists' ratings and my own rhetoric coding may be explained, in part, by the differences in the tasks pursued by the raters and myself. In the Student Science Rhetoric coding scheme, for example, function scores assigned to the various sections were intended to be as independent as possible. That is, the rhetorical functions score for the Introduction was not intended to effect the rhetorical functions score for the Conclusion in any way. In the scientist raters' holistic judgments, however, scores on the various dimensions seemed highly interdependent.

To explore this interdependence, I constructed three regression models. Using the correlation matrix presented in Table 11, I constructed models which attempted to account for the variance in raters' judgments of the papers as a whole, the arguments presented, and

* Indicates $p<.05$

the research conducted, using the five other scales from the rating form. Among the variables on the rating form, raters' judgments of the article as a whole were best accounted for by their judgments of the Conclusion (or Discussion) section and the Question or problem framed in the article. These variables accounted for 86% of the variance in the "Whole" variable. Raters' judgments of the Argument presented were best accounted for by these same variables (82.6% of variance).

In an interesting contrast, raters' judgments of the Research presented were more difficult to account for, and were best accounted for by different variables. The strongest relationships to the Relationship variable were found in raters' judgments of the Method and Conclusion sections of students' papers (76% of variance). These relationships are somewhat interesting in themselves, but most relevant here because they shed light on the contingent nature of the raters' holistic judgments.

Table 11: Correlations among raters' judgments of the quality of report sections and holistic attributes (most significant in italics)

	Question	**I Rating**	**M Rating**	**R Rating**	**D Rating**
Whole	.819	.796	.849	.772	*.874*
Argument	.779	.749	.780	.667	*.900*
Research	.721	.780	*.854*	.787	.834

According to the comments supplied on their rating forms, my six scientist raters also took a wide range of criteria into consideration which were not reflected in the Student Science Rhetoric coding scheme. A raters' free-text comments from the rating forms made this clear. Below are a selection of these comments, to which I have prefixed the apparent criteria applied:

Interestingness: "No glaring deficiencies. Interesting idea for a topic, too."

Focus, Grammar: "Not only is the structure of this paper poor (grammar, spelling, etc.), but it lacks any focus. Heck, the title doesn't even describe what the paper is attempting to do!"

Length: "Well thought out, if terse, however."

Breadth: "Although the students admit that their research question is very broad, the lack of a problem/question here makes writing conclusions almost impossible."

Ambition/Restraint: "Not good, just a synopsis of general Jupiter and SL9 facts. This team realized the difficulty of their research topic shortly after starting. They should have re-framed their question/problem to one more easily determined."

As the range of comments indicates, there was quite a difference between the nature of the holistic rating task conducted by the volunteer scientists and the coding task which I had performed using relatively explicit and independent criteria. In retrospect, the lack of significant correlations between the volunteers' holistic ratings and most of the rhetoric scores discussed earlier (for example, the Perspectives score) is not surprising. It is, however, comforting that the scientists and I appear to have applied many of the same criteria in judging students' Method sections; especially given the importance I placed on students' understanding of its role in my argument of Chapter 1.

Summary

The results of coding 31 research articles written by telementored students in Wagner's 1995/96 class reveal that teams which invested greater effort in sustaining their relationships with telementors were likely to produce more sophisticated written arguments about their research, whether or not they scored high on a traditional content test. Holistic ratings solicited from six volunteer scientists revealed that despite considerable variation in the criteria they applied, the rhetoric coding captured a significant part of what scientists valued in students' Method sections. This is a promising result, given the argument presented in Chapter 1 regarding the importance of this aspect of the rhetoric of Research Articles and the difficulty that students typically have in understanding it.

Chapter 7: Sustaining Volunteer Telementoring

In Chapters 4 and 5, I explored two project-based telementoring relationships in great depth. These case studies were intended to show how telementoring relationships function, and how the shapes that they take are influenced not only by the participants themselves, but by the events and rituals of the classroom context which motivates and sustains them. While these cases reveal important constraints on the design of activity structures for telementoring, however, they are only a small part of the story to be told about the design experiments that I carried out with Wagner and Whitcomb. Taking these case studies as a background, this chapter will consider a larger question: how did our designs function on the scale of the entire class, and what might be done to improve them?

Answering this question well is critical, since the quality of designs for telementoring will ultimately determine whether it can be sustained as a strategy to support innovative teaching and learning in the years to come. Can the designs for telementoring which I discussed in Chapter 2 bring volunteers back repeatedly, and keep teachers and students engaged? While the participants in my design experiments may not represent all of those whom one might hope to involve in telementoring, it is worth asking what they expected in return for their efforts, and how often these desires were fulfilled. In order to continue and grow, volunteer telementoring must, at a minimum, satisfy the desires of those who invest their time and effort in it.

What did the Teachers Want, and What did They get?

To begin with, I would like to consider the desires of the teachers who took such initiative in crafting and implementing these design experiments with me. I believe they are the most important participants to satisfy, since it is they who will decide, on their own grounds, whether or not to make telementoring a routine part of their professional tool kits for teaching.

Wagner's Objectives for Telementoring

Early in 1995/96, I asked Wagner about his objectives in orchestrating telementoring for his students. His initial response to this question focused primarily on the learning resources and advice that telementors could provide to make unique and ambitious projects more feasible for his students:

> My hope is that because I'm trying to connect them with people that, on a day to day basis, are more versed in a topic that they're interested in [than me]...that these people will be able to provide them with more up-to-date information [than I could], ways of doing things, places to look for data...all the kinds of things that are important to them and important to that particular project, that I can only deal with in generalities. I mean, I can talk to kids about astronomy, meteorology, oceanography and geology and lots of other things; but when it gets to plesiosaurs [an aquatic dinosaur that one student team had researched in 1995/96], I don't know squat about plesiosaurs. So, if I can get you in contact with the world's foremost...expert on plesiosaurs and dinosaur movement, then I think I've done a good thing for you in terms of getting your project done.

Wagner's mention of plesiosaurs (a kind of aquatic dinosaur) refers to one case in which his objectives were clearly met. Around the time of our interview, a team of his students had begun studying the locomotion of this dinosaur, and in the process were building a telementoring relationship with a published authority on the subject. In Chapter 4, I detailed another case (the Black Holes project) in which students pursued a unique, ambitious and timely project with the help of a telementor. While these cases are impressive, though, orchestrating telementoring requires too great an effort on a teacher's part to be justified by these cases alone. This leads one to ask, in how many other instances were Wagner's wishes at least minimally satisfied?

Telementoring Dialogues in Wagner's Class

To address this question, I examined my sample of e-mail logs from 24 telementoring relationships that Wagner orchestrated in the final quarter of 1995/96. Chapter 3 discusses the collection and coding of these logs at length. The coding scheme was developed inductively, and includes nodes for the speakers (e.g. mentees and telementors), topics of conversation (e.g. project ideas, domain phenomena, data sources), and types of conversational "moves" made (e.g. questions, advice, complaints and apologies). Table 12 summarizes the results of the topical coding for the 24 logs, showing the number and percentage of dialogues in which a variety of subjects related to the students' project work and their domains of study were raised.

Table 12: Numbers of relationships in which domain-related topics were raised, Wagner's 3rd project

Topic of Conversation	Number of Relationships	%	Scope of Topic
Project	24	100	Students' ideas for investigations, progress on their work, standards by which it will be judged, etc.
Students' project ideas	22	92	Students' ideas for their research (questions to answer, hypotheses to test, or simply topics to learn about)
Status of students' work	14	58	What students have and have not yet accomplished on their projects
Domain	12	50	Phenomena, learning resources, methods, practices, data sources and standards of evidence specific to the students' research domain
Phenomena	12	50	Events, processes or objects under investigation
Learning resources	10	42	Resources such as web sites, periodicals, books or journals relevant to an investigation.
Methods	7	29	Ways of going about an investigation
Terminology	5	21	Terminology used by investigators in this domain
Standards of Evidence	1	0.4	What does and does not constitute proof

While the figures in Table 12 do not reflect the depth to which particular topics were discussed, they do provide a useful cross-section of the e-mail log data. Below, with the aid of this cross-section, I will discuss the prevalence of several different types of telementoring dialogues in the log data from Wagner's 1995/96 class.

Abortive Dialogues

The figures in Table 12 show that while every one of the 24 telementoring dialogues raised students' project ideas (usually in the students' "hello" messages), only half of them proceeded as far as raising specific domain-related phenomena. Seven of the 12 dialogues which didn't progress this far were apparently abortive relationships like the one I studied in Chapter 4, which ended almost as soon as they began. In a few cases, it appears that the telementor was simply unresponsive to the students, while in others, the students wrote their first message to their telementor at such a late date that it was impossible for him or her to be of help. Below is an example of one such case:

Date: Tue, 14 May 1996 09:00:40 -0600
To: mentor@covis.nwu.edu
From: jamie@schools.covis.nwu.edu
Subject: raindrops
Aemon,
Our project is due on friday. We have chosen a proposal, however, we have not proceeded from there. We decided to write about, what do raindrops form around? What is this called' Is there any info that you can give us as soon as posible? This would be very appreciated.
Thank you for your time.
Jamie and Ken

From: Aemon
Date: Thu, 16 May 1996 22:35:40 -0600
To: mentor@covis.nwu.edu
Subject: Re: raindrops
D'Oh!
I've been out, and I didn't get this message until now. :-(
If just the _subject_ is due on Friday, let me know, and I can see if I can find more info for you. But, it will be too late for you if your project is due tomorrow.
Aemon

For reasons made clear in Chapter 4, the frequency of abortive dialogues like this one must be kept below a certain threshold if any telementoring model is to be sustainable; particularly if the pool of potential volunteers is small to begin with. Incidents like this one generate frustration for the students, telementors and teachers alike; but their worst potential consequence is attrition from the volunteer pool.

"Research Librarian" Dialogues

Another type of dialogue that appears in Wagner's logs I refer to as the "research librarian" dialogue. Here, the students' contribution to the exchange consists primarily of factual questions or requests for references to data or articles on the topics they are studying. If the telementor satisfies these requests routinely, and does not succeed in either problematizing the students' work or building some other form of participation in it, he or she may be left with little or no influence over how the relationship develops, or even whether it continues. In the worst case, students can decide to "take the data and run". Below is an excerpt from one such dialogue:

Date: Mon, 29 Apr 1996 08:51:20 -0600
To: mentor@covis.nwu.edu
From: ken@schools.covis.nwu.edu
Subject: flood help
Hi,Richard, We are two students doing a project on floods. We are looking for some concrete data to observe. Our teacher said that you might be able to help. We have acces to the web, so if you know of any good web cites we would love that. Thanks for your time.
sincerly, Ken ane Cody

From: rich@usgs.gov
Date: Thu, 2 May 1996 21:09:34 GMT
To: mentor@covis.nwu.edu
Subject: Re: flood help
If you are interested in studying Illinois floods, the website you will want to look at is "http://wwwdilurb.er.usgs.gov/pub/floodinfo/", which maintains both historical and real-time flood (and other streamflow) data for Illinois rivers.
You will also want to browse the US Geological Survey homepage, which is at "http://www.usgs.gov/". Note the link at that page to water resources, which will lead you to a wealth of flooding information for sites and events all over the country.
Let me know how else I can help, especially with your study design and/or interpretation of the field data.
Richard

Date: Wed, 22 May 1996 08:09:02 -0600
To: mentor@covis.nwu.edu
From: ken@schools.covis.nwu.edu
Subject: final paper
Richard,
Cody and I would like to thank you for all of your help on our floods project. We also appologize for a lack of keeping in touch. The net sites that you told us

about, the USGS ones, were absolutely great and helped a lot. thanks again. We
also thought you might want a copy of our paper so here it is.
Thanks,
Ken and Cody

While Ken and Cody's behavior was not particularly harmful in itself, it is no more likely to bring volunteers back to telementoring repeatedly than the abortive dialogue discussed above. Unfortunately, in the radical project-based classroom that Wagner runs, it is difficult to prevent this kind of behavior altogether. By the time the log data discussed here were collected, the majority of Wagner's students had experienced telementoring at least once before; but despite Wagner's discouragement, a few students persisted in treating their telementors as librarians. Preventing this entirely would require such draconian measures as prohibiting students from sending e-mail without Wagner's approval, or rigorously "training" telementors to rebuff all requests for resource pointers until certain conditions are met. Both measures would run counter to the spirit Wagner's largely "free" classroom, and are of dubious practicality given the resources available to a single teacher.

Domain-Oriented Dialogues

Referring back to Table 12, we see that half of the 24 logged dialogues turned at some point to specific domain phenomena and data resources. In these discussions, telementors and their students more closely approached the ideal of a research partnership in which the telementors served as a responsive critical audience. Unlike the research librarian discussions just mentioned, telementors asked questions or made requests almost as often as their mentees (although on different fronts).

As an example, below is a lengthy excerpt from an exchange between a telementor and a research team beginning a project on sea surface temperatures. As the conversation begins, the students are nearly directionless, having already begun and aborted a project on riverbeds:

From: David@llnl.gov

To: mentor@covis.nwu.edu
Subject: Re: hi

Dear Byron and Vanessa,

> We are two highschool students in an earth science class
> reserarching sea surface temperatures. We, if we can find any data, are
> going to research the question: How do the temperatures in the Northern
> Atlantic Northern Pacific compare? And try to find a reason for this.
> If you have any questions, comments, pointers, or anything else, we would
> be grateful to hear about it! Thanks,

You have chosen an interesting topic. Where are you in your research now?

A lot of data exist on sea surface temperatures (SSTs). Compiled data sets of historical measurements from ships are one data source. Another data source is satellite data. An introductory textbook on general oceanography (e.g., Grant Gross's _Oceanography:_A_View_of_the_Earth_) would be a good place to do some of your initial research.

> P.S. What do you do ? and so forth and so on???

I work as a physicist at a national laboratory. I study the physics of the ocean. Mostly, this means studying what makes the water move. I am part of a large group that researches climate, so our interest in the ocean has to do with its influence on climate.

I have a Ph.D. in oceanography. In junior high and high school, I wanted to be a Marine Biologist. In college, I shifted my emphasis slightly to wanting to be a Marine Ecologist. During that time, I got perhaps the best advice I've ever gotten from anybody: a Marine Ecologist advised me that, no matter what else I took, I should take a lot of math. This advice saved my career, because there are almost no jobs in Marine Ecology now. Taking lots of math allowed me to shift my emphasis to Physical Oceanography while I was a Master's student, which I've been doing ever since.

Regards,
David

In his first message, David was helpful without being merely compliant. He immediately asked Byron and Vanessa for a report of their progress so far. Not only did he get this report, but his mentees deferred to him in a way that is quite rare:

Date: Wed, 1 May 1996 13:52:10 -0600
To: mentor@covis.nwu.edu
From: byron@schools.covis.nwu.edu
Subject: WE are...

Hey David, currently we are working on finding places on the web where we can find out data about oceans and their temperatures. One site I found to be useful was a site from a Japinese company(not that I remember the name or anything...). But I found it very helpful. We need to re-write our Backround INnformation(on oceans/their temperatures and how they are controled). But this can wait untill next week (unless you think we should do it now.). so thanks a lot,

BYRON AND VANESSA

Date: Thu, 2 May 96 08:59:58 PDT
From: David@llnl.gov
To: mentor@covis.nwu.edu
Subject: Re: WE are...
Dear Byron and Vanessa:
I would start writing ASAP. Writing often takes longer than you think it will.
The Levitus `94 data set has global ocean temperatures and salinities as a function of latitude, longitude, and depth. You can access it at
http://ingrid.ldgo.columbia.edu/SOURCES/.LEVITUS94/
Another site that may be helpful to you is (perhaps it's the Japanese site you mentioned?):
http://dpo.ori.u-tokyo.ac.jp:81/ocean/toolmap/Levitus-map.html
It not only has a link to the Levitus `94 data set, it allows you to specify what parts of it you want to look at (e.g., only North Pacific SSTs).
Enjoy,
David

Date: Sat, 4 May 1996 00:59:07 -0600
To: mentor@covis.nwu.edu
From: byron@schools.covis.nwu.edu
Subject: SST(again...)
Hey!! thanks for the web sites!! while looking them over, I realized that my question (about the comparison of pacific and atlantic ocean sst's) wasn't a very good one. So I have a question. attached is a document gotton off page:
http://ingrid.ldgo.columbia.edu/SOURCES/.LEVITUS94/.SEASONAL/.temp/html+viewer?plot=X+Y&zoom=Zoom&plotcoast=draw+land&CS=&CE=&plottype=plaincolor&X.width=360.0000&Y.width=180.0000&Z.value=0.0000000E00&T.value=2.500000&X.first=0.5000000&Y.first=-89.50000&X
(yes it is a real page...)
I was wondering about the circled areas, is it just a flaw or is this something that would be worth researching(why...)??
as you can see we are changing our question... once we decide what we will be researching then we will deside what to put in our backround information(they don't take that long to do...)
thanks Byron and Vanessa

From the messages above, it is clear that Byron and Vanessa's research was scattered. Still, they remained engaged in their relationship with David. Despite the heavy deadline pressure that put the students in Chapter 4 in doubt about the value of telementoring, Byron and Vanessa sustained this relationship; and this sustained conversation gave David natural opportunities to provide a number of mentoring functions. Among these were parables drawn from his own educational decisions and career (the "take lots of math" story), advice on writing reports ("start early"), and guidance to data sources and analytical tools.

Ultimately, Byron and Vanessa settled upon on a research agenda that they and David were happy with. Because the students had made an investment in keeping David informed of their progress and their thinking, he was able to reinforce their choice and guide their research through to a conclusion. While it is unclear what lasting effect David's mentoring will have on Byron and Vanessa, it is clear that it presented a rare opportunity for them to engage a practitioner's perspective on science. Perhaps they will reflect upon this experience years later, the way that Wagner reflects upon his experiences with his thesis advisor, or Whitcomb remembers her English teacher (as I discussed in Chapter 2). Perhaps not; but one thing is clear. While it is often difficult to get students to discuss their science projects with one another or their teacher, telementoring can clearly provide occasions in which students see a need to explain themselves and their thinking in detail, rather than simply arguing for a grade. Another good example of this appears in the following section.

Methodology Discussions

In Chapter 1, I offered several examples of poor Method sections written by students about their research projects. I argued that these misconstruals of "method", which bore the clear stamp of concern over grades, could lead to an impoverished view of scientific practice. Part of the value of telementoring, as it was experienced in Wagner's classroom, is that it can offer occasions for students to explain the investigations that they are planning to do, or have done, to an audience which is primarily concerned with knowledge-claims rather than invested effort. This offers the hope that students will come to see "method" as not merely a sequence of steps for which marks are allotted, but as a strategy for formulating and establishing new knowledge.

In about a third of the 24 telementoring dialogues I coded from Wagner's class, research methods were broached by the mentees, telementors, or both. The instances included exchanges like the following, in which a telementor attempts to save his mentees from a desperate dead-end in their research by offering a rather specific, and practical plan for them to pursue:

To: mentor@covis.nwu.edu
From: philip@schools.covis.nwu.edu
Subject: lightning

Dear Boris,

We tried to contact the lady that has all the information relating to lightning and forest fires, but she did not write us back. Our situation now is pretty brutal: We don't really have a specific question (because we can't find any data), our paper is due in a little over a week, and if this lady doesn't talk to us, we have no more leads to follow and we will have to start from scratch. If there is any way possible for you to think of another aspect of lightning to study and write about, we are in desperate need. We especially could use something that won't take a month to gather all the research on. Thanks for all your help and effort.

Philip

From boris@u_topia.edu Mon May 6 07:36:20 1996
Date: Mon, 6 May 1996 08:43:27 -0400
To: mentor@covis.nwu.edu
Subject: Lightning
Good morning,

Did you look at the web-site I mentioned in my last message? It contains the 1995 fire statistics, noting cause and state. That's about the best data you'll get on-line, I suspect. If you can then find data on either the acres of forest in each state (should be available somewhere relatively easy to find) or the population density in each state, you can look at some comparison of the % of fires started by lightning and the population density, or the forested area.

Taking the population density issue, you should be able to get state populations from either an atlas, or the US Census Bureau (I'm almost certain they're online with a web page.) State areas should also be easy to find. With this info and the Fire statistics, you could easily calculate 50 (x,y) pairs of coordinates where x and y are the populations density and the % of fires started by lightning. (Which of these would be the dependent and which the independent variable?)

Do you know about least-squares-fit, or linear regression? Do you expect to find that %lightning fires increases as pop. density increases, or should %LF

decrease when pop. density increases? Does a linear regression agree with what you expect?
I hope this gives you some more help. Let me know if you've decided to bag the fire-aspect of lightning, I'll try to think of other ideas.
Boris

This message illustrates several effective telementoring strategies. While it satisfies the students' pragmatic need for pointers to data and proposes a clear research plan, it presumes a great deal of initiative on their part and recommends ways in which the they can stretch their understanding (i.e. learning about linear regression). As we have seen in other dialogues, Boris also poses a couple of useful heuristic questions, designed to push the students' thinking forward. However, he does not presume that the students will take up the research agenda that he suggests. He makes it clear that he will follow them down another path if they prefer, or suggest other research agendas that might interest them more.

In Wagner's classroom, deadline crunches like the one reflected in the exchange above were often responsible for breakthroughs in telementoring relationships, helping to forge stronger bonds between the participants. In focus groups, students rarely spoke better of their telementors than when they credited them for escaping a narrow scrape. Even if the telementor's aid itself does not prove helpful, seeking it may have benefits of its own. In a case from the final project of 1995/96, a team which had been attempting to grow several varieties of crystals in the classroom sought advice on how to recover from the apparent failure of their experiments. In order to secure advice from their telementor, they found it necessary to explain what they had done, and their reasons for doing it, in considerable detail:

Dear Kevin,
We tried to make crystals using powdered sugar, regular white sugar, brown sugar, and salt (we couldn't get epsom salt) we mixed 2 tablespoons (30 mL) of all the solids with 150 mL of tap water 'till all the solid was dissolved. Then we tied string to a popsicle stick and put it on the glass so that the string was hanging in the liquid. This was about four days ago, but there are only crystals in the salt and it looks like there's mold or something in the powdered sugar and in the regular sugar. Did we use too much water? I used that much water so that there would be a

> lot of string in liquid. Should we try again or wait 'till all the water evaporates? we're also going to do the same thing only put the beakers in shade, light, cold, and on a hot plate to see if darkness, heat, etc. has any effect on crystal growth. I know that the crystals on the hot plate will grow faster but do you have any suggestions on what we should do with the beakers we've already mixed? should we use less water for the other experiments? --Katie

Katie's message is a nice example of a circumstance in which students engaged their telementors as a helpful and critical audience, though in a less involved way than we saw in Chapter 4 with Andy, Cori and Bill. Katie goes to the trouble to explain what she and her teammates have done, not because she has been required to do so or is trying to impress her telementor, but because she needs him to understand the situation in order to get informed advice.

Wagner's Assessment

As the figures in Table 12 suggest and the quotations above illustrate, only about a third of the telementoring dialogues from Wagner's third project of 1995/96 involved the kind of consultation over research methods and data sources that one might associate with a research apprenticeship. The remainder were a combination of much briefer discussions of domain phenomena and learning resources (i.e. "research librarian" discussions), or "abortive" dialogues which barely began before they ended. This having been said, some might be surprised to hear how pleased Wagner was with the contribution that telementoring made to his teaching in 1995/96. In our closing interview, he rated the year's telementoring "an eight out of ten", holding back from a nine or ten only because he saw room for improvement in his own preparation of students for the experience:

> Yeah, I'm generally, again, satisfied. But...how do you prepare the students better for dealing with mentors? I think that's something that I need to think about better ways of implementing that in the future.

When I introduced Rory Wagner in Chapter 2, I stressed that his implementation of telementoring was a pragmatic response to the challenges of sustaining his innovative project-based teaching strategy. Over time, telementoring has evolved into an integral part of this strategy. Because Wagner chooses to follow through so completely on his belief that students learn best through the pursuit of their own curiosities in the domains that interest them, he faces a great need to support the initiatives of teams pursuing a wide variety of research agendas at once. Without the aid of his volunteer telementors, he and many of his students are convinced that he could not sustain this style of project-based teaching. First and foremost, the telementors' practical role in Wagner's classroom is to fulfill his students' needs for support and guidance in diverse domains of study.

My analysis of the e-mail logs from Wagner's class shows that his telementors fulfill this part of their role well. A breakdown of the conversational moves made by telementors in available message logs shows that the largest single portion of mentors' message text is devoted to suggestions and advice. Following as a close second are explanations of domain phenomena, research methods and so on.

Table 13: Percentage of mentor text devoted to various conversational moves, Wagner's 3rd project

	Suggestions /Advice	**Explanations**	**Requests**	**Questions**	**Apologies**
Percentage of total mentor message text	16	15	11	9	9

Ultimately, Wagner's consistent efforts in orchestrating telementoring must be understood from the perspective of investment and return. While telementors' guidance may in some cases be rebuffed (as we saw in Chapter 5), it routinely enables a few of Wagner's students to exercise tremendous initiative and produce unique, high-quality projects (like the Black Holes project discussed in Chapter 4 and the Plesiosaurs project mentioned at the start of this chapter). In these cases, it is clear that the work could not have been accomplished without the advice and guidance of a telementor. Not only do Wagner and his volunteers find these projects rewarding, but the time that telementors dedicate to them frees Wagner to assist other students in their work: formulating viable project ideas, locating, charting and interpreting data, and so on. All of this work is quite time and energy intensive.

In the end, the net effort that Wagner is spared in producing unique learning outcomes for a few project teams each year justifies the investment of time he makes in orchestrating telementoring for all of his students. There are, in addition, other rewards for Wagner's efforts, such as the enjoyment he gets from corresponding with telementors and the reinforcement they provide that his work in helping students to understand scientific practice is appreciated.

Whitcomb's Objectives for Telementoring

When Whitcomb and I discussed her plans for the Community in Balance project, she had a very specific role in mind for her 6 volunteer telementors to play. In her mind, their primary benefit would be in making up some of her own perceived deficits in content knowledge:

> You know, I don't *know* sometimes even when I give [my students] information, because I teach general science, and because I'm a late bloomer in science myself, and I still have a whole bunch of science blocks and a whole bunch of lacking concepts myself. So I'm glad they will have another source to go and check out even if I give them some information, to verify. ...our kids are real dependent on one-source...advice, and so possibly, conceptually, you know they hear one thing from me, they read something in a book, and then they talk to a mentor, maybe...the concepts that they do develop will be not be so one-sided. And if I'm dealing a misconception, that I'm sharing with them...they'll be able to have other sources for, you know, getting rid of or correcting that misconception.

Because of the focus that Wagner and I had developed on students' defense of knowledge-claims and consideration of multiple perspectives, Judy's concern over students' "one-sided concepts" was an important touchstone for us in our work together. Not only did she expect her students to use their telementors as a way to verify what they were learning through their project work, but she expected the influence of the telementors as an audience to be quite strong:

> I'm hoping that by being involved with [their telementors], that they're putting [their work] out there for someone else, one, that they're going to be a little more critical of themselves, because it's not me that they've known for three years and they know that if they smile nicely I won't get so mad about it.... You know, that kind of thing. They'll have somebody new that they're presenting it to, and somebody who will give them a *different* kind of feedback than I feedback I've given them, which they've learned very nicely because I can tell from their visual presentations they're doing all the kinds of things that I would like to see. So I hope that by having a new audience that it will help them grow in that respect....

Telementoring Dialogues in Whitcomb's Classroom

In the e-mail message that Whitcomb sent to her volunteers to kick off the Balanced Community Project, she asked her volunteers to be mindful of the strong influence that they might have as an audience:

> As you advise, suggest and point them in a direction, remember that this is the first time that they have had an audience to present their ideas to that wasn't their teacher. Your comments will most likely have a greater influence to them than mine.

As I will discuss at some length below, Whitcomb's prediction (and mine) about the telementors' influence proved overly optimistic; yet her students engaged their telementors as research partners in a way that Wagner's often did not. Table 14 presents an overview of the topics broached in the six telementoring dialogues from the Balanced Community project. This overview reveals some interesting points of contrast with the telementoring dialogues from Wagner's class, as I will discuss below.

Table 14: Numbers of relationships in which various topics were raised, Whitcomb's Balanced Community project

Topic of Conversation	Number of Relationships	%	Scope of Topic
Students' lives	6	100	Students' scholastic and non scholastic interests, siblings, etc.
Telementors' lives	4	67	Telementors' interests and hobbies on and off the job, families, etc.
Telementors' jobs	2	33	Telementors' work lives
Project	6	100	Students' ideas for investigations, progress on their work, standards by which it will be judged, etc.
Students' project ideas	5	83	Students' ideas for their research (questions to answer, hypotheses to test, or simply topics to learn about)
Status of students' work	5	83	What students have and have not yet accomplished on their projects
Domain	6	100	Phenomena, learning resources, methods, practices, data sources and standards of evidence specific to the students' research domain
Phenomena	6	100	Events, processes or objects under investigation
Terminology	6	100	Terminology used by investigators in this domain
Practices	3	50	How work (other than research) is organized carried out by practitioners in the domain
Learning resources	3	50	Resources such as web sites, periodicals, books or journals relevant to an investigation.
Methods	0	0	Ways of going about an investigation

Biographical Exchanges

One of the most obvious contrasts between the telementoring dialogues orchestrated in Wagner's class and Whitcomb's lies in the frequency of students' social exchanges with their telementors. As Table 14 shows, biographical details from students' and telementors' lives were mentioned in a strong majority of the dialogues in Whitcomb's class, whereas these came up in fewer than 17% of the exchanges from Wagner's class. This difference reflects a significant contrast between the two teachers' activity structure designs (discussed in Chapter 2). Because of her concern with establishing the trust necessary for mentoring relationships, Whitcomb began the Balanced Community project by handing each research team a short, one-page autobiography by its assigned telementor. After reading these autobiographies, Whitcomb's students were instructed to reply with brief autobiographies of their own, describing their ages, their likes and dislikes, and their favorite subjects in school. An example shows how friendly these biographies often were:

> Date: Wed, 15 May 1996 18:54:45 -0500
> To: mentor@covis.nwu.edu
> From: brandi@schools.covis.nwu.edu
> Subject: All about me
> Hello! My name is Brandi Thomas. Im 12 years old and in the seventh grade. I like to dance and sing, and hope to be a singer when I grow up. I like to read Goosebumps books, I have 14 books. I have 3 sisters and 3 brothers, I'am the second youngest out of seven kids. I use to live on the west sid e but now i live on the north side. I stay with my aunt and she takes care of me.
> I have a cousin, shes in 8th grade, shes about to graduate from grammer school and I have a dog her name is Pooch.
> P.s. Im looking foward to you respond.

Whitcomb's six volunteers took quite different approaches in responding to their mentees' biographies. Two of the telementors chose not to respond to them at all, but the most popular telementors responded to each biography individually, often in a friendly, almost childlike fashion:

> Date: 16 May 1996 08:38:08 PST
> From: paul@local.agency.gov
> Subject: All about me
> To: mentor@covis.nwu.edu
> Subject: All about me
> Hey Brittany! It's great to meet you. I also have a 12 year old daughter named Noelle. She also likes Goosebumps books and all sorts of scary stuff. And I like to sing too! When I'm not working at my job I play guitar and sing in a rock & roll band. My dog's name is Tika. She's mostly black and very furry. I'm really looking forward to working with you and your team.
> Paul
> Principal Planner/Environmental Coordinator
> Sunnyplace, CA

While the number of students involved here is too small for strong generalizations, Whitcomb felt that when telementors made these personal gestures, her students were far more responsive to their advice in later work. In our closing interview, Whitcomb brought up the case of Trevor and Craig. These two relatively disengaged teammates were quite impressed with their telementor's curiosity over Trevor's favorite pastime, gymnastics. Trevor had referred to this in his biography as "flipping". Not being familiar with this term for gymnastics, Trevor's mentor, Parker, asked for an explanation of what "flipping" meant. Whitcomb explains the significance of her students' response to Parker's question:

> For my level [of students], I think [the telementors' personal responses to the biographies were] very important. The ones who took the time to do that, the kids were a lot more responsive to. I think it was Parker [a telementor] who asked Trevor about flipping? Now, Craig is very motivated, just very scattered. Trevor is not motivated at all. But they both at the end made a big effort to put this project together, and to write back to him. And I think that the key to it was the fact that they felt he really cared about them. Because he asked about flipping. Just a little tiny thing; and then to write back and say, "Oh! That's cool. Now I know what that is." I think that personal thing is important for this to work well with the junior high.

Domain-Oriented Dialogues

While some of the biographical exchanges between students and telementors were quite lengthy, the bulk of the students' correspondence with their telementors in the Balanced Community project centered on the phenomena students needed to understand to draft their proposals for the construction of the paper mill in Nadroj (see Table 14). For instance, how is paper typically made? What pollutants and other emissions can be generated in this process (chemicals, thermal pollution, etc.)? How might these emissions harm plants, animals, and people, and what strategies and technology are available to reduce the impact of these pollutants?

On the whole, Whitcomb's telementors devoted the largest volume of text in their messages to explanations of the phenomena or the practices of environmental assessment. They spent slightly smaller proportions of their message text offering encouragement to their mentees on the project and making suggestions about how to get the work done (see Table 15).

Table 15: Percentage of mentor text devoted to various conversational moves, Whitcomb's Balanced Community project

	Explanations	**Encouragement**	**Suggestions /Advice**	**Questions**
Percentage of total mentor message text	38	30	21	11

The excerpt below from one e-mail exchange in Whitcomb's class shows how her volunteer telementors sometimes artfully combined explanations of domain phenomena with heuristic questions and opportunities for the students to exercise initiative in their research:

> Let's think about what happens inside of a paper mill. Paper is made from wood and sometimes from recycled paper. These are the raw materials. These materials are ground up and mixed with water to make a sort of paste that is then squished into sheets of paper. But along the way, lots of chemicals are added to this "paste". These chemicals are used to make the paper whiter, stronger, shinier and so on. Many of these chemicals are hazardous or poisonous to animals and plants. If they are released into the environment (air, water or soil), they become pollutants. When the paste is squished into paper, most of the water comes out and many of these chemicals are contained in the water. This water now becomes waste from the paper mill and has to go somewhere, right? Some paper mills dig large ponds in the ground where the discharge this water. Now, go and read the note I sent to you on Friday. How do you think all of this would affect the soil where the pond is?

In both the message above and the one below, by a different telementor, the telementor skillfully manages to suggest specific actions for the students to take, while assuming initiative on their part:

> I don't have many books for kids but you might be able to get some information and ideas out of Paul Ehrlich and Anne Ehrlich, Population, Resources, and Environment: W.H.Freeman and Co. Look in the index under soil and you will see several pages of stuff about soils. A regular textbook on soils is: Roy L. Donahue, Raymond W. Miller, and John C. Shickluna, Soils, An Introduction to Soils and Plant Growth: Prentice-Hall, Inc. There will be a lot in a book like this that you won't understand, but you may be surprised at how much you can understand. Don't worry about all of the ridiculous names they give to different soils like entisols and vertisols. You don't need to know them. Only specialists use them. But you can get the idea that soils are about half minerals and the other half is dead organic material and lots of bugs, worms, bacteria, fungi, and air and water.

The above volunteer's unpretentious introduction to soil science and his reassurances about difficult-looking vocabulary are good examples of what Judy described as a vitally important part of her own experience of mentoring. In the way that her English teacher inspired Whitcomb's self-confidence and encouraged her to stretch herself, so too does this telementor.

Status Reports

Another strong point of contrast between the telementoring dialogues that took place in Wagner's class and Whitcomb's is the volume of text that students devoted to reports on their progress. In Chapters 4 and 5, I demonstrated the importance of status reports in providing fodder for telementors' advice and criticism. In her activity structure design (detailed in Chapter 2, Table 3), Whitcomb required her teams of students to submit a number of milestones both to her and their telementors. These milestones included an initial set of research questions and a later statement of research focus. An example is given below:

> To: mentor@covis.nwu.edu
> From: dmadison@schools.covis.nwu.edu (Dara Madison)
> Subject: our group's focus
> Dear Mr. More
> Our teacher has made us choose a main problem we want to focus on from or questions and this is what we are focusing on. We are focusing on is what the cutting down of the forest will do to the soil like what kind of erosion it may cause that might make a slope and hit the town or might deposit all the nutrients of the soil into a nearby body of water which in turn make the soil poor so that the people will not be able to farm on it or no trees will grow. Now were not asking you to give us any answers but we haven't been able to find a lot of information on these subjects and were wondering if you knew any web sites on the net or any books we could check out abouts these things.
> P.S. We would be thankful for any help you could give us
> Our group,
> Soil 1

Perhaps because of the level of trust established through the formal biographical exchanges, students offered little resistance to sharing these milestones with their telementors, and were usually rewarded for their trust with more pertinent advice.

Discussions of Telementors' Work Practices

With respect to our goal of engaging students in scientific discourse and practice (discussed at length in Chapter 1), the most impressive aspect of the Community in Balance project was the natural opportunity that it provided for telementors to explain various aspects of professional practice in Environmental Science to students. One telementor, for instance, responded to a mentee's stated dislike of "snobs" with an explanation of zoning approval:

> Incidentally, one of the important elements of a project like the proposed paper mill is the effect of "snob zoning" which means that some people don't want to put up with other people's proposals because they want to protect their "investment" in a neighborhood, or a community. So they "zone" out the possibilities of having undesirable industry or in some cases, economic development, in order to prevent it from happening. Sometimes this is done by requiring large fees for permits, sometimes it is managed by requiring large expenses for property lots, sometimes it is done by requiring "architectural approval", and by other means. So when you arelooking at the plusses and minuses of this project, don't object and find ways to prevent the project from happening based on "snobbishness"!

In another instance, a young woman who was surprised at her telementors' lengthy responses to her teammates' biographies suggested to him that he must have quite a bit of time on his hands. Perhaps concerned about being cast in the image of a lazy civil servant, the volunteer responded:

> Your letter suggested I must not have a lot of work to do! Well, I think you need to follow me around for a day and see how much work I have to do. I repair computers (take them apart and put them back together, and hopefully they work!) and program them. So I'm not far from a computer all day. But I try to respond to you and your class during lunch and early in the morning before everyone gets here. I get up every morning at 4:30 a.m. (before the sun rises) and at work after riding a train into the city for an hour and a half. Then I start checking my mail, and do my replies. I get home in the afternoon at 5:30 p.m. and usually have to go to meetings at night for the Boy Scouts. So I'm busy.

While this may not be the way that one would prefer students to learn about their telementors' work lives, this response was probably quite memorable to the young woman and her teammates. It certainly was to Whitcomb, who raised the anecdote in our final interview.

Student Research Articles: an Audience Unrealized

Now I would like to leave the telementoring dialogues from Whitcomb's class behind and, as I did for Wagner's class in Chapter 6, consider the apparent influence of these dialogues on students' written science rhetoric. At the opening of this section, I mentioned the high expectations that Whitcomb and I had for her telementors' influence as an audience. Given the promising preliminary results we had seen in Wagner's classes, we were optimistic that students' experiences of telementoring in Whitcomb's class would also influence the form that their written arguments took, and their awareness of alternative perspectives on their research. Unfortunately, as I will explain at length below, this goal seems largely to have gone unrealized in our 1995/96 design experiment.

Five of the six team research reports from Whitcomb's class were available for inspection in the preparation of this report (the other was misplaced at the school). As I mentioned in Chapter 2, these research reports were one of several products required for submission in the Balanced Community project. Other products and performances that were required included team milestone documents, a journal by each student about his or her contributions to team work, a physical model by each team representing the operation of some facet of the proposed paper mill, and an in-class oral presentation at the close of the project.

These submissions were not only greater in number than those required in Wagner's class (which focused exclusively on the production of a research paper and 15-minute class presentation), but had to be produced on a shorter schedule than in Wagner's projects: five weeks versus seven or ten. As a result of the shorter work schedule and the number of submissions required, the research reports produced in Whitcomb's class were brief and hastily written; though no more so than the worst of the papers from Wagner's high school class. The five Balanced Community reports averaged three double-spaced typewritten pages in length, and students' work journals indicated that they were written in as little as a single class day.

Unfortunately, the shortness of time in the Balanced Community project not only prevented lengthier or more thoughtful reports, but made it infeasible for students to get feedback on these reports from their telementors by the end of the school year. This fact, and the fact that Whitcomb's students lacked the repeated experiences of telementoring which seem to have been so important to the audience effects in Wagner's class (see Chapter 6), may be largely to blame for the lack of consideration that Whitcomb's students apparently gave to telementors as an audience for their work.

Form and Rhetorical Function in the Whitcomb Reports

Like the reports from Wagner's class discussed in Chapter 6, the reports from Whitcomb's Community in Balance project were coded using the Student Science Rhetoric Coding scheme. This coding, however, was intended primarily to inform the revision of the scheme, and not to support statistical analysis. The small number of reports from my experiment with Whitcomb renders the reductionist analysis used in Chapter 6 unnecessary; in its place, I will provide a richer discussion of the contents of the reports through two especially salient examples.

On the whole, the most striking contrast between the research reports from Whitcomb's class and those from Wagner's is the wide variety in both their heading structure and order of presentation. In contrast to the consistency of organization in the Wagner reports (particularly in their use of traditional IMRD sections), only two of the five reports from Whitcomb's class followed the form of a scientific research article in a recognizable way.

As I will mention later, this inconsistency seems partly to have been the result of unclear guidance on the IMRD genre, for which Whitcomb and I are equally to blame.

Like the examples of assessment-related rhetoric from Wagner's class that I discussed in Chapter 1, the contents of the Balanced Community reports make clear that the teacher was the primary audience considered by the writers. As a first example, I take the report of a group of five students whose chosen research specialty was the potential effect of the paper-making process on the water supply in the town of Nadroj. The title of this report, "Paper mills and what we learned", hints from the beginning that the students have either not grasped, or have chosen to abandon the idea of preparing a scientific report for the fictional town council described in the assignment. Otherwise, one might have expected a title such as "Recommendations for water filtration at the Nadroj paper mill".

The body of the paper begins with a brief statement of purpose which assumes considerable shared knowledge about the nature of the assignment (I have included the assumptions in parentheses):

> The purpose of this project is to find out how we can prevent harmful chemicals [from the proposed paper mill] from contaminating the water [in the town of Nadroj].

With their statement of purpose on the table, the writers jump straight into a kind of encyclopedic writing more typical of library research reports than scientific articles or opinion papers:

> Paper got its name from the word papyrus, which was a reed that Egyptians used for making paper. But, paper that is used here in America was invented in China.
>
> Paper is made from trees or logs. When it reaches the paper mill, the bark is removed with a bark-removing drum....

The writers continue in this fashion with a good deal of well-targeted background information, outlining the process of paper-making, listing the chemicals used in this process, and describing industrial water filtration methods in general terms. However, there is little in the way of persuasion offered for a particular interpretation of this material.

In about the middle of the paper, squeezed between their list of chemicals produced in paper-making and their description of water filtration methods, the team offers its conclusion:

> These are some of the many chemicals used in making paper. The question is how can we get rid of them? Our group came to the conclusion that if the paper mills use chemicals that are harmful, it won't contaminate the water if the paper mill uses a superior filtration system and if they restore the water back to the water source they got it from.

While Whitcomb could describe the activity which led the students to this conclusion, in the context of the report it appears to come from nowhere. There is little in the team's description of filtration methods to explain how the chemicals produced by the mill will be eliminated by the proposed filtration system, and there is no proper Method section in the report to explain how the team derived its primary knowledge-claim. Like most school reports, this one is squarely aimed at describing "the way things are" according to authoritative sources. It is more or less a book report; except here the sources are the telementor (whose aid the students acknowledge and describe) and a collection of industry web sites to which he referred his mentees.

Contrary to my hopes and Whitcomb's, these students did not exercise any rhetoric that is unique to scientific reporting. While they did quite a competent job of presenting the material they studied, they apparently did not feel it necessary or appropriate to justify their main knowledge-claim very rigorously. Thankfully, though, they avoided the type of assessment-related rhetoric apparent in my next example.

A second paper that helps to illustrate how Whitcomb's students constructed their work and its audience was composed by a team studying the potential effects of paper-making on soil's ability to support plant growth. This paper, titled "Paper Mills and How They

Work", borrows more of the visible trappings of a research article than the paper discussed above: in particular, section headings. To the writers' credit, they appropriate these trappings in a relatively thoughtful way, rather than "shoehorning" the contents of a book report into Introduction, Method, Results and Discussion sections. However, the jumbled order of the sections and sketchy treatment of research methods suggest that the writers had less concern to justify the knowledge-claims they made than to testify about their hard work to their teacher. As I argued in Chapter 1, this is the hallmark of the assessment-related rhetoric that Whitcomb and I had hoped to undermine through telementoring.

The report begins with an Introduction that lays out the purpose of the students' research, states a hypothesis, lists the materials used in a small experiment, and summarizes its results. All in all, this section does quite a good job of fulfilling the customary rhetorical functions of an Introduction in a research article:

> The purpose of this investagation is to see if the chemicals which come out the paper mill have an affect on the soil, and the plant that is planted in the soil.
>
> Are prediction was that it did not harm the soil. So we did an experiment with soil, bleach, and bush beans, and a straw, and a cup. We did not know if the bleach would affect on the soil and the bush beans. So the results came back, and we found out that the bleach does not harm the soil, it just seems like it made the seed grow faster. It took two weeks for us to get our results back.

From this point on, however, some important omissions appear. While the students provide a good initial overview of their simple experiment (cultivating beans in one sample of soil containing bleach, and one without), they do not describe the conditions of the experiment in any further detail. They mention that the experiment took two weeks, and that the "bleach bean" seemed to grow faster; but they do not show any particular concern over possible objections to the experimental conditions or their interpretation of the results. Were the two beans equally viable for growth? Were they planted in similar soil? Did they get equal light and water, on the same schedule? And *how much* bleach was used to contaminate the bean in the experimental condition? These details are left unclear in the

Results and Method section, which, strangely, provides only a narrative description of how wood is prepared for paper-making:

> Results and method:
> Wood is cut in small logs and then thrown into a bark removing drum. Then the bark is removed, the wood is choped up into little chips....

From my experience in judging science fair projects at Jordan Community School (some by the very students involved in this class), I know that students at this level are capable of reasoning and arguing about the control of variables and conditions. Rather than discussing the particulars of their experiment, however, these students choose to impress upon their teacher what hard work they had done. This is made clear by the presence of *two* subsections in the report titled "What we Learned": one in the report's Results section, and one in the Discussion section. The subsection from Results reads as follows:

> We learned about the paper mill, and how it works, and we learned that bleach does not harm the soil, it just makes the soil brake up. It was an interesting project and we made lots of progress. We also found out that the other chemicals that are in the paper mill does not have an affect on the soil it just makes it mushy. Through the weeks and the days we have learned alot thou the experience was sort of hard but are team stuck together and we were doing a good job. And I am pleased to say that I'm glad I worked with Mark, Jeff, Bill and Mary. I think we were a great team.

As in the examples of assessment-related rhetoric I cited in Chapter 1, the students' main objective here is to present a compelling adventure story about their work in completing the assignment. The goal of persuading the audience of a particular interpretation of its research findings unfortunately takes a back seat. This is not an indictment of Whitcomb's teaching or of her students, but an indication that our first design experiment in telementoring failed to impress upon Whitcomb's students the unique character of scientific persuasion. This is a tall order, and well worth further attempts. Considering that Wagner's approach to project-based telementoring has taken a period of years to refine, and shows measureable effects on persuasion only at the end of a year of project work, the telementoring dialogues produced by participants in the Community in Balance project are impressive.

One area in which Whitcomb and I have already begun to improve upon our 1995/1996 efforts is in clarifying the guidance provided to her students in composing their research articles. For the work reported here, Whitcomb's students took part of their guidance from a rudimentary guidebook prepared by the Chicago Public School board titled "Pinnacles of Exploration" (CPS, 1996), and from their experiences with science fair presentation boards. Not only was this guidance probably inadequate, but my discussions with students in focus groups suggest that the "position paper" idea presented in Whitcomb's assignment handout confused some teams about which genre they were expected to pursue in their reports. Whitcomb has already chosen to act upon these suspicions by preparing a standard set of guidelines for research reports at Jordan Community School. These new guidelines integrate elements from guidelines that Wagner and I prepared for his students.

Whitcomb's Assessment: The Benefit of "Stepping Back"

While Whitcomb was impressed with the excitement and the specialized knowledge that her six volunteers brought to the Balanced Community project and her classroom, her greatest enthusiasm about her first telementored project sprang from an unexpected source. In Chapter 2, I discussed Whitcomb's strategy of monitoring the correspondence between her students and their telementors as a sharp point of contrast with Wagner. In our closing interview, Whitcomb repeatedly stressed the unique perspective that this monitoring gave her on her teaching:

> One of the things that we've talked about already was my ability to step back from being immersed in the project itself. So that I have gotten a lot of good information as far as where there's breakdowns when I ask the kids to do something. On my part, or something that isn't clear. By being able to read the communication between the kids and the mentors, that was very helpful for me, and gave me a lot of insights that I'm going to try to specifically address when I set up a project like this again.

What did the Telementors Want?

While less initiative was required of volunteer telementors than of teachers in these design experiments, their role is, of course, equally essential. I will argue in Chapter 8 that the long-term success of telementoring in supporting innovative teaching rests on the ability of teachers to provide experiences that will keep volunteers coming back; and on this front, I believe my design experiments with Wagner and Whitcomb provide encouraging news. Interviews with several volunteer telementors revealed that while what motivates them to volunteer may vary enormously (from simple altruism to a desire to increase the representation of women in science, for instance), what they expect in return for their effort is, in operational terms, quite uniform and usually within teachers' capabilities to provide.

Getting to Know You

As I mentioned in Chapter 2, one popular conception of traditional mentoring relationships holds that they must be deeply personal in nature: otherwise, they do not constitute "real" mentoring. This stance has been best addressed by Kram (1988), whose study of mentoring in the workplace is the single most influential in the field. While she acknowledges the important contribution of friendship as a mentoring function, she is quick to point out its limitations:

> In general there are limits to the friendship function. Most individuals choose to contain informal social interaction to the work context in order to minimize the conflicts created in being both boss and friend. Thus a senior manager influences the boundaries of the friendship so that she can also evaluate and judge the young manager without feeling guilty or ambivalent. While friendship adds spontaneity and enjoyment to each manager's life at work, it is limited by other relationship functions and cross-gender dynamics that cause each individual to maintain a comfortable distance. (Kram, 1988, p. 39)

In my experience thus far, volunteer telementors have not often had a strong expectation of developing deep friendships with students, nor have these friendships often occurred. In fact, in my sample of 24 e-mail logs from Wagner's class, I can find evidence of telementors revealing biographical details in only three. Two of these instances occur in relationships discussed in earlier chapters: the Black Holes project discussed in Chapter 4, and the Earthquakes project discussed in Chapter 2. Furthermore, in two years of studying the telementoring in Wagner's classroom, I can report only two clear instances of friendships developing from project-based telementoring. One of these occurred 1994/95 between a one of Wagner's students and a Physics undergraduate in Ireland; the other will be mentioned later.

Some might attribute the lack of intimacy in many of the telementoring relationships studied here to the impersonal nature of e-mail communications. In fact, several of Wagner's telementors used this explanation in their interviews with me. However, the sharp contrast provided by Whitcomb's experience in this regard suggests that the level of intimacy in a telementoring relationship may have more to do with the curricular context and performance pressures which surround and provide motivation for the relationship. Wagner raised this set of issues in one of our interviews:

> Sometimes I see the mentors making real genuine attempts to do the mentor thing more the "right" way, in that they are sharing stuff about their lives. They're trying to make this a partnership. And kids are kids, so they're going, "what is this guy, a whacko? He's telling me all about his wife and his kids. I don't care about that. I have a project to do. I need the data, now." So they think people are weird when they're trying to be people.

A good case in point is the reaction of a young man in one of my focus groups to the purely social exchanges that a teammate of his had carried on with their telementor using his home computer. These exchanges led, in time, to some innocent disclosures on the part of the telementor, like the names and ages of his children. While Wagner had never done or said anything to discourage this type of conversation (on the contrary, we encouraged them), the student I spoke with clearly considered it out of place:

> The problem with [my first project] was that Don [a team member] kept on going home and e-mailing [our mentor] from his house, and they were having a social

> relationship. I got really scared! (laughs facetiously) I found out about this guy's wife and kids! I'm just like, oh! OK! (more laughter)

In this case, the student was convinced that his partner's social conversations with their telementor actually damaged the productivity of the relationship. The student in question did not simply have a bad attitude about telementoring; later on, he sustained a dynamic and productive telementoring relationship with a different volunteer telementor. But while he asked his telementor, a university professor, what he did for a living and why he enjoyed it, the two of them did not feel a need to discuss any other details of their lives outside their shared work. In their eyes, the work alone was apparently enough to sustain a fulfilling relationship.

Perhaps the appropriate objectives of teachers and telementors with respect to friendship is be best summed up by the following quote from an interview with Whitcomb:

> I believe in mentoring there is a friendship that develops, too, but it's not by connotation what we think of.... You know, a friend is someone we bum around with, have fun with, and everything else. Although I think there has to be a certain bond of friendship if a mentoring situation is going to be positive. And maybe when I say friendship I mean comfort zone. Trusting you enough to know that if I do screw up really badly, or ask a really dumb question, you will be tolerant enough to help me see where my mistake was or something like that.

To a large extent, I believe that the self-selected volunteers who worked with Wagner, Whitcomb and I were quite capable of providing this comfort zone, despite a lack of special training. The much better reception that mentors' more personal revelations got from students in Whitcomb's class could well be explained by the fact that the exchange of biographies was formally orchestrated. In this way the revelations could not be construed as personal gestures in the way that they sometimes were in Wagner's class. They were simply par for the course.

Witnessing Growth and Experiencing Growth

A universal theme in my interviews with telementors was their desire to see evidence of growth in students' thinking through the course of a project. This is natural, since to witness and influence human development is, after all, the very meaning of mentoring. Strongly tied with this desire from volunteers was the belief that witnessing this growth was the best way for a telementor to refine his or her skills. Few volunteers, it seems, wanted to engage in telementoring on an ongoing basis without the prospect of gradually becoming more expert at it.

This having been said, a telementor might observe mentees' growth in a variety of ways. Some volunteers expressed a clear expectation that they would see an increasing sophistication in students' plans for their project work, the questions they posed and the requests they made. These volunteers were sometimes frustrated with the small volume of e-mail they received and what they could glean from it. This does not necessarily spoil the experience for a telementor, but in the absence of a reciprocal partnership such as the one discussed in Chapter 4, or regular reports of their mentees' progress, most telementors simply want to know the end of the story. How did the students' project turn out? What influence did their efforts have? As one telementor put it, " I would have been more gratified to know what problems the students had that I was helping them to solve. It's kind of like if you’re tutoring math, you want to know how the kid did on the exam afterward."

This point was also expressed well by Lauren, whose disappointing experience as a telementor was discussed at length in Chapter 5:

> I would think that the reward would have been seeing a really good end product -- a really good report. And maybe you’d want to see the reports from the other groups as well. I don't know if one would want these things to pile up, whether you'd want to get a mailing of all the reports that the class did, or just the report that your group did..... But THAT was to be the reward really, was to mentor these students

> long distance and still have them come up with a really good project as if you had been going to that class 2 or 3 times a week, and helping them as if you were there.

Unfortunately for his volunteers, Wagner experienced chronic difficulty in getting his students to send the final text of their project reports to their telementors. In fact, in my sample of 24 logs from the final project of 1995/96, only six (25%) show evidence of this being done. The difficulty of getting students to share their reports, combined with their telementors' insistence on it, became a concern to me so early in this research that I asked students about it directly in most of the focus groups I conducted. A typical response from resistant students was that they felt they should not be compelled to share their reports with their telementors if they did not feel that they had been helpful.

Simple reluctance was not always the issue, however. Equally often, students seemed frustrated with the technical difficulty of transmitting their papers via e-mail. This is no small matter, given the great diversity of word processing formats and e-mail reading software used among telementors. A healthy proportion of the time, telementors were forced to respond to students' attempts to share their papers by requesting them in some other data format. This was greatly frustrating to students whose sophistication in such matters was, on the whole, quite limited.

Ultimately, a system like the CoVis Mentor Database (discussed in Chapter 8) could be extended to address this set of problems. The developing cross-platform capabilities of the World Wide Web could be exploited to create a very simple, integrated facility for sharing richly-formatted research papers. A key design issue, however, would be how to construct a system which could be quickly learned by both students and telementors, and not require the teacher to become the full-time custodian of an electronic paper archive.

Building Reciprocality

Despite substantial dissensus in the traditional literature on mentoring (discussed in Chapter 2), all researchers in the field appear to agree that one of the hallmarks of mentoring is its reciprocal nature. That is, one way in which mentoring is distinguished from other helping relationships is the degree to which it supports the development of *both* mentors and mentees. A necessary condition for this kind of mutual growth in the contexts studied here is a mutual regard and partnership.

In some instances (such as the Dinosaur Extinction project discussed in Chapter 5), students were simply not communicative enough with their telementors about how their projects were progressing for a reciprocal relationship to develop. Under such circumstances, students often become frustrated that their telementors are not of greater help, while their telementors are frustrated at being left in a knowledge vacuum, unsure how to intervene to assist their mentees. Wagner and I had discussed this problem on several occasions. In one of our interviews, he mused:

> You know, another thing that pops into my head is...I wish that the mentor could be more a part of the group, as opposed to the way the kids see it, which is, "give us information. You're the expert, you have all this stuff, you know all this stuff; just give us the answer or where we can get the stuff so we can get on with it."

In Chapter 4, I offered an example of what this kind of telementor-as-teammate relationship looks like (the Black Holes project), and illustrated the kind of regular participation that it requires on the part of students and volunteers.

What are the visible signs that the telementor is being treated as a genuine team member? One important sign can be students' initiative in keeping their distant advisor up-to-date on the status of their shared work. The frequency of these reports was of special concern to the teachers and I because, for reasons made clear in Chapter 4, students who do not provide their telementors with this type of fodder for advice and criticism may leave them in a "black box". In the worst case, telementors are able to do little more than refer their mentees to information resources such as periodicals and web pages. The telementor's role degrades from that of a research advisor to that of a reference librarian; a role for which most of them are unlikely to volunteer often.

On this front, the results from Wagner's classes were somewhat disappointing. Out of the 24 telementoring relationships that these logs cover, in only 8 did the students provide their telementors with reports of their progress. My criterion for a status report was simply that a message make some mention, however vague, of what the students have and have not yet accomplished in their project work. What was coded as a progress report therefore ranged from the following brief communiqué,

> Dear Sandy Holmes
> Hi, how are you? I'm Caroline. Thank you for being my mentor. I have decided to do my project on volcanoes. I haven't done much except for my background information. I am trying to figure out what I am most interested in for my proposal question. Possibly something along the lines of lava. Well, I will talk to you later.
> Christine

to the following, relatively detailed report:

> My milestone project is on earthquake. I have been collecting data on Earthquake such as the number of Earthquake in the United States in differnt region such as Alaska, Hawaii, west coast and east coast. I also have data on the number of earthquake magnitude 7.0-higher from 1900-1989 in the U.S. and last but not least is the data of the number of Earthquakes worldwide for 1985-1994. According to my data Alaska soars in the numbers of earthquakes occurence. If you know if there is anything different in alaska compare to hawaii and mainland USA?

Encouragingly, despite many teams' neglect of regular progress reports, in half of the relationships for which logs of e-mail were available, the teams of students and their telementors managed to carry on discussions about domain phenomena, or research methods, or other aspects of scientific practice besides literature and data sources.

What did the Students Want?

As the case studies in Chapters 4 and 5 illustrated, students' desires for telementoring are also very important to consider when addressing the question of how telementoring can be sustained and developed. Students' active participation in telementoring relationships is so vital to their success that without it, a teacher cannot hope to accomplish what he or she desires from telementoring. At the same time, however, it is difficult for students to get precisely what they want from their first experiences of telementoring. Their initial expectations and desires are usually uninformed and unreasonable. Because mentoring is a developmental phenomenon, one would hope and expect that repeated experiences of telementoring would teach students about not only about the scientific phenomena they study with the guidance of their telementors, but about the nature of mentoring relationships as well. There is evidence to indicate that this occurred in Wagner's classes.

As I mentioned in Chapter 3, Wagner's students completed a brief survey about their experiences of telementoring after the completion of each of the three telementored projects in 1995/96. (A version of the survey form is included in Appendix A.) Among the items on the survey was one which asked students to rate their overall satisfaction with the telementoring relationship they had just experienced. Accompanying this item were a number of others which asked students to rate their telementor's helpfulness with particular aspects of the project, and several aspects of their rapport with their telementor, including his or her friendliness and the degree of trust between them. After examining the simple correlations among these variables for 22 survey respondents who had mentors for each of their three projects, I constructed three regression models to examine the apparent importance of these variables in determining their satisfaction with each relationship. The results are presented in Table 16.

Table 16: Variance in students' overall satisfaction with telementoring accounted for by other survey variables in multiple regression models

Project	% Variance Accounted For	Variables Used in Regression Model
1	90	Help finding data, overall variety of help provided
2	87	Help finding data, careful reading of messages
3	57	Feedback on progress, explanation of scientific ideas, asking useful questions

The respondents' overall average satisfaction with telementoring does not change significantly from project to project; however, the variables which best account for their satisfaction ratings change dramatically. At the end of their first telementoring relationship, students' attention seems to focus on very tangible forms of help, such as help locating data to analyze. At the end of the second project, help finding data is still the best predictor of students' satisfaction, but the care that telementors are judged to show in reading the students' messages also plays a role. Finally, when students complete their last project, their satisfaction is best predicted by less concrete forms of help, such as the helpfulness of their telementors in providing feedback on their progress, explaining scientific ideas and asking useful questions.

Not only did the factors influencing students' ratings of their satisfaction appear to change with additional experience of telementoring, but the distribution of these ratings changed as well. Figure 8 illustrates the shifts in the distribution of satisfaction ratings reported by 22 students who were assigned telementors for every project of the 1995/96 school year. For the sake of clarity, these ratings have been grouped into three categories: "Happy" includes satisfaction ratings from 5 to 7, "Neutral" includes satisfaction ratings of 4 only, and "Unhappy" includes satisfaction ratings from 1 to 3. While the average satisfaction rating for the 22 students does not change significantly from project to project, the number of unhappy respondents drops steadily from project 1 to project 3. One explanation of this drop is that students' expectations of telementoring grew more reasonable with experience.

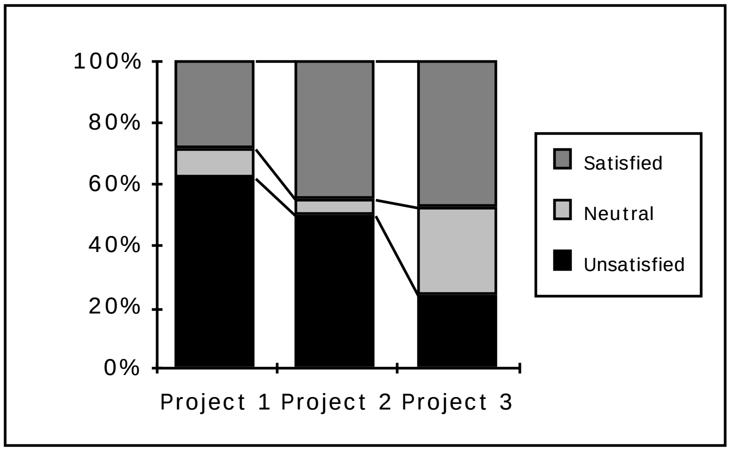


Figure 8: Students' agreement with the statement, "Overall, the mentoring was a success for me"

The practical implication of these findings, I believe, is that telementoring will not work as well as a one-time, hit-and-run affair as it will as a routine classroom practice. While students and adult might be better prepared for telementoring than they were in our design experiments, ultimately, nothing will better enable them to make the most of the experience than repeated practice.

Designing for Sustainability

This chapter has discussed quite a quantity and variety of data, from telementoring dialogues and student research reports to survey responses. Hopefully, though, my reader has not lost sight of the purpose of my analysis: Informing improved designs for telementoring which can ensure all participants' continued commitment. While this report is based on just a few design experiments in two school settings, I believe that a few safe generalizations can be made about making project-based telementoring rewarding and sustainable.

First, the telementoring dialogues from Wagner and Whitcomb's classes should make clear that the types of benefits that students derive from telementoring is not uniform across a class. In part, this is because the benefits students derive are critically dependent upon their investment in each relationship. Project milestones and their associated activity structures also play an important role in shaping telementoring dialogues, however, and here the teacher has considerable control. When the activity structures surrounding telementoring activity are well designed, they can ensure the telementors a base level of access to knowledge about students' progress on their work, and enable students to secure more pertinent advice and guidance.

In the experiments reported here, attempts to provide students with up-front instruction about the nature of mentoring relationships was largely unsuccessful. While our efforts could undoubtedly be improved upon, its seems that to a large extent our students needed to learn about the nature of mentoring relationships in much the same way their teachers did: through first-hand experience. Wagner's series of three identically-structured telementored projects is well-adjusted to provide students with the sort of experience they need to make the most of telementoring, but it may be impractical for many other teachers. It is for Whitcomb, but she has the benefit of teaching a mixed-age class which allows her students to accumulate telementoring experiences over a period of two years.

Finally, for their part, volunteer telementors find their efforts more personally satisfying if they are able to review the final products of students' work and see what influence they may have had on it. With this in mind, students' work in a telementored project should ideally be designed to allow telementors to serve as a primary audience. In practical terms, this means that a considerable amount of the work should be done in electronic form, and stored in such a way that telementors are able to see and review it *before* it is graded. In the best case, students should have some responsibility to respond to telementors' criticisms and advice so that it is clear it is being heeded. This type of arrangement will provide the best incentive for volunteers to return again and again.

Chapter 8: Taking Telementoring to Scale

How big could Telementoring Grow?

In Chapter 1, I argued that telementoring could be part of a solution to several problems in science education, providing both an aid to students and teachers in long-term project work and a critical audience for the fruits of their labor. If this argument seems persuasive, it is natural to respond by asking how widely telementoring could be implemented, and how many students might benefit from it. On occasion, this question has been put to me as crudely as “why would a Nobel prize-winning scientist want to waste his time writing e-mail to grade school kids?” While this is not the most useful way to put the question, it is worth wondering where enough telementors could be found to make telementoring part of an equitable solution to a general educational problem.

To address this concern I would like to offer a conservative, back-of-the-envelope estimate of the largest currently conceivable volunteer workforce for telementoring, based on some of the best available data on voluntarism, educational attainment, and access to network services in North America. These calculations should be understood as an attempt to represent the *potential* of telementoring as a component strategy for educational reform. With this set of calculations as a background, the final section of this chapter will concentrate on my efforts to maximize what can be drawn from this potential through the design of a network service called the CoVis Mentor Database.

How Many Telementors Could There Be?

In 1987, survey-based studies of volunteering were conducted in both the United States and Canada using sample sizes of and 60,000 and 70,000 people respectively (Hayghe, 1991, February; Ross & Schillington, 1988, November). The American study, based on data from the U.S. Bureau of the Census’ Current Population Survey, showed that about

22 percent of women and 19 percent of men did some work as unpaid volunteers during 1987. In Canada, almost 30 percent of women and almost 24 percent of men contributed time to volunteering of one form or another during the same period. Taken together, the North American volunteer labor force in 1987 amounted to roughly 43.3 million people (5.3 million in Canada, 38 million in the U.S.). Most volunteers contributed between 3 and 5 hours per week to their chosen causes, considerably more than the average time commitment required of telementors in the initiatives reported here.

Having established that volunteering is alive and well in North America, the next question that arises is how many of these volunteers might make suitable and willing telementors? In what follows, I will assume that this relies on three factors:

- The proportion of potential volunteers who possess the education required to be accepted by teachers as telementors
- The proportion of potential volunteers who choose to donate their time and effort to educational organizations, rather than churches, political parties or other popular causes
- The proportion of potential volunteers who regularly use the media required for telementoring

Educational Attainment

While in some cases it may not be necessary, I will conservatively assume that telementors should have attained at least a university degree. Encouragingly, the studies cited above show that the tendency to volunteer increases with level of education in both Canada and the U.S. Roughly 46 per cent of all Canadian university graduates performed some volunteer work during the year studied by (Ross & Schillington, 1988, November), and roughly 38 percent of U.S. graduates did in the same period (Hayghe, 1991, February).

Willingness to Donate time to Education

As one might expect, all volunteer causes are not alike in the eyes of volunteers. According to the studies of volunteering cited above, North Americans are far more prone to volunteer their time to religious organizations than educational ones. Still, Hayghe (1991, p. 21) indicates that in the U.S., 17 percent of university graduates who chose to volunteer time in 1987 chose to dedicate some to educational efforts.

Use of Network Services

The last important determinant of the size of the potential volunteer force available for telementoring is convenient and regular access to the media used. Currently, electronic mail is the medium of choice for telementoring. There are several reasons for this. To begin with, the asynchrony of e-mail is of great benefit for telementoring, since the schedules on which K-12 schools, universities and corporations run are very different. The ability to leave a message which can be retrieved at any time by the addressee is therefore crucial. Videoconferencing, while more visually appealing and offering a “personal touch”, is far less practical than e-mail when it comes to conducting cross-institutional work.

Another factor in favor of e-mail over synchronous media such as telephone or videoconferencing is that it is relatively unobtrusive, allowing telementors to contribute a few minutes of time to their mentees here and there around their regular work hours, either during breaks or before and after work. This kind of volunteering influences telementors’ work routines and productivity so little that in most cases it is unnecessary to seek approval from a supervisor to carry it out. Many of the telementors who participated in the design experiments reported here cited this convenience as part of the attraction of telementoring for them.

Last of all, and perhaps most important, e-mail is the most ubiquitous form of asynchronous “groupware” available at this time. Because it is one of the oldest network services, the technical infrastructure to support it is well-developed, robust, and modifiable for a variety of network configurations. This makes it by far the most widespread service of its kind, and also the cheapest. With respect to our target population, a recent study

(Anderson, Bikson, Law & Mitchell, 1995) showed that 34% of college graduates in the U.S. had home computers and made use of network services in 1993.

Estimated Upper Limit of Telementors and Telementor-Hours

These data are enough to try our back-of-the-envelope calculation. For simplicity, I will assume that:

- There has been no proportional increase in network use by university graduates since 1993. (A generous assumption, given the recent explosion of interest in the Internet and the rapidly dropping cost of Internet services.)
- University graduates will be no more (and no less) willing to contribute time to telementoring than to other educational causes.
- Willing telementors would contribute only 15 minutes per week to assisting their mentees. (This, too, is a generous assumption, but in fact, most of the telementors involved in the experiments reported here found that they could discharge their duties in this amount of time.)

Based on these assumptions we can calculate the likely limit on the number of willing and qualified volunteer telementors available in 1997 at just over 2.3 million people, who could contribute over 25 million person-hours (See Table 16). Their formal qualifications are spread across a wide variety of fields. Table 17 provides a breakdown of the likely telementors in a few fields of study.

Table 16: Likely limit on the number of willing and qualified telementors and telementor-hours available in 1996/97 school year

Country	Number of University Graduates[4]	Percentage of Graduates Giving Time to Education[5]	Percentage of Graduates with E-mail Access at home[6]	Likely Limit of Willing/ Qualified Telementors	Likely Limit of Telementor Person-Hours Available over 1996/97 school year
Canada	2,998,512	46	48.5	668,968	6,020,712
U.S.	38,280,740	17	34.0	2,212,627	19,913,643
Totals	41,279,252			2,881,595	25,934,355

[4] Figures from Day, J. and Curry, A. (1996, August) and Statistics Canada (1996).
[5] From Hayghe (1991) and Duchesne, D. (1989).
[6] From Dickinson, P. and Sciadas, G. (1996) and Anderson, Bikson, Law and Mitchell (1995).

Table 17: Breakdown of likely telementors by field of degree

Field of Degree	Percentage of All Graduates[7]	Number of Likely Telementors
Arts/Humanities/English	10.7	2,297,661
Business/Economics	20.7	4,445,008
Medicine/Dentistry/Nursing	11.9	2,555,343
Psychology/Social Science	7.9	1,696,404
Sciences/Engineering	15.4	3,306,914

How Should Telementor Effort be Distributed?

With these estimates before us, the next issue is how telementors and their time can or should be distributed for maximum effect. While 2.9 million is in no way a small number of people, this number is dwarfed by the number of students currently enrolled in K-12 schools in North America: over 49 million! Clearly it will be unprofitable to consider designs for widespread telementoring based on one mentor per student per year, the most easily imaginable scheme. This sort of practice could simply never be equitable.

In the design experiments that I have described here, my teacher-collaborators and I took quite a different design path. Rather than matching mentors and students for the whole year, teams of three to five students were matched with one mentor over a limited span of five to seven weeks. The work undertaken by the students and their mentor had a strong curricular focus, and the participants had clear responsibilities to one another during their time together. Under this kind of scheme, a great many students could have the benefit of telementoring. A few more calculations:

36 weeks in school year / 6 -week “match” period = a maximum of 6 matches per year per telementor

6 matches per telementor x 2,881,595 telementors = A limit of 17,289,570 matches per year

17,289,570 matches per year x 3 students per match =
A limit of 51,868,710 students per year who could be telementored

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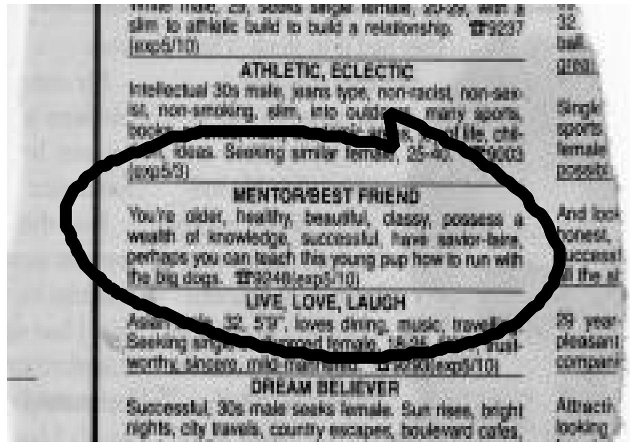
7 Data extracted from Bruno, R.R. (1995).

Under this scenario, the number of students who could potentially be telementored is just slightly greater than the number of K-12 students enrolled in school in North America. Even if, in the worst case, one assumes that each telementor only volunteers to mentor one group of three students each year, 8,644,785 students could still have the benefit of telementoring, or about 1/5 of the total school enrollment.

Ironically, perhaps, the outlook for telementoring becomes yet more promising when one considers that not all teachers, by far, will have the desire or the freedom to become involved in it. Telementoring will hardly be considered appropriate for every grade level or class, nor, in many cases, will the curriculum in force afford a reasonable opportunity for telementors to become involved in students' work. While in principle one may think that adult professionals could contribute to almost any curriculum, telementoring fails miserably when it is "tacked on" to an existing, self-contained curriculum.

I believe that these estimates give us strong hope for the potential of telementoring. The question remains of how to best realize this potential. How can telementoring be orchestrated on a broad scale, and on a continuing basis? Two important issues here are how, given their cramped schedules, educators might reach willing telementors, and how the organizational effort required to orchestrate relationships between these volunteers and their students might be streamlined. The next section describes a World-Wide Web-based service which I designed and built to address these problems.

The CoVis Mentor Database: Technology to Support the Scaling of an Innovative Teaching Practice



slim to athletic build to build a relationship. ☎9237 (exp5/10)

ATHLETIC, ECLECTIC

Intellectual 30s male, jeans type, non-racist, non-sexist, non-smoking, slim, into outdoors, many sports, books, ... ideas. Seeking similar female, 25-40. (exp5/3)

MENTOR/BEST FRIEND

You're older, healthy, beautiful, classy, possess a wealth of knowledge, successful, have savior-faire, perhaps you can teach this young pup how to run with the big dogs. ☎9248(exp5/10)

LIVE, LOVE, LAUGH

... 32, 5'9", loves dining, music, travel... Seeking ... female, ... worthy, sincere, mild-mannered ... (exp5/10)

DREAM BELIEVER

Successful, 30s male seeks female. Sun rises, bright nights, city travels, country escapes, boulevard cafes,

In the previous section, I showed that there is a large potential volunteer force to support telementoring initiatives. At the same time, I raised questions about how that workforce could be mobilized in a way that would be practical and useful for educators in the long run. This Chapter documents the design of a World-Wide Web service called the CoVis Mentor Database that I built to address some of these issues.

Achieving Scale: The Design Challenge

The process of designing the CoVis Mentor Database began as soon as I started making observations in Rory Wagner's classroom and discussing his work with him. While he taught me about his approach to orchestrating telementoring and we discussed potential improvements, we also considered what stumbling-blocks might prevent other teachers from undertaking telementoring. A number of bottlenecks were apparent in Wagner's process where a specialized network service might streamline his work, and that of any teacher wishing to orchestrate telementoring. Some of the most prominent of these included:

Organizational Effort for the Teacher

In order to be successful, telementoring should demand no net effort on the teacher's part. That is, if teachers are to see the worth of orchestrating telementoring, any effort required to establish and maintain the relationships for students should be offset by a reduction in the workload that would be required by the teacher in order to achieve the same quality of outcomes in students' project work.

The major areas in which telementoring requires work from teachers are the following:

- Finding suitable volunteers
- Communicating with volunteers about the students' needs for guidance and support, and the teacher's expectations of students for the project
- Maintaining suitable records regarding mentor-student "matches"
- Managing communication between students and mentors

When I began my work with Wagner, he was organizing telementoring for his students using a number of general-purpose electronic tools which were not designed to work well together: a Usenet news client, e-mail client, spreadsheet and word processor. First-hand observation of his methods for orchestrating telementoring relationships using these tools identified several areas in which the process could be streamlined. These will be discussed at length later.

Souring Volunteer Mentors

A number of the telementors I interviewed by telephone suggested that they were eager to take on new telementoring relationships at the end of their first or second. During 1995/96, a few volunteers worked with teams of Wagner's students for all three academic quarters in which long-term projects were carried out. Obviously, it would be in the interests of all involved to ensure that these enthusiasts be re-matched with a team of students as soon as they have discharged their responsibilities with another. If necessary, these volunteers could be matched with students in a different class or school. There is clear potential for some kind of network service that would make a volunteer's qualifications and contact information available to a large number of teachers.

Unfortunately, this sort of service could result in such an influx of petitions that volunteers might be soured on telementoring. Interviews with volunteer telementors who had been involved in projects with Mr. Wagner's students made it clear that many appreciated being able to focus their effort on a few students at a time, since this allowed them to see the impact of their efforts most clearly and limited the potential for time demands to get out of control. Thus, one possible role for an automated organizational tool might be to provide some guarantee against volunteers being overburdened with requests for telementoring. Ideally, the service would enable available volunteers to be solicited for only one project at a time, but allow them to be introduced to another set of mentees immediately when their project wrapped up.

Unreliable Communications Between Students and Telementors

Two years' observations of telementoring in Wagner's classes made it clear that even when students' access to e-mail was reliable, communications between them and their mentors could be unreliable. Some of my focus groups with student project teams in 1995/96 revealed that one or two students could monopolize the mentor's attention, leaving his or her project partners "out of the loop". In some cases this was the result of students dividing up responsibilities for the project (including communicating with their mentor); however, it could become a problem when the primary contact was absent from school, leaving his teammates unable to communicate with their mentor. On other occasions, mentors who were not scrupulous about "copying" every member of the student team on their e-mail messages could unintentionally imply a lack of interest in the other team members.

Seeing that these problems were an annoyance for teachers, students and telementors alike, I considered the possibility of a technical solution. As it happened, this need coincided nicely with a research-related need, mentioned next.

Lack of Consistent Data on Telementoring Relationships

To continue to refine strategies for orchestrating telementoring, it will be necessary to gather consistent data on students' relationships with their telementors. In the pilot phase of my work this was quite difficult, given that many of the students concerned were novice users of e-mail and did not, for a variety of reasons, maintain a complete record of their e-mail correspondence. Asking students to copy me on their messages was too intrusive and unreliable. On occasion I resorted to asking telementors to send me their archives of the telementoring exchanges, but knew that this could not be a long-term solution to my problem. Ultimately it seemed it would be necessary to have some kind of automated system to capture complete telementoring exchanges. In order to support data collection from classes at different schools, this system would have to be capable of capturing telementoring exchanges regardless of what e-mail server students and their telementors used to communicate.

The Design

As months passed and our research agenda developed, I produced a set of storyboards for the CoVis Mentor Database, then a working prototype, and finally a full-scale system, taking feedback from Wagner and making revisions at every step.

The final product of our efforts is a set of World-Wide Web and e-mail services designed and built to address these problems in orchestrating and studying telementoring. It is written entirely in Perl and uses an Oracle 7 database to store and retrieve data. While ultimately the service is intended to support e-mail based telementoring relationships for students, the bulk of the interface is for the use of their teachers. First and foremost, the service provides a convenient means for teachers to solicit help from a central pool of volunteers. The time-demanding process of recruiting can thus be taken off of teachers' shoulders, while leaving control over the selection of volunteers for particular projects and particular student teams in their hands.

Figure 9 provides an overview of the system's design and use. The process begins when volunteers, who have heard about our service on Usenet newsgroups or listservs or from a colleague, fill out volunteer forms and submit them to the database. This information is held in an unsearchable area until a database administrator verifies that it is correct and that the volunteer indeed works for the organization they claim to work for.

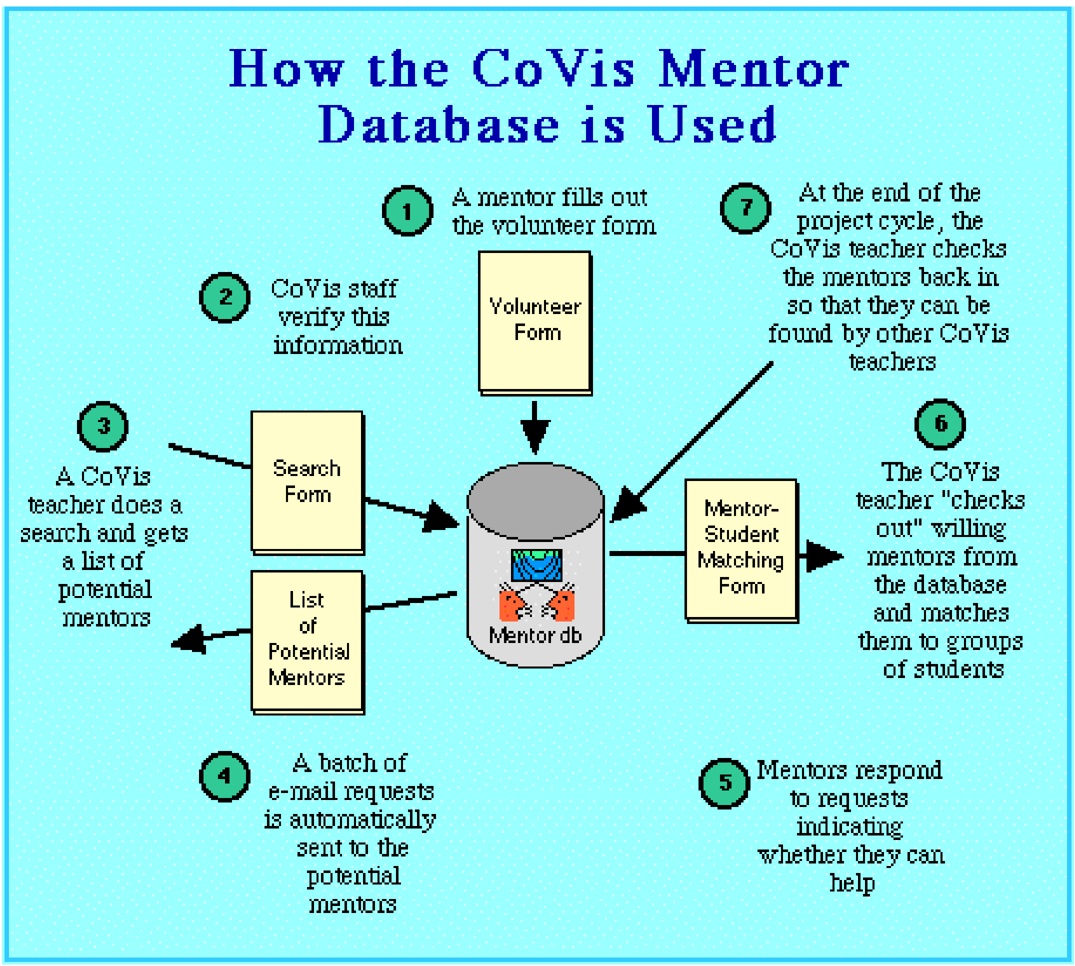


Figure 9: Overview of the CoVis Mentor Database

The next step in the process occurs when a teacher is preparing to begin a telementored project. Figure 10 shows the front page of the mentor database, which provides a link to the teacher's login page as well as the volunteer form.

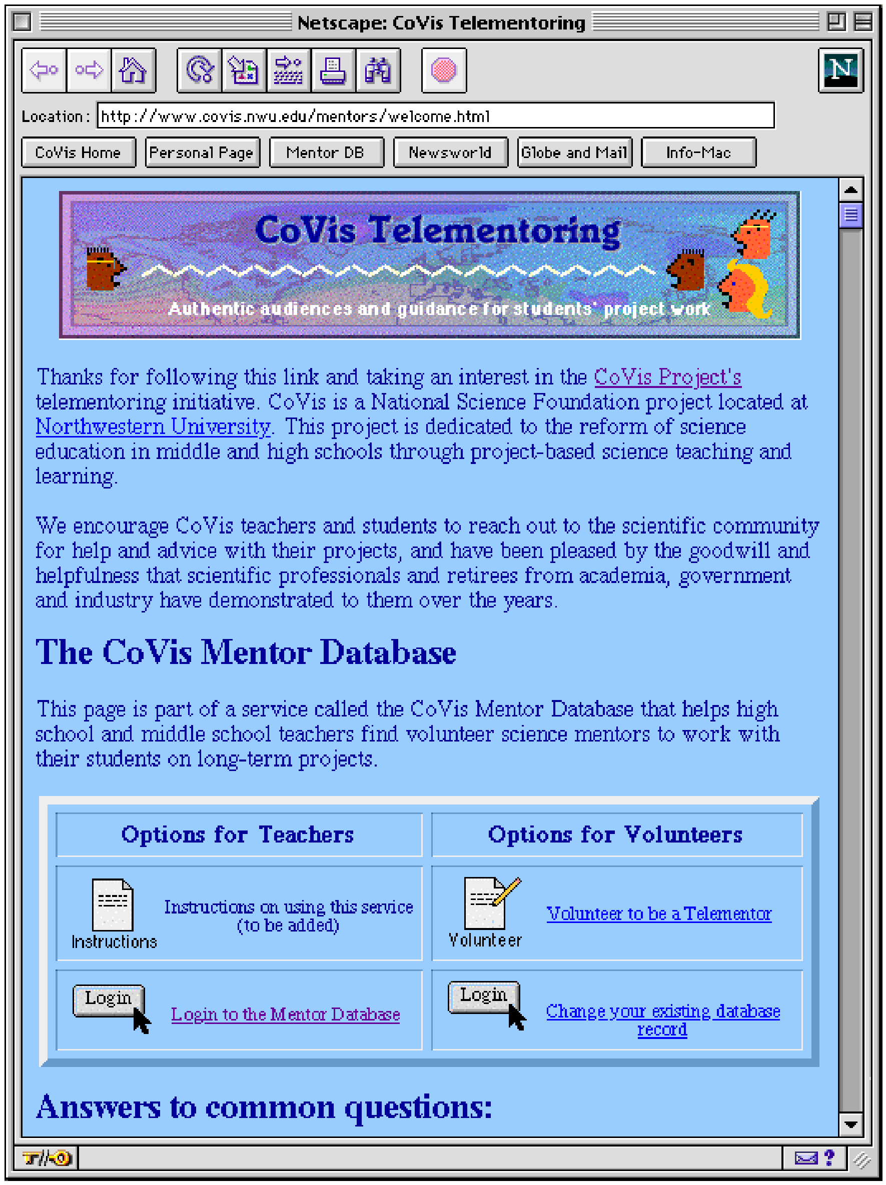


Figure 10: Mentor Database Front Page

It is important that access to volunteers' biographical information be password protected, for several reasons. First, there is the obvious potential for this information to be abused by those outside the CoVis community. Even within the community of CoVis teachers, however, there is the possibility of unintentional abuse. Prior to any experience of telementoring, teachers have proven to have a great range of expectations of what purposes it should serve and what the activity itself should be like. For example, some teachers with whom I have spoken imagine having a telementor for each student in a class: hardly a viable arrangement either with respect to the number of available mentors or, in most cases, students' access to network-capable computers. Others expect all telementors to be university-level researchers.

One reason to password-protect the service is to ensure that teachers have an opportunity for professional development before starting to work with volunteers. Like any other educational innovation, telementoring can be used in pedagogically regressive ways that are averse to its long-term sustainability. Cultural stereotypes about the nature of expertise and the growing prominence of "ask an expert" services on the Internet make these regressive uses of telementoring more likely than not. These factors considered, it becomes clear that some amount of professional development should be a prerequisite for teachers to begin using a service like the CoVis Mentor Database.

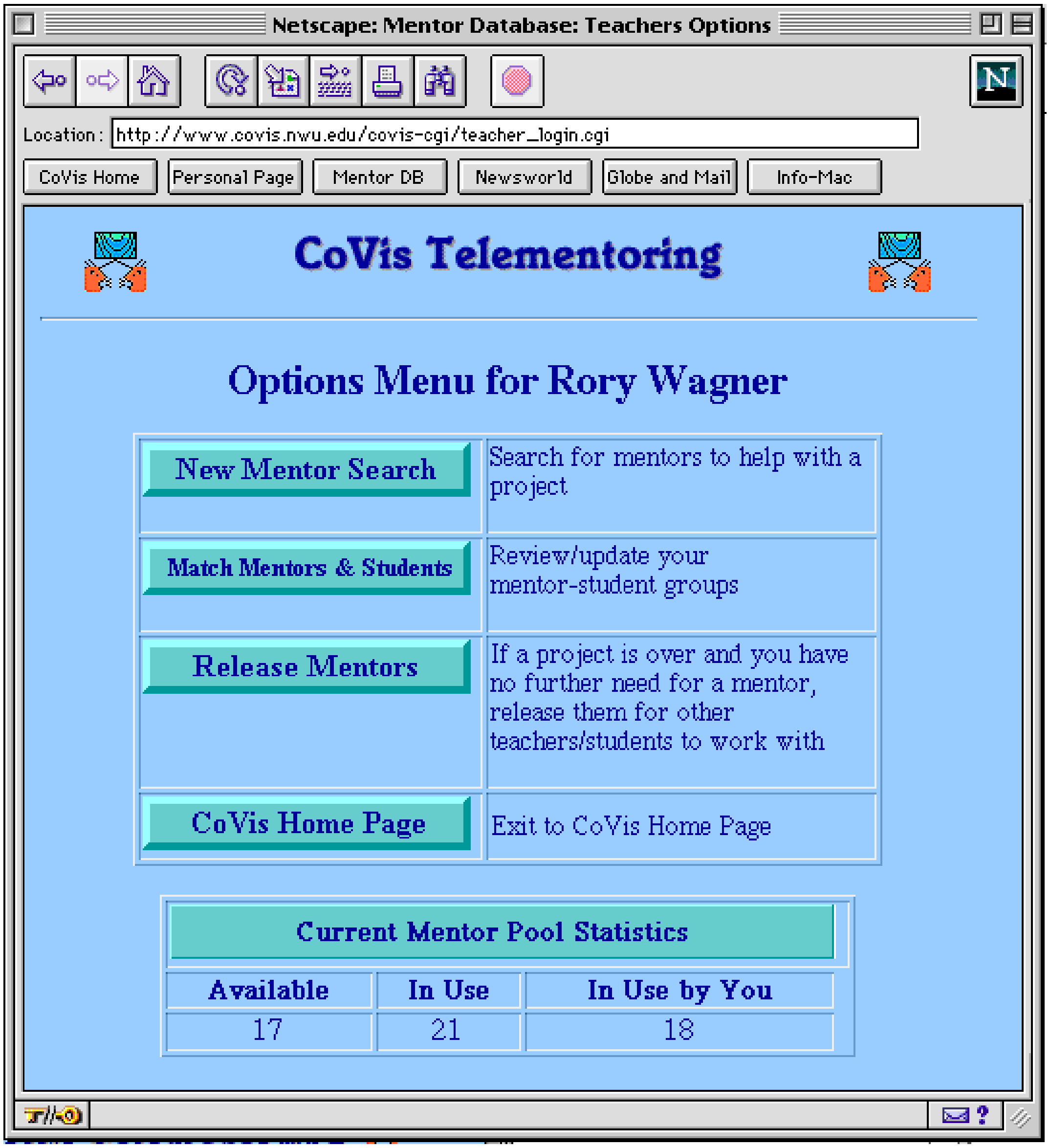


Figure 11: Teacher's Menu of Options

After logging into the Mentor Database, teachers are presented with a set of options which reflects their past use of the service (Figure 11). The menu above was generated for a teacher who is currently running a telementored project and has set up matches between 18 volunteer mentors and teams of students in his classes.

The first menu option, New Mentor Search, is available to all teachers at all times. As my experiences with Rory Wagner showed, recruiting telementors for a given project is often an iterative process. Once an advertisement is posted or a batch of requests is sent out to past volunteers, one may be fortunate enough to secure a suitable number of qualified volunteers right away. It is more common, however, to secure only a few at a time and to repeat the recruiting process two or three times before the start of a project.

Teachers who have already conducted searches for suitable volunteers for a project are presented with the option to "Match" willing mentors with specific teams of students. Once they do, these volunteers are "checked out" of the database so that other teachers conducting searches will not see them. This allows telementors to concentrate on one team of students at a time and limits the possibility of telementoring interfering in their daily work.

The third menu option shown in Figure 11, "Release Mentors" is for teachers who have some number of mentors already checked out. At the completion of the project, they release them to work with other teachers and students. At this point the volunteers' records become visible to other teachers conducting searches.

At the bottom of the page in Figure 11 is a table of "mentor pool statistics" showing how many volunteers are currently available, how many have been checked out by all teachers, and how many have been checked out by the teacher who is logged on. These use statistics are provided under the assumption that teachers can be more responsible about their use of the available volunteers if they can see what proportion of the total pool of mentors they are using.

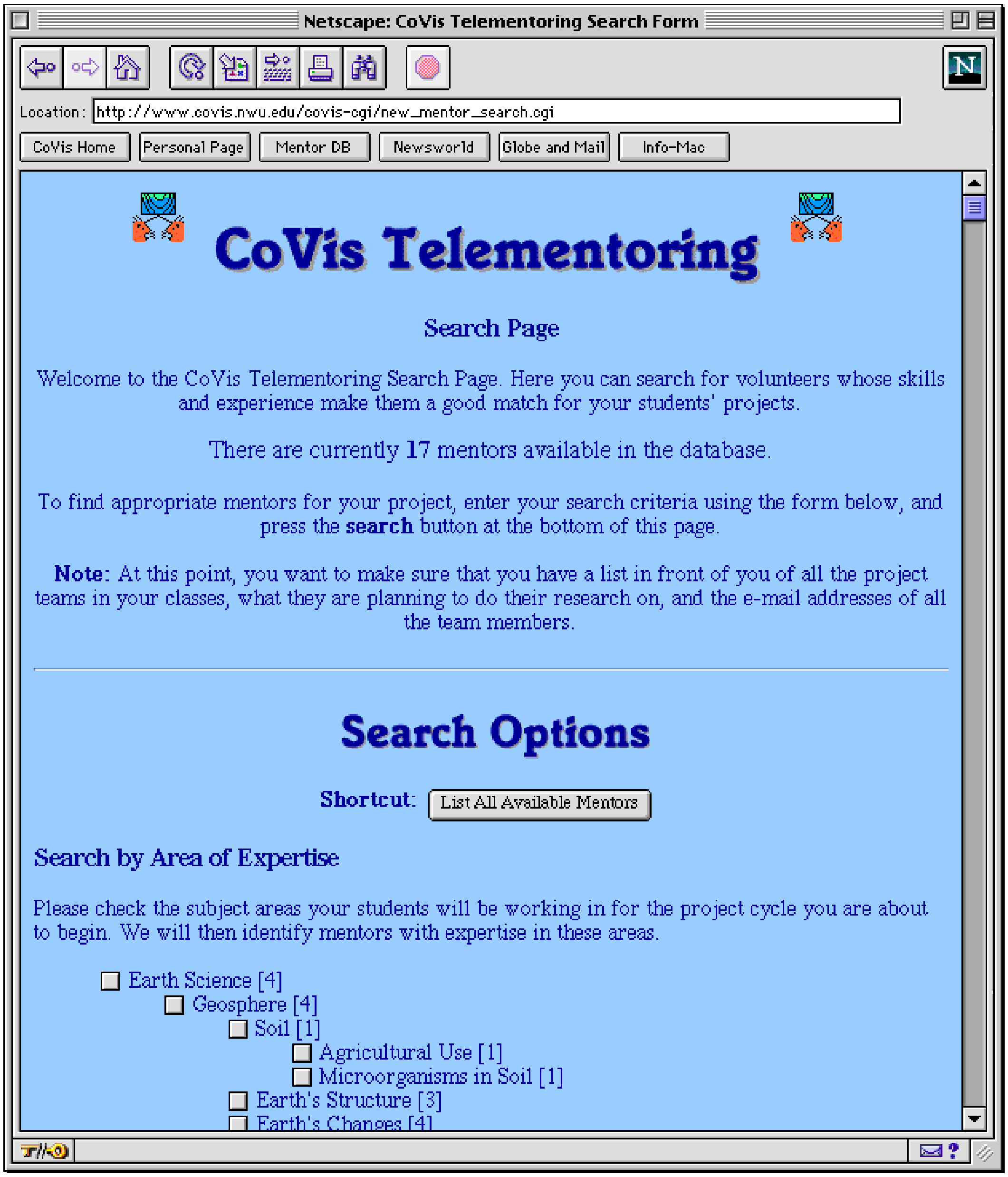


Figure 12: Search form for new mentors

Figure 12 shows one portion of the page used by teachers to search for mentors within the available pool who might be suitable for a project. This search form permits teachers to search for mentors with expertise in a particular area of the geosciences, with a particular type and amount of teaching experience, a certain level of education, or who are employed by a certain organization or type of organization (e.g. government, academia or industry).

More detail of the geosciences expertise hierarchy is shown in Figure 13. This hierarchy is organized much like a textbook. Beside each area of expertise, in square brackets, is a number indicating how many registered volunteers have checked that particular box in the hierarchy. The hierarchy allows volunteers to check boxes at any level of generality or specificity to express their confidence and interest in working with students in either a broad or narrow range of research areas. For example, a specialist in water pollution and remediation may initially be wary of working with students outside this area. After some experience in working with students, however, she might log back into the Mentor Database and alter her expertise records to indicate an interest in working with students on erosion as well.

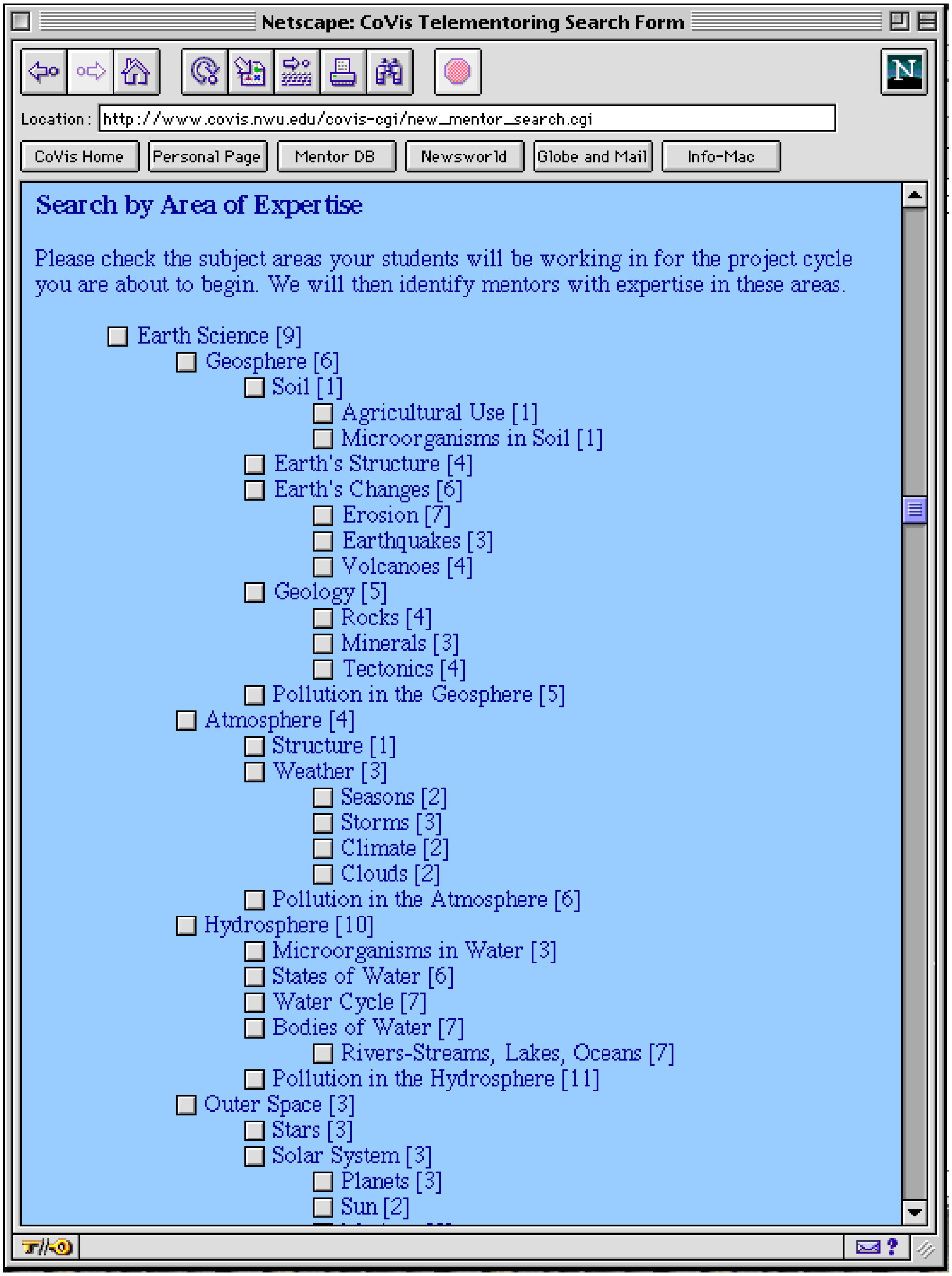


Figure 13: Detailed view of mentor expertise hierarchy

The nodes of the expertise hierarchy are stored in the underlying database and the search and volunteer forms are generated dynamically on the basis of this data. This would permit the Mentor Database to be readily modified for use in orchestrating telementoring in a variety of domains.

After selecting the appropriate search criteria and conducting a search for mentors, a teacher is presented with a list of prospective mentors like that shown in Figure 14.

Figure 14: List of prospective mentors (with names covered for anonymity)

Full detail on any of the prospective mentors listed in the search results can be obtained by pressing the magnifying glass button in the rightmost column beside each name (see Figure 15).

Figure 15: Detailed bio review page

After reviewing the detailed biographies, the teacher can select any number of volunteers whom they would like to ask to be involved in a current or planned project by checking the envelope boxes on the left side of the Search Results page (Figure 14). After submitting this form, the next step is to contact these people to see whether they are interested in the project and available to dedicate the necessary time to it. It cannot simply be assumed that volunteers will be prepared to participate, since depending on the popularity of the volunteers' areas of expertise for students' projects, it may have been months since these volunteers originally submitted a sign-up form to the Mentor Database. Volunteers may also have out-of-town commitments during the term of the project.

Normally, sending a large batch of e-mail requests like this would be a time-consuming and error-prone process requiring the teacher to cut-and-paste e-mail addresses from a number of different windows into an outgoing e-mail message. With the Mentor Database, the e-mail addresses of each of the prospective mentors is automatically inserted into the outgoing message. By itself this saves minutes of aggravating work that may be difficult to find time for during the school day.

Teachers have two options as to how they wish to compose letters of request to the prospective mentors (Figure 16). For those new to telementoring or who have not arranged it in some time, there is a form letter that is designed to include the details most frequently requested by telementors prior to committing themselves to a project (Figure 17). Of special concern to volunteers are the number of weeks the project will run, the amount of time it will require from them each week, and what they will primarily be expected to help students with.

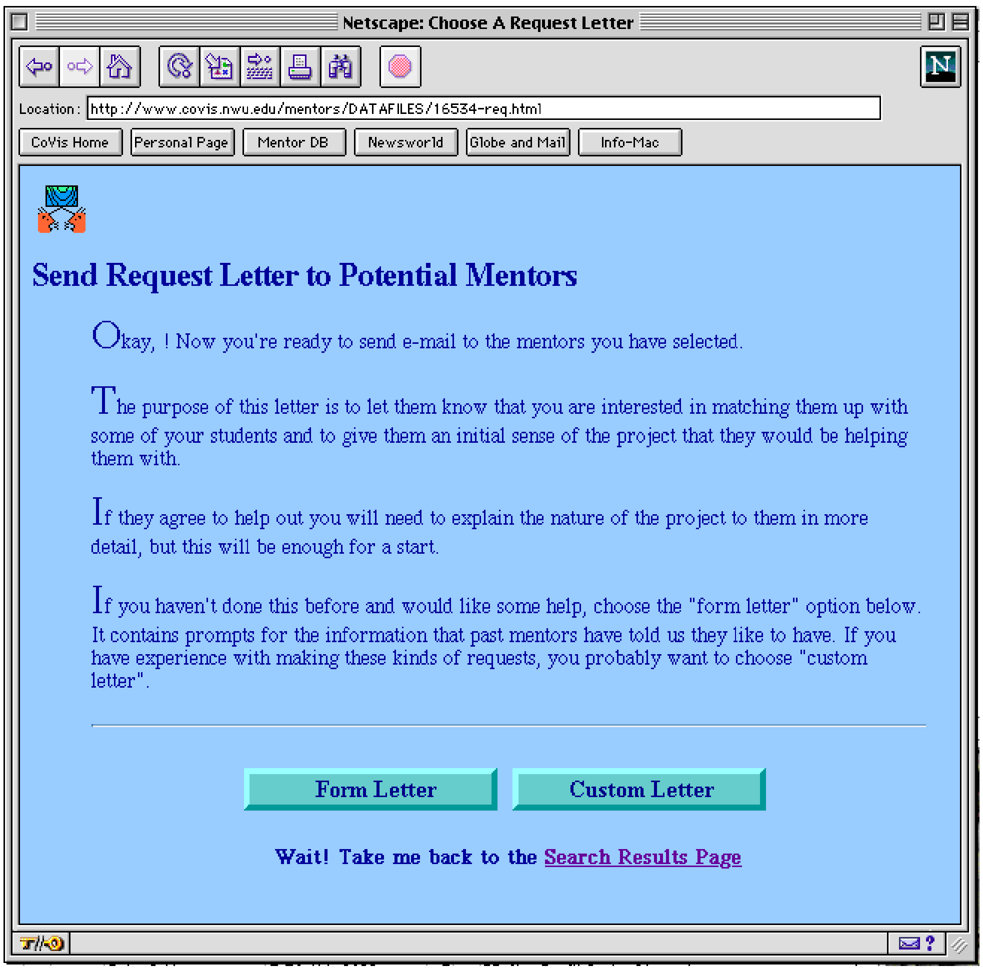
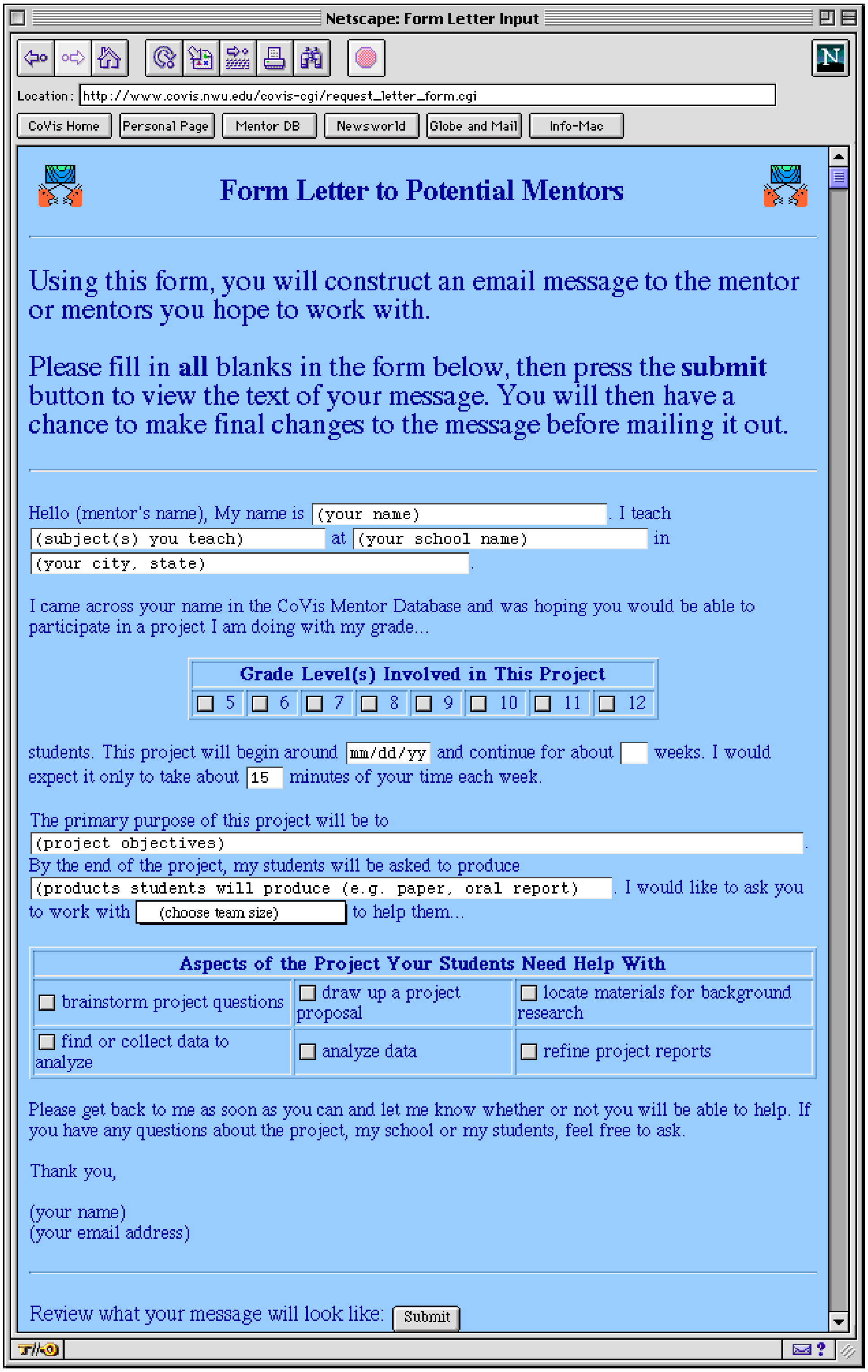


Figure 16: Choosing a free-form or custom letter to potential volunteers



Netscape: Form Letter Input

Location: http://www.covis.nwu.edu/covis-cgi/request_letter_form.cgi

CoVis Home | Personal Page | Mentor DB | Newsworld | Globe and Mail | Info-Mac

Form Letter to Potential Mentors

Using this form, you will construct an email message to the mentor or mentors you hope to work with.

Please fill in **all** blanks in the form below, then press the **submit** button to view the text of your message. You will then have a chance to make final changes to the message before mailing it out.

Hello (mentor's name), My name is (your name). I teach (subject(s) you teach) at (your school name) in (your city, state).

I came across your name in the CoVis Mentor Database and was hoping you would be able to participate in a project I am doing with my grade...

Grade Level(s) Involved in This Project							
☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	☐ 10	☐ 11	☐ 12

students. This project will begin around mm/dd/yy and continue for about [ ] weeks. I would expect it only to take about 15 minutes of your time each week.

The primary purpose of this project will be to (project objectives).
By the end of the project, my students will be asked to produce (products students will produce (e.g. paper, oral report). I would like to ask you to work with (choose team size) to help them...

Aspects of the Project Your Students Need Help With		
☐ brainstorm project questions	☐ draw up a project proposal	☐ locate materials for background research
☐ find or collect data to analyze	☐ analyze data	☐ refine project reports

Please get back to me as soon as you can and let me know whether or not you will be able to help. If you have any questions about the project, my school or my students, feel free to ask.

Thank you,

(your name)
(your email address)

Review what your message will look like: Submit

Figure 17: Composing a form letter to potential volunteers

After submitting this form, the teacher sees and can edit the text of the message on the following page. One button click sends a personally-addressed copy of this message to each of the mentors whose envelope box was checked on the Search Results page. It is worth noting that normally, sending a large batch of e-mail messages would be quite a time-consuming and error-prone process requiring the teacher to cut and paste addresses from a number of different windows into the outgoing message. It might be quite difficult for a teacher to find enough continuous time on a computer during the school day to complete this task. With the Mentor Database this operation takes only a few seconds. The teacher then logs off.

After hearing back from each of the prospective telementors by return e-mail about their availability for the project, the teacher logs back in to match them with teams of students. After clicking the "Match Mentors and Students" button from the menu of teachers' options (see Figure 11), the Mentor Database asks to be updated on the responses of the telementors to whom requests were sent previously (Figure 18).

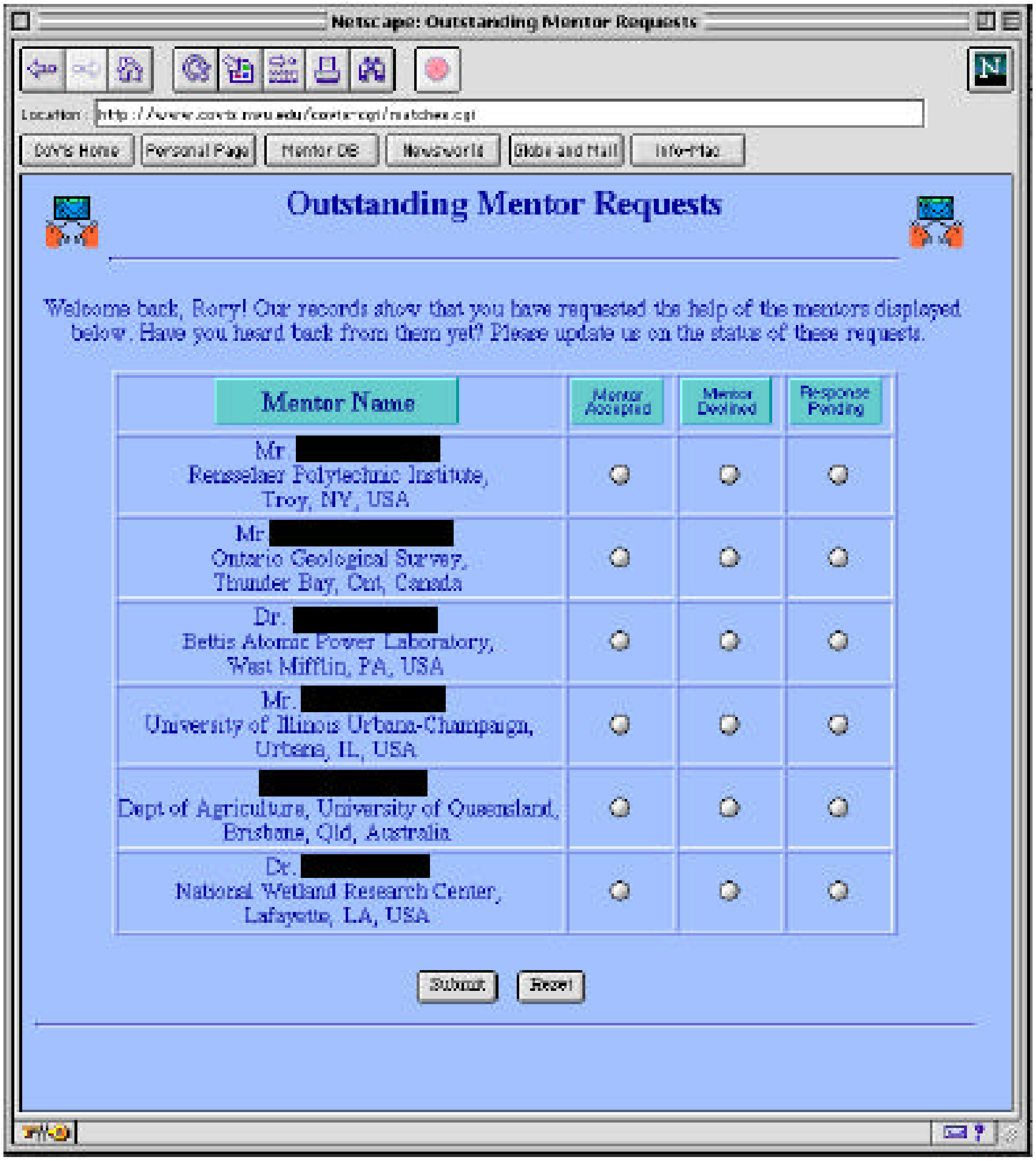


Figure 18: Updating the database on outstanding requests to mentors

After this form is submitted a page appears requesting the e-mail addresses of the students who will be working with each mentor and offering instructions on the automatic e-mail routing feature.

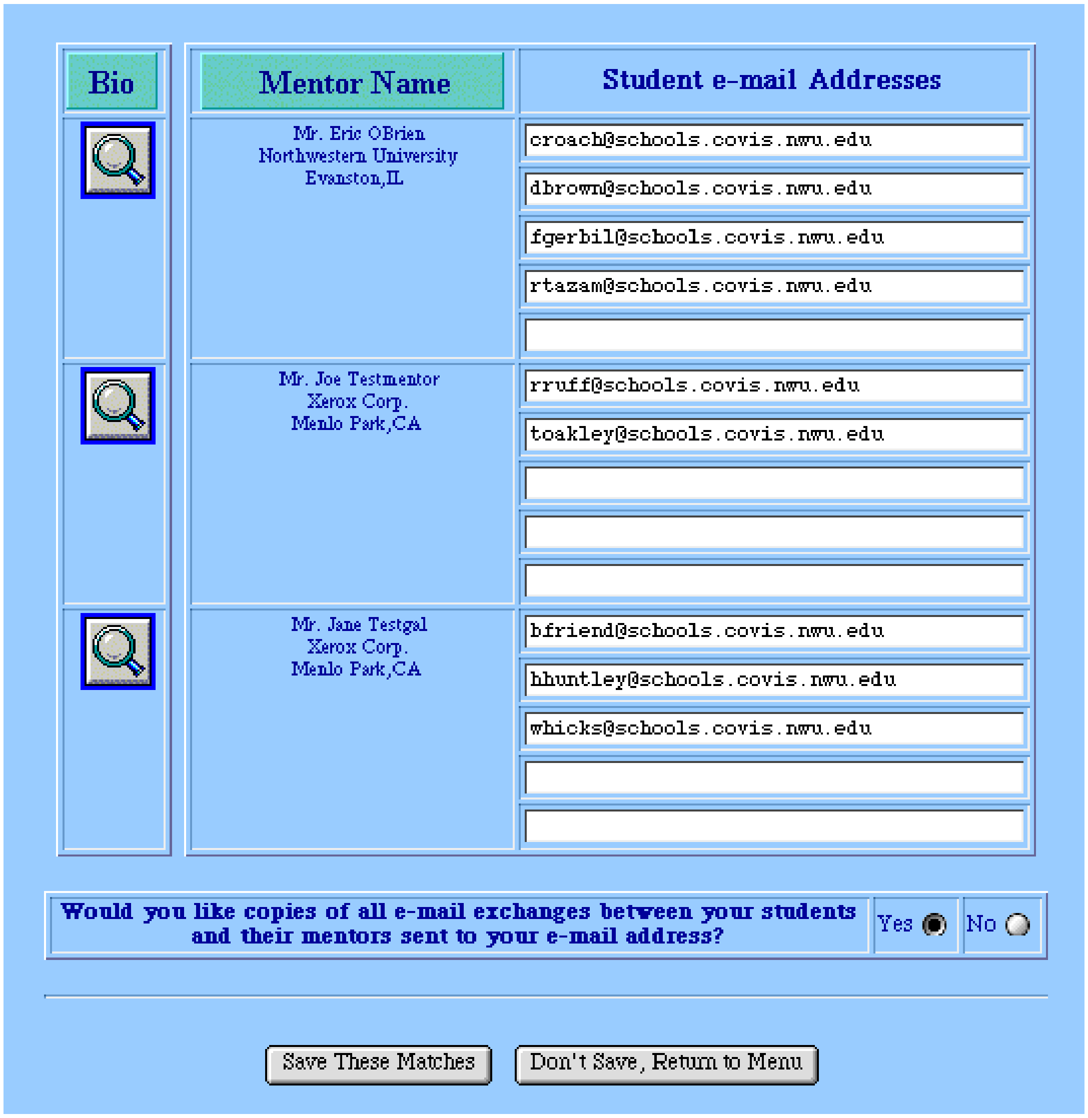


Figure 19: Setting up matches between telementors and student teams

The e-mail addresses submitted on this page are stored in the database where they can be retrieved by an e-mail routing program. This program, similar in some respects to a listserv processor, facilitates the reliable exchange of e-mail among telementors and student project teams. In the past, members of student project teams have inadvertently been left out of e-mail exchanges with telementors. The new routing mechanism allows telementors to send e-mail to all members of their assigned project teams through a central address (Figure 20). Likewise, students send e-mail to the central address, where it is forwarded on their team's mentor and copied back to each of the other team members (Figure 21). This service means that absenteeism and absent-mindedness cannot interfere with a team's telementoring relationship as they have in the past.

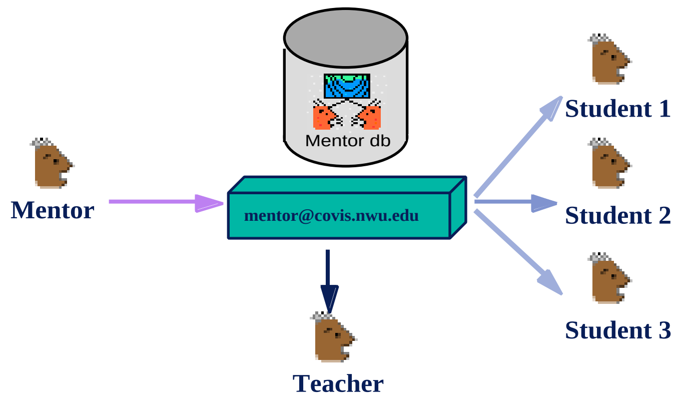


Figure 20: The Mentor Database routes e-mail from a telementor to the members of a student research team

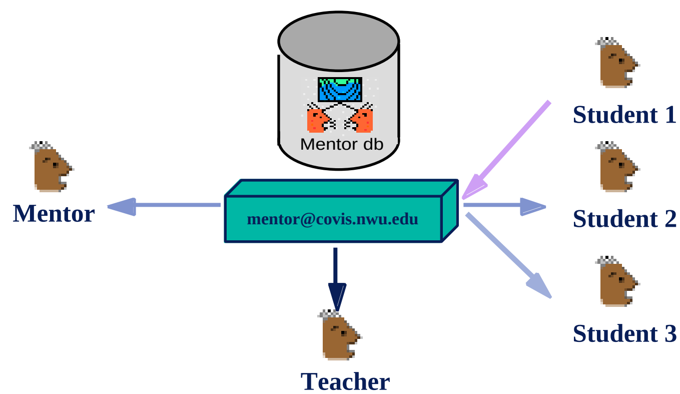


Figure 21: The Mentor Database routes e-mail from a student to teammates and their assigned telementor

By clicking a button on the same web page, teachers can also indicate whether or not they would like the e-mail router to automatically send them copies of all e-mail exchanged by their students and telementors. This feature is particularly useful when parents have concerns over students' correspondence with adults outside the school.

Implications and Possible Extensions

The Mentor Database exemplifies technology design that supports and extends *existing* innovative teaching practices. This, I believe, is a more adaptive strategy than seizing upon an interesting technology and attempting to develop teaching practice around it *de novo*: a daunting and failure-prone task. By streamlining the most arduous aspects of teachers' work in orchestrating telementoring relationships, the CoVis Mentor Database will hopefully enable more teachers to follow the examples of Wagner and Whitcomb, at reduced cost in terms of preparation time and trial-and-error learning.

The design experiments that I conducted with Wagner and Whitcomb suggested a number of worthwhile extensions to the Mentor Database which will have to wait for a future version. Whitcomb's work on the Community in Balance project, for instance, suggested that the database should contain space for richer, full-text autobiographies from telementors. Whitcomb solicited such biographies from her volunteers separately in email, and found them of great use in the beginning stages of the Community in Balance project. Accompanying these biographies should be a feature allowing them to be quickly and easily printed out, so that they can be distributed to students in class.

Observations of Wagner's work in class during the process of "matching" mentors with students indicated a further need for a convenient hard copy "matching" page (see Figure 19). Given his students' propensity to change their research topics frequently in the early stages of a project, Wagner finds it necessary to change mentor matches frequently as well. These matching and re-matching decisions are often made in circumstances where a computer is not readily available: for instance, during class when students are using all the available computers. The organizational burden of revising matches and entering them into the Mentor Database might be substantially lightened with a hard copy form for record-keeping which could be carried into class and revised in pen. Later, these changes could be transcribed to the computer.

Finally, both Wagner and Whitcomb regularly needed to contact their entire cadres of volunteer telementors to notify them of school holidays, update them on changes in project deadlines, or to clarify project objectives. In its current design, the CoVis Mentor Database provides no support for this kind of e-mail "broadcasting", requiring teachers instead to maintain and update mailing lists for volunteers in whatever e-mail client software they normally use. Many novice users of e-mail consider mailing lists of this sort an "advanced" feature, and may never learn to use them. In light of this, it seems sensible to add a simple "broadcast" feature to the teacher's menu, to facilitate better communication between teachers and telementors.

These simple extensions, arising from observation of teaching practice, are a further illustration of the practice-based philosophy of design which I have attempted to pursue with the CoVis Mentor Database. In the future, I hope to make services like this one readily available to teachers, schools and school boards.

Chapter 9: Conclusion

Recapping the Argument

In the preceding Chapters, I argued that appropriately-designed activity structures and technological resources could enable telementoring to become an important piece of a professional tool kit for science teachers. In conjunction with project-based teaching strategies, it could aid teaching professionals in building a science pedagogy more oriented toward scientific practice than toward the unwieldy, and questionably-relevant bodies of content that currently define what "science" means to most students. Through this research, I have attempted to demonstrate how volunteers from a variety of backgrounds in basic and applied science can provide some of the vital intellectual resources that students need to pursue ambitious projects exploring their curiosities about the natural world. More important, by serving as a rare adult audience for students' work in science classes, telementors can provide an opportunity for students to engage scientific practice and discourse in a personally meaningful way.

I argued in Chapter 1 that a science pedagogy centered around practice is not only feasible, but more worthwhile than the alternative of content coverage for at least two reasons. First of all, complete content coverage in science is a hopeless cause. Thousands of capable, well-trained teachers struggle each year to cover science curricula which grow ever-broader, either failing in their attempts or succeeding only in making the content a bewildering blur for their students. Often, the cherished content is merely forgotten after students leave school. In contrast, a science curriculum directed at helping students to understand common facets of scientific practice (such as reporting in customary genres), through the deeper study of a smaller range of phenomena would have greater relevance and value, both to students who aim to continue in science or engineering and those with no such plans. In the ideal case, students would deeply investigate the phenomena that they are most curious about, and would have a critical audience for their research besides their teachers. This audience would follow their work continuously for a period of weeks or months: not the paltry few minutes that a typical science fair judge can spend with a student.

As it is currently structured, K-12 science instruction has a difficult time supporting this sort of practice-oriented, interest-driven approach to learning. Part of the problem, as Rory Wagner discovered early in his attempts to implement project-based pedagogy, is that sometimes even the best-educated and most energetic teachers cannot stay well-enough informed about the status of research in every sub field to have the most current learning resources at their fingertips. Telementoring is one adaptive strategy for addressing this problem, and has unique benefits which distinguish it from other strategies, such as sophisticated indexes of web-based learning resources. In Chapters 2, 4, 5 and 7, I illustrated the wide range of benefits that telementoring relationships can have, showed how they operate (both when they succeed and when they fail), and examined the dynamics that govern their development in a project-based classroom. In Chapter 6, I presented some evidence that when teams of students invest greater effort in developing telementoring relationships, the formal reports they produce about their work are more likely to revolve around the defense of scientific knowledge-claims than the recitation of content, or bald declarations about the quantity of effort they invested in their work. I view this more sophisticated argumentation as a promising step away from the caricatures of scientific practice that schools often reinforce, toward the ideal of engaging students meaningfully in science practice.

Finally, the preceding Chapter examined the issue of how large the potential volunteer force for telementoring might be, and came up with a relatively hopeful picture of the prospects for telementoring in Canada and the United States. Locating and organizing the efforts of willing and qualified telementors is, undoubtedly, a problem requiring considerable creativity and organizational effort. However, a healthy portion of the organizational burden imposed by telementoring might be eased through the development of appropriate technological tools. In the latter part of Chapter 8, I described the CoVis Mentor Database, a web-based application which I designed and built in cooperation with teachers to help streamline their work in orchestrating telementoring relationships for their students. This is an early example of the services that could make telementoring a practical reality for many teachers, students and scientists.

Recommendations for Teachers and Researchers

My readers will expect some general recommendations at this point, and I will do my best not to disappoint them. While the design experiments reported here are just a sample of what it is possible to achieve through telementoring, they do justify a few general recommendations for those who may choose to undertake similar efforts.

Do More Design Experiments

Others wiser than myself have argued for the importance of design experiments in developing the knowledge needed to improve school-based technological innovations like telementoring, and to make them more broadly useful (Hawkins & Collins, in press). I believe that in the best case, the inspiration for design experiments will come from practicing teachers, and their insights will play a large role in sustaining them. As I explained in Chapter 2, most of the innovative teaching and learning practice that I have discussed here was instigated by Rory Wagner, on his own initiative and using the resources of his own school. My work with Judy Whitcomb to adapt Wagner's approach to her students and curriculum shows that urban school environments can also support this kind of innovation, given adequate technical resources and the efforts of a committed teacher.

Both Wagner and Whitcomb had considerable influence over the design of our work together, and their classroom work benefited substantially from their experiences as both long-serving teachers and former protégés. While the designs we produced for telementoring activity structures are suitable for use in many other school environments, however, they will not be suitable for everyone. It is therefore essential for researchers to seek out teacher collaborators in a range of other settings, and to develop models of telementoring better adapted to their unique capabilities and circumstances. Only in this way will a sufficient range of telementoring activity structures and tools be developed to realize the full potential of this innovation.

Telementoring Is Not a Curriculum Spice

My experiences with Wagner, Whitcomb, their students and our volunteers suggest that telementoring is unlikely to satisfy anyone as a way to "spice up" traditional science curricula. When compared with other network-based activities that are more easily integrated into lecture-and-lab curriculum (particularly those of the "ask an expert" variety), most traditional teachers will consider telementoring too labor-intensive to be worthwhile. While ask-an-expert activities may take only a few days and demand little organizational effort, telementoring relationships require a level of coordination which can only be justified by more ambitious, longer-term projects. What is more, the people who volunteer to become telementors tend to consider extended interaction with students an important part of their reward. Thus, for volunteer-based telementoring to be sustainable, students cannot treat their mentors simply as a source of "help" or "information"; they must invest effort in cultivating partnerships with volunteers which allow them to serve as a responsive and critical audience for projects. Since this kind of partnership is what our volunteers almost universally appeared to want, we educators would be foolish not to be guided by their desires.

Managing Failures and Preserving Potential

As Chapters 5 and 7 showed, telementoring relationships can fail even in a relatively constraint-free project-based environment like Wagner's classroom. Such failures may result from students' resistance to the curriculum that telementoring is meant to assist, from logistical or technical difficulties, or from a simple mismatch of expectations on the part of students and their mentors. In any sustainable design for telementoring, failed relationships should come at low cost to the teacher and students, and should be explained to volunteer telementors as fully as time allows. The volunteers whom I have interviewed from failed relationships were usually willing to accept that each project was "the luck of the draw", and would apply themselves with equal vigor to another group of students. Nobody's patience is limitless, of course; so to preserve the enthusiasm of volunteers, telementoring should be made optional for students who have given it at least one try. The case study I presented in Chapter 5 demonstrates how self-defeating it can be to force students to participate in telementoring relationships if they are not prepared to invest effort in them. In the end, forcing telementoring on students can only cause the attrition of volunteers from a program, and this serves no one's interests.

This piece of advice has some important implications for the practice of classroom assessment around telementoring. If telementoring relationships are made an optional part of any curriculum implementation, fairness requires that telementoring activity not be directly graded. This means that students should never be allotted marks on the basis of how many messages they exchange with their telementors or when, since not all telementors can or will be equally helpful to their mentees. Rather than being assigned marks based on the number of messages they exchange, students should be given good reason to believe that participation in a telementoring relationship will help them to achieve a higher standard of work, and should be rewarded for achieving that higher standard. This suggestion is analogous to the widespread practice of encouraging, but not requiring students to submit drafts of their work to their teacher for review prior to "final" submission and grading. If telementoring is presented to students in a similar fashion, as a fair opportunity to improve the quality of their work, they can choose to seize this opportunity or not, as they desire.

Fostering "Genuine" Mentoring On-line

The case study presented in Chapter 4 is one of a number of telementoring relationships from Wagner and Whitcomb's classrooms which I consider to be "genuine" mentoring — despite the fact that it was curriculum-based and continued for only a few weeks. I hope that this report has offered some persuasive evidence to researchers and organizers of traditional mentoring programs that modern telecommunications have made possible a new type of mentoring with promises similar, though not identical to face-to-face mentoring relationships.

While mentoring need not take place face-to-face or span years, however, we must not forget that at its heart, it is a developmental phenomenon. As some of my analysis suggested in Chapters 6 and 7, students' ability to understand the potential benefits of telementoring relationships and to engage in them actively and profitably may rely on repeated experiences with them. Thus, while a single telementored project may serve the short-term goal of supporting students' work, and may provide a net labor-savings for the teacher, it seems unlikely to produce many reciprocal mentoring relationships or satisfied telementors. The best setting for telementoring activity is one, like Wagner's classroom, in which students can have repeated experiences with it over an extended period of time. This repetition could also be provided through a multi-year curriculum which includes one or more telementored projects each year.

Finally, there is clearly room for improvement in the preparation that students, teachers, and volunteer telementors are given for telementoring. At the end of Chapter 4, for instance, I suggested that prior to their first experience of telementoring, students could be presented with "walk-throughs" of successful and unsuccessful telementoring relationships by their teacher, to illustrate the ways in which students can help telementors provide informed advice. This is one strategy for combating the problem of the "black box" that Lauren, Lynn and Charlotte's case exemplifies. Unlike other organizers of telementoring, however, I do not believe that it is possible or desirable to provide telementors with prescriptive "training" for their task. Most of the volunteers who have pursued an involvement in my work have brought considerable experience to it as mentors or protégés, and it is insulting to suggest that we could teach them much more about mentoring *per se* in a few days' time. The approach that Wagner, Whitcomb and I have chosen instead is to make each volunteer as aware as we can of the needs and capabilities of the students with whom they are working, and the teacher's specific objectives for the project they are involved in. Most often, when volunteers have sought out help in their mentoring, it was these sorts of issues that needed clarification.

The Future of Telementoring: Promise and Challenge

Before closing, I cannot restrain myself from offering a few predictions about the future of telementoring, which time and my peers can judge.

I am satisfied that given the proper resources, a considerable number of teachers could undertake design experiments similar to those that Wagner, Whitcomb and I have conducted. Not all teachers, certainly, and not tomorrow; but with time, telementoring is an innovation that could reach every school in North America. Just how quickly this could happen, or whether it happens, will depend on many things.

My experience with Mark Ballard (discussed in Chapter 2) suggests that teachers' time in service and their personal experiences of mentoring may be important factors in their readiness to pursue project-based telementoring. Wagner and Whitcomb each brought over 20 years of teaching experience to the work described here, as well as significant personal experiences with mentoring which helped them to frame students' project work in ways that gave a meaningful role to telementoring activity.

In the long run, I suspect that teachers' chances of implementing rewarding telementored projects will be greater if they and their peers are professionally rewarded for tailoring telementoring to the variety of clientele and curricula they are familiar with. Researchers have an important role to play in co-designing, supporting, and evaluating design experiments like those described here; but there are too few of us to go around. Furthermore, given the general reputation of university research as irrelevant to teaching practice (Kennedy, 1997), researchers often lack the credibility to persuade teachers to undertake new innovations. Thus, bringing an innovation like telementoring to scale will more likely rely on networks of mutually-supportive teachers who have experimented with it and believe in its worth on that basis.

As I discussed in the previous Chapter, carefully-crafted technology can also play an important role in the expansion of telementoring as a routine practice in science classrooms. To be useful, however, such technology should be designed in light of observations of the teaching practice surrounding telementoring. This is the best way to ensure that new technologies solve the problems that teachers need solved (however humble), rather than merely advancing a researcher's private agenda. I have begun this design work with the CoVis Mentor Database, and intend to continue it.

While I am enthusiastic about the role that specially-crafted technological supports can play in the spread of telementoring, and while I am confident in the ability of enthusiastic teachers and researchers to refine and spread this innovation, I realize that there are many educational settings in which the cleverest technology and the brightest people will not allow telementoring to take hold at the moment. At this writing, many teachers in the United States and Canada face mandated, lock-step curricula and high-stakes tests which severely limit their freedom to innovate. In these settings, telementoring may only subsist at the margins of teaching practice: as an enrichment program for the gifted, an extra-credit exercise for eager students, an end-of-term perk, or a motivational exercise that is squeezed into a traditional unit of content.

While this prognosis may be frustrating to a legion of educational technologists wishing to enter the field of telementoring (quite a few of whom I have already corresponded with), I do not see it as a bleak one. Like many other innovations, telementoring must prove its educational worth on a small scale before teachers and administrators can be expected to trust it. As my accounts in Chapters 2, 4, 5 and 7 should make clear, the practice of telementoring is still relatively immature, and I could think of no worse fate for it than to become part of the mandated practice in any school system. The most likely result would be for teachers and students to resent and resist it, causing its premature demise.

While telementoring matures, other forms of network-based curricular activities will proliferate, to be sure. The world is impatient to make the Internet part of every students' school experience, and will undoubtedly find ways to do so. In most schools, Internet activities will compete with traditional curriculum for classroom time, and are likely to be hit-and-run affairs. One-shot videoconferences with distant experts will become increasingly common, and despite objections from myself and others, these may even be referred to as "telementoring". At the same time, the great generosity and skill of volunteer telementors will continue to inspire long-term projects and long-term relationships which transcend the traditional experience of schooling. Telementoring and its "contagion of mind with mind" will eventually find their place.

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Appendix A: Student Survey

Today's Date: ____________________

Your Name (first and last):____

Your School: ____

Your Project Topic:____

Purpose of this Survey

- This survey is meant to tell your teacher and the CoVis researchers what your class got out of working with mentors during *your last project*.
- This is not a test, but <u>every survey will be read and analyzed carefully</u>.
- Your teacher will be told how your class answers the questions *on average*, but <u>your individual answers will be strictly confidential</u>.
- We ask for your name at the top because we would like to be able to compare your answers with the other members of your group to be sure that we get the best possible idea of what mentoring was like for you during your project.

Your Mentor

Your mentor's name: ____

The place (university, company, etc.) where your mentor works or studies:

____

❑ I didn't have a mentor for my last project

If you DIDN'T have a mentor for your last project, please give your best guess as to why:

- ❑ There weren't enough mentors for everyone in my class
- ❑ A mentor wasn't available who specialized in what my project was about
- ❑ My teacher didn't want to give my group a mentor
- ❑ My group told the teacher we didn't want a mentor
- ❑ Other (explain) ____

(If you didn't have a mentor for your last project, complete only Question 3)

1. Group communication with your mentor

For this question, **estimate** the number of times that **your group** (anyone in your group, not just you) wrote to your mentor and got responses from your mentor during each part of the project. Write your estimates in the boxes below.

a) How often did **your group** send and receive messages with your mentor?

Please fill in the boxes below with the appropriate numbers:

	Beginning	Middle	End
# Sent			
# Got			

If this is confusing, here's an example that may help: A project group sent 2 messages to their mentor during the first two weeks of a 6 week project. They got 1 message back. During the second two weeks they got 2 more messages and sent back 1 thank-you message. They didn't communicate with their mentor at all during the fifth week, but in the sixth week they sent their mentor a copy of their final project report and got 1 message back containing comments. At the end of the project, one student completed this question in the following way:

	Beginning	Middle	End
# Sent	2	1	1
# Got	1	2	1

b) How much of the communication with your mentor did you write yourself (without the help of others on your project team)? (Check one)

All of it	About 3 quarters	About half	About a quarter	None of it
❑	❑	❑	❑	❑

2. Mentor's Helpfulness

In the list below, rate in importance the things your mentor did for your group during your last project. Check the "no" box to show things your mentor didn't do.

Mentor's Action	No	Not Helpful						Very Helpful
Helped my group come up with a project proposal	❑	1	2	3	4	5	6	7
Answered the question we had set out to answer for the project	❑	1	2	3	4	5	6	7
Asked questions to help us think about our project	❑	1	2	3	4	5	6	7
Answered questions we had about scientific ideas	❑	1	2	3	4	5	6	7
Gave my group background information on our topic	❑	1	2	3	4	5	6	7
Gave my group data to analyze for our question	❑	1	2	3	4	5	6	7
Suggested places where my group could find data to answer our question	❑	1	2	3	4	5	6	7
Gave my group exact locations on the Internet where we could find data to answer our question	❑	1	2	3	4	5	6	7
Helped my group to analyze data	❑	1	2	3	4	5	6	7
Suggested challenging things for us to do that would improve our project	❑	1	2	3	4	5	6	7
Reviewed our work as we went along and helped us keep on track	❑	1	2	3	4	5	6	7
Gave us the names/addresses of other people to contact about our project	❑	1	2	3	4	5	6	7
Suggested books/magazines/scientific journals that we should read	❑	1	2	3	4	5	6	7
Other (describe)		1	2	3	4	5	6	7

3. What would your mentor ideally have done?

In the list below, rate in importance the things you think a mentor would ideally have done for your group during your last project. Check the "don't care" box to indicate things you don't care about.

What you would have liked your mentor to do	**Don't Care**	**A Little**						**A Lot**
Help my group come up with a project proposal	❑	1	2	3	4	5	6	7
Answer the question we had set out to answer for the project	❑	1	2	3	4	5	6	7
Ask questions to help us think about our project	❑	1	2	3	4	5	6	7
Answer questions we had about scientific ideas	❑	1	2	3	4	5	6	7
Give my group background information on our topic	❑	1	2	3	4	5	6	7
Give my group data to analyze for our question	❑	1	2	3	4	5	6	7
Suggest places where my group could find data to answer our question	❑	1	2	3	4	5	6	7
Give my group exact locations on the Internet where we could find data to answer our question	❑	1	2	3	4	5	6	7
Help my group to analyze data	❑	1	2	3	4	5	6	7
Suggest challenging things for us to do that would improve our project	❑	1	2	3	4	5	6	7
Review our work as we went along and helped keep us on track	❑	1	2	3	4	5	6	7
Give us the names/addresses of other people to contact about our project	❑	1	2	3	4	5	6	7
Suggest books/magazines/scientific journals that we should read	❑	1	2	3	4	5	6	7
Other (describe)		1	2	3	4	5	6	7

4. Things you asked your mentor

Did you ever ask your mentor...	**Yes**	**No**
To do part of the project that was too difficult for you to do?	❑	❑
For his/her opinion on your project idea?	❑	❑
To explain how s/he became a scientist?	❑	❑
To explain why s/he volunteered to be a mentor?	❑	❑

5. Your relationship with your mentor

For each of the statements below, circle a number to show how strongly you agree or disagree with it.

Statement	Don't Know	Disagree Strongly						Agree Strongly
My mentor told me the history of his/her career	❑	1	2	3	4	5	6	7
My mentor told me why s/he volunteered to be a mentor	❑	1	2	3	4	5	6	7
My mentor encouraged me to prepare for college	❑	1	2	3	4	5	6	7
I agree with my mentor's attitudes about education	❑	1	2	3	4	5	6	7
I respect and admire my mentor	❑	1	2	3	4	5	6	7
My mentor showed respect for me	❑	1	2	3	4	5	6	7
My mentor seemed to have read my messages carefully	❑	1	2	3	4	5	6	7
My mentor gave me feedback on how I was doing with my project	❑	1	2	3	4	5	6	7
My mentor was friendly to me	❑	1	2	3	4	5	6	7
My mentor helped me to meet project deadlines that I couldn't have met otherwise	❑	1	2	3	4	5	6	7
My mentor suggested specific strategies that would help me get my work done	❑	1	2	3	4	5	6	7
I trust my mentor	❑	1	2	3	4	5	6	7

6. Overall Success of Mentoring

a) Circle a number to show your strength of agreement or disagreement with each statement below.

	Disagree Strongly						**Agree Strongly**
It was worthwhile to have a mentor for this project	1	2	3	4	5	6	7
Overall, the mentoring was a success for me	1	2	3	4	5	6	7

If the mentoring was a NOT a success, check the line that you think best explains why:

❑ My mentor never answered my group (not even ONE response)

❑ My mentor was too busy to help my group very much

❑ My mentor responded too slowly to be helpful

❑ My mentor tried to help, but didn’t understand what my group needed

❑ My mentor tried to help, but didn’t know much about my group's topic

❑ My mentor answered my group’s mail, but was insulting to us

In what way was your mentor insulting? ____

____

❑ My group didn't keep in touch with our mentor because we didn't really need/want help

❑ Other problem (explain) ____

____

7. Your Final Paper

b) About how much of the final paper did you write yourself (without the help of others on your project team)? (Check one)

All of it	About 3 quarters	About half	About a quarter	None of it
❑	❑	❑	❑	❑

8. Should we not use your answers?

Sometimes people aren't at their best when they are asked to fill out surveys. They may be sick, or bored, or find it hard to concentrate for some other reason.

If you feel that we shouldn't bother reading your responses to this survey, check the box below and we will ignore them.

Don't use my answers
❑

Comments

Do you have anything to say about this survey, or any suggestions about how it could be improved? Please write them below.

Appendix B: Student Focus Group Tasks

Introduction

Before we start off I want to make it clear that I am not out to prove that Internet mentoring is the best thing since sliced bread. One of the reasons I'm talking to you is that I want to know what you see as imperfect about it and try to figure out how it could be done better.

I wanted to talk to you guys in particular because you seemed to have had (a comparatively good, a really bad, a pretty average) time with mentoring in the (first, second, third) project, and I want to try to figure out why that was and what might be changed to improve that experience.

Q. So, what do you have to say?

<Give them **5 minutes** to sound off any way they like, but try to make sure the students get equal time.>

For less than successful cases:

Q. How come you didn't communicate with your mentor more?

List-Making and Ranking Tasks

OK, now I have a few specific questions to ask all of you about what you think of mentoring based on your experience of it, and here's how I'd like to do it. Each of you get a pad of paper and a pencil. **(hand these out)** I'll ask a question, and I'd like each of you to write down whatever answers come to mind in the next minute or so. Then I'll and ask each of you what you thought and we'll discuss your answers a bit. This is a little strange, but I want to be sure I hear what each one of you has to say.

Mentor's Role/Relationship

a) An Internet mentor could be helpful at different times during a project. They could also be helpful in different ways at each time. Based on your experience so far, when do you think a mentor can be helpful to a team in your class (any team) and and in what ways can he or she be helpful? List a few times and ways that come to mind. If there are things you think mentors definitely can't do, you might want to mention that, too.

Clarification: Basically I want to know what kinds of things you think a mentors can do for students in your class and when.

Probes: near the middle, finding data to answer the question; helping understand how to analyze the data; figuring out what conclusions to draw; reading parts of your paper to help you do the best you can on it.

OK, let's hear what you wrote down.

Q. Why don't you think a mentor can be helpful at (whatever stage(s) of the project they don't mention)?

Mentor's Role/Relationship

b) Potentially, students could get a lot of different kinds of value out of mentoring. I'd like you to list different kinds of value that you think students in your class could reasonably get out of mentoring.

probes: "could get better grade", "project could be less work", "could help you to do something you find more interesting", "could get to know a real scientist", "could find out whether you might want to be a scientist"...

Q. Which of these do you think is most important to mentoring being worthwhile? Why?
Q. Second most important?
Q. Third most important?

Teacher's Drives

a) It takes a fair amount of work for your teacher to set up mentors for you and keep them up to date on what's happening in the class. S/he could do this for a variety of reasons. List the reasons you think s/he might have (3 or 4 would be plenty).

probes: "help us find data", "introduce us to professional scientists", "save himself work"...

Q. Which do you think is the single most important reason for him/her?
Q. The second?
Q. The third?

Mentor’s Drives

b) A mentor might want to be involved in your work for a variety of different reasons. Write down as many as you can think of.

probes: "just likes working with students", "knows a lot about the subject and likes to tell it to others", "doesn't know a lot about the subject but is interested", "has too much spare time"

Q. Which of these do you think is most important one to a mentor? Why?
Q. Second most important? Why?
Q. Third most important? Why?

Research Article Genre

a) Your teacher had you write your final paper for the project in a particular format (with an Abstract, Introduction, Methods, Data/Analysis, Conclusions). There could be a number of different reasons for choosing that particular format. What reasons do you think your teacher had for asking you to you do this kind of paper? (3 or 4 is enough.)

probes: “this is just the way science papers are done”, “This is the way your teacher has always asked for papers”, “This kind of paper best allows him to judge the work you have done”, “adult scientists write papers like these”

Q. Which of these do you think is most important one to your teacher? Why?
Q. Second most important? Why?
Q. Third most important? Why?

Mentor’s feedback on Paper

Q. Did you send your paper to your mentor to look at?

(if yes) Did you get comments back? What were they like?

(if no) Why not?

Appendix C: Mentor Post-Project Interview

- My name is Kevin O'Neill. I'm a graduate student at Northwestern University, working on the CoVis Project...

- First, I'd like to thank you for taking part in telementoring CoVis students. I'd also like to thank you for taking the time to talk to me. A lot of people are very interested in your experience and what we can learn from it.

- Part of my research involves trying to find out whether orchestrating distant mentoring (or telementoring, as I like to call it) on a volunteer basis will be able to assist education reform efforts in the long run, or what limitations it has. So what I need from you is your honest view of your own personal experience. I'm not asking you to generalize.

- I have about 20 questions prepared for you, which should each be pretty brief to answer. If you wanted to, though, you could probably spend several minutes on each, so just keep in mind that I have quite a few things to ask.

- Do you mind if I record our conversation on tape? **(start tape if yes)**

- Do you have any questions for me before we begin?

Demographics

Mentor's Name ____

Mentor's Age ______

Years in current job ______

Opening question

Q. First, I'd like to ask you a very open-ended question. What do you have to say about your experience of telementoring?

❑ Expectations

Q. Was your telementoring experience much like what you thought it would be?
Q. What did you expect or hope it would be like?
Q. What was different from your expectation?
Q. Is there something you think you should have known that would have better prepared you for the experience?

❑ Salient Story

Q. Is there one part of your experience that stands out in your mind that you could tell me a story about? For instance, something you found funny or frustrating or especially satisfying?

❑ Role Issues

Q. How many teachers did you work with? _____
Q. Were you asked by either the students or teacher to do things or answer questions that you thought were unreasonable? _____
Q. Can you give me an example?

❑ Question-steering Issues

Q. What did you think of the students' questions? _____
Q. Sometimes the questions that students ask their mentors are vague or poorly formulated. Did you ever find this to be the case? _____
Q. Did this happen very often? _____
Q. How did you cope with vague questions when they arose?

❑ Relationships

Q. How would you describe the relationship(s) you developed with the teacher(s)?
Q. How would you describe the relationship(s) you developed with the students?
Q. Would you have liked these relationships with teachers and students to have been different? If so, what would you have liked them to be like?
Q. Do you think the relationship you had with the students is appropriately described as "mentoring", as you understand the term?

❑ Fit With Work Context

Q. Did you do all of your telementoring from your place of work, or some at home?
Q. How did telementoring influence your work life?
Q. Did you ever discuss what you were doing with any of your co-workers?
Q. Did you ever discuss it with your boss?
Q. Did you feel that others at work supported what you were doing?
Q. Did you feel that they were enthused about it?

❑ Desire to Repeat and expand

Q. Did this experience teach you anything new about yourself or your job?
Q. Do you think you would like try telementoring again?
Q. Would you want to make a habit of it? Perhaps do it a few times a year?
Q. Do you think there would be any opposition to this in your workplace?
Q. What kind of recognition or incentives do you think would be necessary or helpful in getting this to be accepted in your workplace?

❑ Advice to coordinators

Q. What do you think could have been done to make this a more rewarding experience for you?

❑ Wrap-up

I've run out of questions. Is there anything else you'd like to say before we end?

Appendix D: Teacher Pre Interview Guide

Teacher's Name ____

Date Interviewed ___________

Demographics

Age ________ Years in current job ______

Opening question

Q. It's been a while since we talked last. What's on your mind?

Introduction

- Thanks for taking this time to talk to me. I'm hoping that through this interview and the other research I'm doing, I can learn some things that will help you and many more teachers who will be implementing telementoring in their classrooms in future years.
- Do you mind if I record this conversation? **(start tape if yes)**
- This first interview is meant for me to find out a bit about your personal and professional reasons for running telementoring in your classes, and what you expect from it both for yourself and your students.
- After your first experience of telementoring with your students, I'll interview you again to see how you felt it went.
- For now, what's important to me is how you expect to approach it and how it fits into the rest of what you do.

What mentoring means to you

❑ **Q.** First, to be sure that I'm on your wavelength, I'd like to ask you to explain what mentoring means to you. What you think of when you hear the word "mentor"?

- One way to approach this is: how would you distinguish a mentor from a tutor, a teacher or a friend?

❑ **Q.** Going with that definition, do you recall ever having a mentor?

- (If more than once) What was your most significant mentoring relationship?
- Where and when did you meet this person?
- What did you do together?
- How long did this continue?
- What would you say sets this relationship apart from others you've had?

❑ **Q.** What about this relationship was most beneficial and enjoyable?

❑ **Q.** What was difficult or frustrating about it?

❑ **Q.** What lasting effects do you think this relationship has had on you?

About pedagogical goals and commitment to the concept

❑ **Q.** How do you expect your students' experiences of telementoring to differ from your own experiences of mentoring face-to-face?

- What limitations do you think might be involved in telementoring, by comparison to traditional mentoring?

❑ **Q.** How do you think you will convey to your students what telementoring can or should be like?

- What personal experiences can you draw upon to do this?

❑ **Q.** What are you hoping your students will get out of telementoring in relation to:

- ...their understandings of scientific concepts ?
- ...their understandings of how the scientific community operates?

Institutional Setting

❑ **Q.** Do you think telementoring *complements or conflicts with* the official goals or initiatives of your department, school or district in any way?

❑ **Q.** How do you think other teachers and administrators in your school will see what you're doing?

- Have you talked to any fellow teachers or administrators about it?

Orchestration

❑ **Q.** Do you expect to match every group or student with a mentor?

- ❑ **Q. (if yes)** Is there something important to you about that?
- ❑ **Q. (if no)** Why not?
  - Do you have any concerns about how some students will present themselves?
  - How do you think you might deal with those issues if they arise?

Projects and Assessment

- ❑ **Q.** What projects will you be incorporating mentoring into this year?
- ❑ **Q.** What are your main instructional goals for these project(s)?
  - How do you hope telementoring will contribute to accomplishing those goals?
- ❑ **Q.** Will you be involving the mentors in the students' assessment somehow?
  - Do you have any reservations about that? Can you explain them to me?
  - Why? (Why not?)
- ❑ **Q. (If yes)** What kind of involvement would you like the mentors to have in the students' assessment?
  - ❑ To provide a major component of the students' grades
  - ❑ To keep the kids on task
  - ❑ To keep the mentors involved in the students' work
  - ❑ Something else?

  ____

- ❑ **Q. (If no)** How come?
  - Do you know if there are any regulations against this in your school, district or state?
- ❑ **Q.** Will you be assessing the students in any way on how they work with their mentors?
  - How will you do that?

Teaching the RA Genre

Hopefully by now you've had a chance to look over the materials I prepared about the research article genre (the set of Teacher's Guidelines and the assessment rubrics).

❑ **Q.** Have had students write articles like this in the past?

- When?
- How often?
- How pleased have you been with the results?

❑ **Q.** Do any of your students come to you already knowing about this genre?

- Where do they learn about it?

❑ **Q.** How do you normally teach them to write these articles?

- ❑ Handouts?
- ❑ Examples of good research articles?
- ❑ Whole-class discussions or verbal presentations?
- ❑ Reviewing drafts and providing comments?
- ❑ Ask for re-writes?
- ❑ Team teach with an English teacher?

Wrap-up

✔ Go back and check for skipped questions.

Well, that does it for my prepared questions.

❑ **Q.** Is there anything else you think I should know about that I haven't asked you?

Thanks again for taking the time for this interview. I'm looking forward to talking to you again after the project is over to hear what your experience has been like and to learn from that.

Appendix E: Teacher Post Interview Guide

Teacher's Name ____

Date Interviewed ___________

INTRODUCTION

The purpose of this interview is to look back over the year and try to address some of the questions that we have been developing together about telementoring. In particular, I want to ask you to think about your own implementation of it and what you think might be done to make it more effective, more manageable, or both, and where the trade-offs between those two things lie.

OVERALL IMPRESSIONS

- ❑ **Q.** On the whole, how satisfied are you with the contribution that telementoring made to your work and your students' work this year?
- ❑ **Q.** What are the biggest open questions for you about telementoring, in relation to your own teaching?

BENEFITS

- ❑ **Q.** What benefits does telementoring have for you as a teacher?

MENTORS

- ❑ **Q.** To what extent do you think the mentors you worked with understood what you wanted from them?
- ❑ **Q.** To what extent do you feel they were committed to that idea?
- ❑ **Q.** What do you think they didn't understand about what you wanted from them?
- ❑ **Q.** How do you think that could be more effectively explained to them?

STUDENTS

- ❑ **Q.** To what extent do you think your students understood what they were supposed to do with their mentors?
- ❑ **Q.** To what extent do you think they were bought into that idea?
- ❑ **Q.** What implications are there for your teaching practice from the fact that some students are unenthused about, or even resentful of mentoring?

ASSESSMENT

- ❑ **Q.** What kind of involvement did the mentors have in your students' assessment?
  - o To provide a major component of the students' grades
  - o To keep the kids on task
  - o To keep the mentors involved in the students' work
  - o Something else?
- ❑ **Q.** Did you assess the students in any way on how they worked with their mentors?

• How?

- ❑ **Q.** Not all mentors can or will be equally helpful to the students they work with. How do you deal with issues of fairness when you assign grades?

PRAGMATIC/WORKLOAD ISSUES

- ❑ **Q.** What was the biggest surprise for you in implementing mentoring this year?
- ❑ **Q.** What part of mentoring made the biggest demand on your time?
- ❑ **Q.** Do you think this time demand would decrease with more experience?
- ❑ **Q.** What parts of mentoring do you think would require the same amount of time or more time in the future?

CONTINUATION AND SCALING

- ❑ **Q.** Are you expecting to involve mentors more, less, or the same amount in projects next year?
- ❑ **Q.** Do you believe that many of your peers would be willing and able to implement telementoring in a way similar to what you did?
- ❑ **Q.** What would you tell them about it before they tried it?

Wrap-up

✔ Go back and check for skipped questions.

Well, that does it for my prepared questions.

- ❑ **Q.** Is there anything else you think I should know about that I haven't asked you?

Thanks again for taking the time for this interview.

Appendix F: Student Science RA Rhetoric Coding Form

Paper Title: ____

Team Number: __________

Date Submitted: ____

Writers & IDs ________________________ ID ________________

________________________ ID ________________

________________________ ID ________________

________________________ ID ________________

________________________ ID ________________

________________________ ID ________________

Teacher, Period: ____

Date Coded: __________ Coder: ______________________________

Notes:

Section-Specific Rhetorical Functions

RA Sections Present (i.e. marked with a labeled heading)

❒ Abstract	❒ Introduction (sometimes labeled "Background")	❒ Method (sometimes labeled "Procedure")	❒ Results (sometimes labeled "Data")	❒ Discussion (sometimes labeled "Conclusions")	❒ References (sometimes labeled “Bibliography” or “Literature Cited”)

Other Sections Present

❒ Materials	❒ Purpose	❒ Acknowledgments

Abstract/Introduction

❒ States a purpose in the form of a problem, question, or issue to be resolved In this section? ❒ Y ❒ N	❒ Explains the significance of this purpose to the general audience (i.e. why do we care?) In this section? ❒ Y ❒ N	❒ Summarizes Method In this section? ❒ Y ❒ N
❒ Provides background research into the broad topic area In this section? ❒ Y ❒ N	❒ Summarizes important findings from earlier work on the problem by others (names names and gives citations) In this section? ❒ Y ❒ N	❒ Summarizes Results In this section? ❒ Y ❒ N

Methods

❒ Describes what was done by the investigators (built a physical model, collected samples, gathered research sources from libraries or electronic archives, etc.) In this section? ❒ Y ❒ N	❒ Does this description in terms and with precision appropriate to others who might want to reproduce the results In this section? ❒ Y ❒ N
❒ Explains why the method followed by the writers could be expected to lead to a resolution of the problem, or to an answer to the question In this section? ❒ Y ❒ N	❒ Mentions specific search goals and/or criteria employed at library or in Internet searches (e.g. ‘we searched with the keywords "sea surface temperature’") In this section? ❒ Y ❒ N

Results

❒ Foreshadows results briefly (in a sentence or two) In this section? ❒ Y ❒ N	❒ Presents the data collected or found (in tabular or graphical form, a set of images, etc.) In this section? ❒ Y ❒ N
❒ Characterizes or "glosses" the data for the non specialist In this section? ❒ Y ❒ N	❒ Provides an interpretation of data with respect to the original question (in the form of calculations and/or prose that refers specifically to the data) In this section? ❒ Y ❒ N

Discussion

❒ States the conclusions that can be made about the original question or problem from the data or information collected In this section? ❒ Y ❒ N	❒ Attempts to explain how the data support, refute, or are unrelated to a question or problem mentioned earlier In this section? ❒ Y ❒ N
❒ Discusses the importance of the results with reference to the significance of the original question In this section? ❒ Y ❒ N	❒ Makes suggestions for further study In this section? ❒ Y ❒ N

Persuasive Features

Text Types Used (check *at least one*)

❒ Expository (lays out facts, frameworks, or key terms)	❒ Narration (relates a sequence of events in past tense)	❒ Overt Persuasion (argues for a particular interpretation with words like “since...then...”, “therefore”, or “because”)

Persona Indicators - how do the writers present themselves? (check all that apply)

❒ Describes scientists as Other (e.g. “Scientists say...”)	❒ Assumes guise of scientist (e.g. “In our professional opinion...”)
❒ Speaks in first person (uses “I”, “We”, “Our”)	❒ Uses passive voice to exclude self (e.g. “A data table was constructed” rather than “We constructed a data table”)

Audience Indicators - who does this seem to be written to? (record line numbers and count)

+ ❒ Refers to teacher in 3rd person, or not at all	- ❒ Addresses teacher by name (e.g. “Well Mrs. Whitcomb, what we decided to do was...”)
- ❒ Refers to experience shared with teacher or assumes knowledge that only the teacher or other classmate(s) would have	- ❒ Uses colloquialisms common to students but not to adults

Use of Sources and Authorities (record line numbers and count)

+ Cites named sources for support (e.g. "As (Myers 1985) has said...") [ ] #	+ Cites named sources as examples of opposing views (e.g. "Counter to findings by Wallin (1995), our research showed...") [ ] #
+ Provides precise machine addresses, paths and filenames for Internet resources [ ] #	+ Identifies originators of data or information used *by name of person or institution , or title of work* (not just by the media through which they were obtained, e.g. World Wide Web) [ ] #
- Uses unnamed authorities for support (e.g. “Many scientists believe...”) [ ] #	- Alludes to unnamed opponents, perhaps as straw men (e.g. “many people think...but really...”) [ ] #
- Makes vague references to books or Internet sources (e.g. “The following data come from a Mosaic page” or “This data came from a weather book”) [ ] #	+ Acknowledges the contributions of non-team-members to the work presented (e.g. other student, mentor, teacher, or other adult) [ ] #

Types of Sources and Authorities Mentioned (check) - (these do not need to be bibliographical refs.)

❐ Textbooks	❐ Encyclopedias	❐ Popular Press
❐ Internet resources (e.g. web pages)	❐ Personal Communications	❐ Scientific Journals

Treatment of Perspectives and Opinions (record line numbers and count)

+ Anticipates possible objections and attempts to address them (e.g. “It could be said that...but on the other hand...”) [ ] #	+ Summarizes and weighs several perspectives on a point (i.e. evaluates more than two possibilities for their relative merit) [ ] #
+ Acknowledges viability of a view(s) not shared by the writers (e.g. “It could still be the case that...”) [ ] #	+ Draws attention to a point of general contention in the field (e.g. “There seems to be little consensus over how to interpret the ice core data...”) [ ] #

Hedging (record line numbers and count)

+ Acknowledges possible flaws in method or calculations performed by the writers	+ Acknowledges the limits of the writer's own experience or data	+ Emphasizes the provisional nature of the conclusion or argument put forward (e.g. "More data are needed for a definite answer to this question")
#	#	#

Overall Reflections (record line numbers and count)

Proclaims success	Proclaims lesson learned about the nature or practice of science	Proclaims that important science content was learned.
#	#	#
Proclaims failure	Proclaims lesson learned about doing investigations	Proclaims lesson learned about working in groups
#	#	#

Complaints, Excuses, etc. (record line numbers and count)

Claims crucial resources were not available or convenient enough	Claims team conflict impeded progress	Claims the problem looked deceptively easy, but later proved hard
#	#	#
Claims teacher was unhelpful	Claims mentor let the team down	Talks about long hours or hard work invested in the project
#	#	#
Claims there wasn't sufficient time to do the assignment	Claims the assignment was hard to understand	
#	#	

Appendix G: Student Paper Rating Package for Volunteer Scientists

Enclosed you will find a set of materials for your participation in the paper rating study being conducted by the CoVis project at Northwestern University. I thank you for agreeing to take part. Your participation is essential to the success of this research.

As I explained briefly in e-mail, the purpose of the study is to explore the similarities and differences between volunteer telementors' judgments of students' written reports of independent research projects and the judgments of teachers and researchers like myself. The results of this study will be included in my dissertation and may lead to greater involvement of volunteer telementors in assessing students' work.

In addition to this letter, your package should contain:

- A set of instructions for your participation in the study
- Seven paper rating forms (you will need only six, but I supplied a spare)
- A three-item questionnaire titled "Your Experiences with this Form of Scientific Writing"
- An envelope labeled Package A (containing three papers)
- An envelope labeled Package B (containing three papers)
- A stamped envelope addressed to me at Northwestern University (for returning your results)

The six papers included in your package were written by different teams of students participating in a project-based high school Earth Science course during the 1995/1996 school year. The course drew students of all high school ages, from 9th to 12th grade, and many teams contained students at various grade levels. One thing that many of these students have in common is a comparatively low motivation to study science. They often take Earth Science in order to avoid taking Physics or Chemistry. Partly to develop their interest in science, three-quarters of the scheduled class time is dedicated to students' work on largely independent, team research projects. What you will be reading are the final results of several weeks of effort.

In preparation for this study, the students' names have been removed from their reports and replaced with arbitrary ID numbers. The papers have also been put into a similar word-processing format to make reading them easier. In most other respects they are unchanged from the original submissions to the teacher. Some papers are, unfortunately, missing their original figures (charts, graphs, etc.), since the students did not include them in their word-processing files. However, these figures are usually not necessary to understand the work the students have done.

Please read the instructions carefully before you begin rating the papers, and return your results as soon as they are complete. I will contact you via e-mail when I publish the results of the study.

Again, many thanks for your assistance!

Sincerely,

Kevin O'Neill
CoVis Project

Instructions for Raters

Included in this package are two envelopes of student research papers, labeled A and B. The set of papers in Package A was selected to familiarize you with the range in the quality of work produced by the students under study. All raters will read and rate these same papers as a form of "calibration". To this end, please open, read, and rate the papers in Package A **before** Package B. This will help ensure that any inconsistency of results between you and other raters is due to genuine differences of opinion rather than differences in your exposure to students' work.
You will note that the rating form asks you to focus your attention on certain *aspects* of students' work, but does not provide exact criteria. This is because the issue under study is whether the criteria most important to you are similar to those applied by the teacher and by me. Simply report your judgments as they occur to you, and if you like, make a note of the criteria you apply or other thoughts that occur to you beneath each rating scale.

Proceed now as follows:

- Complete the questionnaire titled "Your Experiences with this Form of Scientific Writing".
- Open Package A.
- **Read all 3 papers** before rating any of them. Then go back and rate each one. If necessary, review each paper quickly before rating it.
- Open Package B.
- **Read one paper at a time** and complete a rating form for it immediately afterward.
- Do not forget to mark the team number and your name on each rating form.
- When you have finished rating all the papers, put the coding forms and the questionnaire titled "Your Experiences with this form of Scientific Writing" in the stamped envelope provided in your package and mail it back to me (do not return the papers).

Please note that some of the papers you will read are missing some or all of their original figures (charts, graphs, etc.). This is unfortunate, but it is usually not necessary to see the figures in order to understand the nature of the research the students have undertaken and how well it has been done. If, after reading a paper with missing figures, you are not confident in your ability to rate it, simply skip it and move on to the next one.
If you would like a letter sent to your supervisor or another superior acknowledging your participation in this study, please send us his or her name and address along with your rating forms and I will ensure that this is done.
Many thanks for your participation.

Sincerely,

Kevin O'Neill
CoVis Project
School of Education and Social Policy
Northwestern University

Paper Rating Form

Rater: ________________________________ Date: ___________

Team #___________

Your Opinions

	Terrible						Excellent
On the whole, I think this paper is	1	2	3	4	5	6	7
(comments)							

Research	**Not at all**						**Absolutely**
The students framed a good question/problem	1	2	3	4	5	6	7
(comments)							
The research appears well carried out	1	2	3	4	5	6	7
(comments)							
Report	**Not at all**						**Absolutely**
The report presents a persuasive argument for a set of findings or claims.	1	2	3	4	5	6	7
(comments)							
The Abstract and Introduction are well done	1	2	3	4	5	6	7
(comments)							
The Method section is well done	1	2	3	4	5	6	7
(comments)							
The Results section is well done	1	2	3	4	5	6	7
(comments)							
The Conclusion section is well done	1	2	3	4	5	6	7
(comments)							

Your Experiences with this Form of Scientific Writing

(Research articles with an Introduction, Method, Results, and Conclusion/ Discussion)

Rater: ____

I have *reviewed* research reports of this general format for the following journals:

Journal	**Number**
____	__________
____	__________
____	__________
____	_________

I have *published* research reports of this general format in the following journals:

Journal	**Number**
____	__________
____	__________
____	__________
____	_________

	Number
I have *written* research reports of this general format in the past	_________