Experiences with TeleMentoring: Lab Teaching over ATM Networks

J. M. Smith†, C. B. S. Traw†, W. S. Marcus‡, T. J. Bogovic‡, S. B. Davidson†, D. J. Farber†, N. B. Goldstein, I. Lee†, V. F. Massa‡ and I. Winston†*

ABSTRACT

Using the Asynchronous Transfer Mode (ATM) network infrastructure of the AURORA Gigabit Testbed§, we were able to carry out a trial of interactive distance learning. The trial used teleconferencing hardware which converts NTSC television and audio signals to and from ATM cells. This hardware connected the Bellcore VideoWindow(TM) with other apparatus to create a realistic two-way interaction. In our trial, the interaction was between teams of undergraduate computer science students and researchers at Bellcore, and was used to support work by these students on advanced laboratory projects for a course.

Our hypothesis was that remote "mentoring" would provide a means with which student learning could be accelerated. Further, projects could be chosen which were meaningful to industrial research goals, so that student training is coupled with gaining relevant experience.

This paper describes our initial TeleMentoring trial, which was done from January to May of 1994, and discusses the results. We conclude that the trial illustrated some flaws with TeleMentoring as implemented this semester, in particular the coordination between TeleMentoring and coursework. We discuss the observed strengths and limitations of TeleMentoring, and propose some further experiments.

1. Introduction

Support of research and education will be an important role for the proposed National Information Infrastructure. TeleMentoring [8] is a research and teaching experiment, based on the observation that undergraduate computer science laboratories are taught using a ‘‘mentoring’’ model rather than a ‘‘lecturing’’ model. This suggested that the unique facilities of the AURORA Gigabit Testbed, described later, could be used to support interactive distance learning between widely separated sites, such as the University of Pennsylvania, Bellcore, IBM Research, and the Massachusetts Institute of Technology.

The essence of the experiment was to augment the laboratory portion of an undergraduate computer science course through interaction with remote ‘‘mentors’’. The mentors chosen are experts in the course topic. The interaction would be supported using experimental telecommunications technologies that are predecessor technologies for the NII [1]. The experimental hypothesis was that the TeleMentored students would be able to absorb more material, at a greater rate, than equivalent students who were not TeleMentored.

There are additional questions of a broader nature.

- First, does this idea permit us and other educational institutions to teach material which would not otherwise be available to our students?

---

† - CIS Dept., University of Pennsylvania. TeleMentoring is supported at the University of Pennsylvania by the NSF under Agreement number CDA-92-14924.

‡ - Bell Communications Research, Inc. (Bellcore)

* - School of Arts and Sciences, University of Pennsylvania

§ - AURORA is a joint research effort undertaken by Bell Atlantic, Bellcore, IBM Research, MIT, MCI, NYNEX, U. Arizona and and U. Penn, sponsored as part of the NSF/ARPA Sponsored Gigabit Testbed Initiative through the Corporation for National Research Initiatives, under Cooperative Agreement number NCR-8919038. AURORA work at Penn is partially supported by Bellcore through the DAWN project, by IBM through a Faculty Development Award to Prof. Smith and equipment support, by SUN Microsystems, and by the Hewlett-Packard Company.

- Second, does it allow experts in industry to participate in the process of educating students in relevant technologies and laboratory techniques?
- Third, does it allow this learning to take place in ways (such as mentoring), and with means (such as video and manipulation of laboratory instruments), over distances which would otherwise prohibit the interactions needed for learning.

We used the Bellcore-supplied VideoWindow(TM) experimental teleconferencing prototype, shown in **Figure 1**, to support the interaction with industrial ‘‘Mentors’’.

In addition, under the TeleMentoring research [8] we have designed and implemented, in collaboration with Bellcore, a low-cost teleconferencing technology [6] for use with ATM networks, and in particular, direct connection to the Sunshine ATM Switch prototyped by Bellcore [5]. A particular advantage of this technology (implemented as a single printed circuit board) is that a teleconferencing system can now be constructed with standard technologies, such as a commercial color television and video camera.

While we intend to deploy high-quality workstation video, our assessment of the state of the art was that today’s workstation video did not perform well enough. This is due to a combination of factors, including software overheads, and the need to simultaneously interface to an ATM network. Given that the goal was education, and our experience told us that minimizing distractions would help keep the focus on education, we chose to use the high-quality video provided by an uncompressed video stream, carried directly as ATM cell traffic.

Figure 1: VideoWindow in Use

2. The TeleMentors

Arrangements were made in the Fall of 1993 between Penn and three researchers at Bellcore in Morristown, NJ. The three researchers, Bill Marcus, Tony Bogovic and Vince Massa were part of the team collaborating in the AURORA Gigabit Testbed. They were senior engineers and had already established good working relationships with Penn faculty and students. One of the TeleMentors participated in the experiment because while in university himself he benefitted greatly from work experiences with engineers in industry.

The research focus of the three TeleMentors is experimental ATM switching [5]. This made ATM a desirable focus for the student projects, as we will discuss later in Section 6.

3. Telementoring Technology Base

TeleMentoring's technologies are those used in the AURORA Gigabit Testbed. AURORA is one of a set of gigabit testbeds [1], and is unique both in that it is the highest-speed Wide-Area Network (WAN) in existence, and that its research goals [3] have been focused on workstations rather than supercomputer technologies. The geography of AURORA is shown in **Figure 2.**

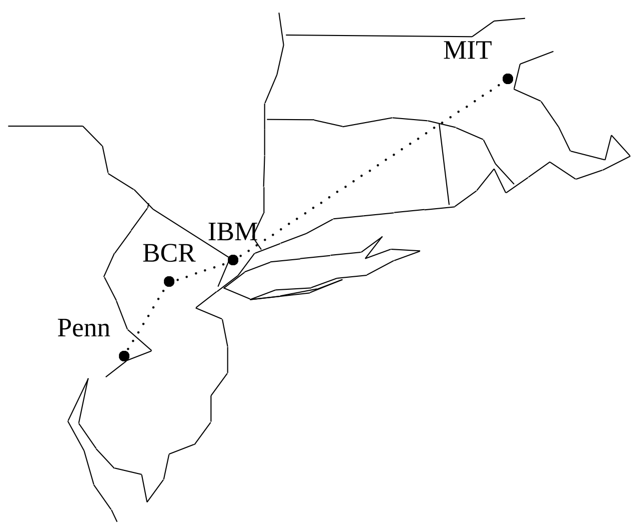

Figure 2: AURORA Geography

AURORA's transmission facilities are 2.4 billion bit per second (Gbps) Synchronous Optical Network (SONET) OC-48 links. As SONET is the standard which the telephony industry has selected for deployment over the next several decades, it appears that results achieved on SONET facilities will be widely applicable. In fact, there is significant indication that the high-speed portion of the NREN will be Asynchronous Transfer Mode (ATM) cell-switching [7] operating over SONET transmission facilities [1].

Cell-switching operates over the transmission facilities in the following manner. The transmission facilities are used to connect devices called switches. The switches have input ports and output ports, and based on the information in a cell, a cell arriving on an input port is routed to the proper output port. At the high speeds employed in the AURORA Gigabit Testbed, the cell-routing decisions must be made very quickly; this sort of cell-switching requires special-purpose hardware, of which none was available when the project was started in 1990 [3]. Therefore, two research prototypes, Bellcore's SUNSHINE [5] ATM switch, and IBM Research's plaNET [2] switch, were built as part of the testbed research. A partial logical topology is given as **Figure 3.**

Devices (such as workstations) connect to the switch ports. They generate cells addressed to the intended recipient. To support TeleMentoring, special switch connection hardware and video cards have been prototyped, as well as significant pieces of new software. In addition, this work has had to take place concurrently, and be coordinated with, curriculum modifications, which we will discuss further in Section 4.

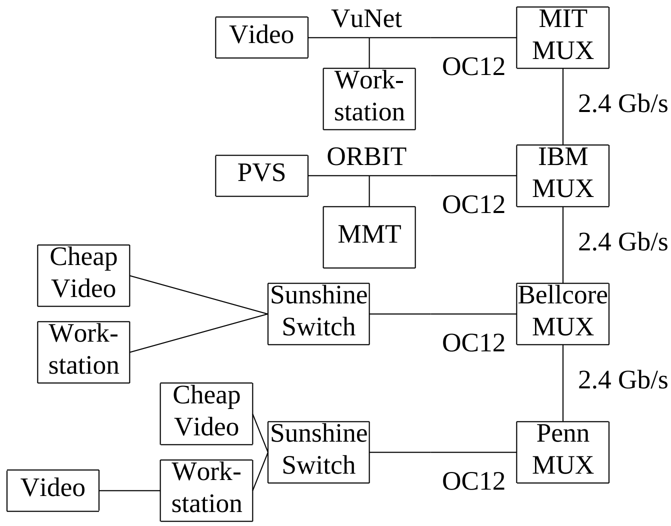

Figure 3: Partial AURORA Logical Topology

3.1. AURORA Technology Status

The last year has seen a great deal of the AURORA technology become operational [4]. In May, 1993 the first ATM cells were sent between workstations located at Penn and at Bellcore. In June 1993, a variety of video experiments were carried out, largely with low-quality video between workstations. The first Sunshine switch became operational, at Bellcore in Morristown, NJ, and was used to switch cells sent between workstations at Penn and Bellcore. The second and third Sunshine switches were deployed at Penn and MIT in Fall 1993.

We have developed a terminal adapter solution [6] (‘‘Cheap Video’’), in cooperation with Bellcore, which connects the VideoWindow directly to a port of the Sunshine switch. We began the first TeleMentoring evaluation in the U. Penn undergraduate course CSE371 this semester. A graduate student familiar with the high-speed networking research (Brendan Traw) served as the teaching assistant for CSE371 in order to facilitate the use of the technologies in the course.

4. Curriculum Changes

One of the curriculum changes we made is a restructuring of the undergraduate digital design sequence, CSE370-CSE371. This course had fallen badly behind the state of the art, for a variety of reasons. In particular, the microprocessor technology employed (Intel 8085) was well over fifteen years old. While principles can be taught using any microprocessor, the use of a current technology greatly increases the relevance of the laboratory exercises, especially where that technology is used in classroom teaching.

For TeleMentoring, we emphasized classroom teaching in the first part of the course, CSE370, which is taught in the Fall. This Spring, the CSE371 course has had a greater laboratory focus, with a larger-scale microprocessor project implementation in addition to a full set of lectures.

Laboratory personnel have been heavily involved in this effort, developing new materials, course guides and exercises. The management of course resources such as microprocessors and I/O chips has been greatly simplified by the development of kits which the students use for the whole semester. An HP16500A logic analyzer was acquired and teaching materials such as guides for use of the machine were prepared.

Using the TeleMentoring research as a basis, we received equipment support from SUN Microsystems to support undergraduate course work, four workstations with multimedia support. These workstations have been used to support a new undergraduate course developed by one of the PIs, Insup Lee, CSE 480. CSE 480, ‘‘Distributed and Real-Time Systems’’ has a major project component, which for Spring 1994 was a small-scale multimedia teleconferencing system. We expect to feed some of the software resulting from this course back into the TeleMentoring software infrastructure.

5. Examples of Current Projects

The current projects were developed in consultation with the TeleMentors from Bellcore. We attempted to size the projects so that teams of two undergraduates had a reasonable chance of success. The projects were chosen to be genuinely useful to the Bellcore staff members interacting with the students, and as mentioned in Section 2, they are gigabit switch designers. The CSE371 class is employing Motorola 68000 processors, and thus all of the projects employ the 68000 processor.

Cell Traffic Generator: The 68000 is used to generate and write ATM cell patterns into a large Static Random Access Memory (SRAM) buffer. This buffer could be dual ported to allow a Finite-State Machine (FSM) to read the ATM cells bodies out, format their headers, and put them into SONET frames. A number of these boards could provide an inexpensive mechanism to load (and hence evaluate the performance of) a switch or workstation-based network subsystem.

Cheap Video 68K: ‘‘Cheap Video’’ is the name we have given the video adaptor we developed for TeleMentoring [6]. A clear upgrade to the initial design is to integrate a 68000 into the original all-hardware cheap video design. The 68000 could perform additional processing to allow more complicated command and status interactions between the cheap video hardware and remote nodes (e.g., at Bellcore, IBM or MIT). It would also be desirable to integrate audio capability into the design, as with ‘‘Cheap Video II’’.

Switch Status Monitor: Each input port on the Sunshine ATM switch has a serial port which could be used to obtain statistics on the operation of that port. These statistics could include: error rates, number of active connections, and utilization level. A 68000 minimal system with multiple serial ports could be used to gather statistics on the overall operation of the switch by connecting to each input port.

There were 8 students involved in the TeleMentoring evaluation this semester. Each group pursued one of these projects. Two groups of 2 students were TeleMentored, and the other two groups are working closely with the undergraduate laboratory staff member, but no TeleMentoring. This gave us a controlled experiment (to the degree possible with students!) and allowed us to draw early conclusions for dissemination to other researchers and educators. The environment for TeleMentoring at Penn was the conference room illustrated in **Figure 1**, with a conference table, and a whiteboard used for illustrating concepts and drawing block diagrams.

The TeleMentors met as a group of three at a table in Bill Marcus’s office at Bellcore’s Morristown Research and Engineering facility. Meetings were scheduled via telephone or e-mail, and were focused on a particular topic in the design and implementation of the projects.

6. Project Management

Project management is accomplished mainly via electronic mail. There is an electronic mail mailing list, `TeleMentors@aurora.cis.upenn.edu`, over which information is distributed between the PIs and Bellcore collaborators. Another mailing list, `telementor@viper.cis.upenn.edu` is also used by the student participants, to facilitate discussion between themselves and the TeleMentors.

Our colleagues at the the industrial sites are included in this mail exploder; they use it as well. We have had several face-to-face meetings, which have included laboratory staff. The laboratory staff have been kept involved, as they are the *de facto* agents of change. They have, in fact, offered a number of practical suggestions about course changes (for the lab courses) which we might otherwise have neglected. These range from the size, scope and implementation steps of the projects to the choice of microprocessor based on available documentation and courseware supplied by the chip manufacturers.

7. Evaluation, Conclusions and Next Steps

The TeleMentoring experiment in teaching undergraduate computer science has been carried out for the first time this semester.

Our experience was mixed. We were excited to actually carry out the TeleMentoring, as it has been a difficult engineering effort to actually get the technology deployed for use. The ATM infrastructure we have built has proven generally useful outside the context of TeleMentoring. The focus of our effort was educational, and that proved less satisfying than the technical successes.

The student lab work was divided into two parts. The first part was the construction of the Motorola 68000-

based minimal system, essentially a processor with some I/O support and a minimal run-time environment. Two groups of two students were TeleMentored and two groups (the ‘‘control’’ groups) were not. One of the control groups was able to complete the minimal system and design project successfully, and one was not. The best control group was stronger than the weaker of the two TeleMentored groups, but the stronger TeleMentored group (which also completed the minimal system and design project) was the strongest of the four groups. Thus, the effect of TeleMentoring was not clear.

To evaluate further, we prodded the TeleMentors and the TeleMentored teams to get more feedback on the experiment. In the following text, to preserve anonymity, the students in the better-performing TeleMentored group we labeled XXXX and YYYY. The one student from the poorer-performing group who we were able to question we labeled ZZZZ.

7.1. Evaluation of TeleMentoring: The Mentors

When asked for an evaluation, one of the TeleMentors replied:

‘‘I'm a bit disappointed with the results so far, but I also think that they were too ambitious for the time allotted. I would have hoped that YYYY and XXXX had a working prototype up and running by now. Being in industry, you are allowed to be more singularly focused. For instance, Sunshine..... Problems defined, solutions outlined, problem solved. A piece of Sunshine hardware was the main responsibility of an engineer. So it is hard for a person in the work force to understand (after being out of the University for many years) how other courses get in the way of the project at hand. I think that Bellcore folks understand this more than most real industry folk, but it is still frustrating how slow things get done on the students side.

‘‘I am also upset that the second group of Telementees met with the Telementors only once. I'm not sure why this happened. Not meeting certainly stymied any chances that the group would finish a project. We might learn something by talking to those folks and asking "why didn't you use the video link!!!"’’

As can be seen from the comments of Student ZZZZ, to be found in the next section, we did indeed learn more by querying the students.

7.2. Evaluation of TeleMentoring: The Students

Students YYYY and XXXX were enthusiastic participants, and Student YYYY is working in our laboratory on related projects. Student ZZZZ's group had significant organizational problems, which we discovered to be a major source of the operational difficulties encountered by that group. This information helps to set the context for the remarks which are in the following three subsections.

7.2.1. Student YYYY

‘‘*Overall, I felt telementoring was a very good learning experience. It was very nice to be able to meet some 'industry friends' and be able to talk to them, not only regarding the project at hand but also about their work at Bellcore. Furthermore, it was very interesting to see how people work in industry - giving me a glimpse of what was expected when I graduate.*’’

‘‘*There were problems ... we did not finish the project we set out to construct. I think this was an inherent problem with structuring TeleMentoring with CSE 371. At the beginning of the semester, my lab partner and I knew absolutely nothing about hardware and its constructs. We did not even know the fundamentals of soldering or wirewrapping. Nonetheless, we were able to complete the minimal system in 6 weeks (I believe). Despite our quick learning of hardware design, we were not prepared for the first few TeleMentoring sessions as we had to be coached and tutored further on the fundamentals.*

This was clearly demonstrated after each of the first few TeleMentoring sessions. After each session, XXXX and I only had a vague idea of what was expected. When we finally realized the expectations of each step in the project, we were faced with questions that could not be answered until the next telementoring session.

This problem naturally cleared itself up when XXXX and I became more adept at hardware design. We were able to anticipate questions as each step was brought up to us and thus, I believe we were able to fully maximize our telementoring time. However, this point was only reached in the final weeks of the semester leaving little time for completing the project.

Rather than complete the project half-heartedly, XXXX and I decided to continue the work during the summer.

I believe that if we had more knowledge going into the first few sessions, we would have gained much more from the telementoring sessions.''

*''The VideoWindow seemed a bit imposing at first, but gradually as time passed, it became very easy to communicate over the VideoWindow. The benefits were clear when Bill Marcus was able to systematically draw out an ATM header on his whiteboard. (Bill has two cameras). Without his explanation of the header (he drew the diagram 3 times in 3 sessions), I do not think XXXX and I would have even finished the first portion of the TeleMentoring project. Although understanding the contents of an ATM header may seem trivial to most networking people, one should consider their hindsight bias. XXXX and I were very confused with the checksum and determining the VCI. Of course, *now* XXXX and I consider the ATM header checks in programmable logic trivial as well.''*

''As I stated earlier, I believe I learned a great deal from TeleMentoring as I received a nice overall picture of hardware. Had I only had the experience of hardware from 371, I believe I would have misconstrued what hardware design really entails. I would have possibly reduced hardware to nothing more than wiring SSI ttl's to obtain counters.

However there were side effects of TeleMentoring. Because we were under a 6 week completion deadline, XXXX and I inevitably ended up dividing the work between us. This was not planned, but happened as a result of our natural maximization of opportunity cost. Whereas, I became the expert of programmable logic devices, XXXX became the expert of 68000 assembly. Thus, XXXX may have skimped on his P.L.D. education, while I may have skimped on my 68000 education. However, I do not count this as an entire loss. While we were forced to specialize, I think we still acquired the same knowledge as typical 371 students in our respectively weak areas. Ideally, however, it would have been nice if XXXX and I were able to obtain the same knowledge...''

7.2.2. Student XXXX

The student was sent a list of 7 questions about TeleMentoring after we discussed the evaluation of Student YYYY.

Q1. *Was TeleMentoring positive or negative overall?*
Positive. It was a new experience.

Q2. *Did you do more advanced work because of the Telementoring interactions?*
I don't think so. In fact I think we would have done more work had we worked directly with Brendan.

Q3. *What was most useful/least useful/annoying about the setup?*
It was annoying trying to arrange for a meeting with the telementors. We would have to email them with a time, and they might reply a day later to confirm it or arrange another time. Then at the arranged time something would crop up with the equipment. It was VERY frustrating.

Q4. *Was CSE371 well-suited for TeleMentoring?*
Yes it was. But we had to put in a lot of work for the first part of the board (the 371 part). The requirements for the first part could have been relaxed in terms of documentation.

Q5. *What class would be better suited, e.g., senior designs, independent studies, graduate seminars, etc.?*
It all depends on what is to be "telementored". I guess having televideo sessions for graduate seminars would be very helpful as experts for various topics can be invited to speak to the class.

Q6. *Were there any limitations of the equipment that you would suggest removing? If so, what were they?*
No.

Q7. *As a comparison, was TeleMentoring better or worse than e-mail? In what way?*
It was better in that diagrams could be drawn, and doubts could be clarified immediately. They sort of complemented each other as a lot of stuff still needs to be put down in writing.

7.2.3. Student ZZZZ

''The first and only time I was TeleMentored, I sat down to meet the folks at Bellcore. I learned each of their names, and their specialties. The rest of the session was spent engaged in what was basically a lecture, consisting of a brief overview of ATM and my options on how to proceed with handling the "receive" side of my project (which was, at the time, to be the traffic generator for the ATM switch.)

I came out of that session with a page of notes and a lot of questions. I suspected my questions could be answered by reference materials. I was already several weeks behind on my project, but I monitored the traffic on the televideo mailing list and kept in touch with XXXX and YYYY about what stages they were in. Generally, in my opinion, the traffic on the mailing list generally consisted of XXXX and YYYY scheduling TeleMentoring sessions to ask a few questions, some of which were basic enough that Brendan or Sanjay could have answered them. However, they refrained from answering, apparently in order to facilitate the use of the TeleMentoring tool.

I do understand that Brendan and/or Sanjay wanted to motivate the students to use the VideoWindow. . .however it appeared to be wasteful to be using the wall consistently for such apparently trivial questions and problems. Perhaps it was indicative of a greater flaw in the program. I personally was not able to use the VideoWindow beyond my first session, so I'm not qualified to make such a judgement.

I do wish to make a few suggestions.... an alternative could have been to have the TeleMentors help debug the projects with the students interactively over the VideoWindow, instead of having the students (XXXX and YYYY) up all nite in the lab hacking on the thing themselves. Yet another alternative could be to have a more structured use of the TeleMentoring sessions; for example, a required session on the basics of ATM, another on interfacing options, etc. I don't think having some sort of "lecture" over the VideoWindow is such a bad idea, simply because it wasn't a professor who was lecturing, rather, a industry researcher who has presumably different points of view about what's important to communicate to the student for this particular project.''

7.3. Assessment of Results

Clearly, some comments from the previous section are disturbing. While not a clear failure, the TeleMentoring experiment was by no means a success:

1. The students did not complete the projects
2. For all of the effort invested in TeleMentoring, the students did not see significant advantages compared with e-mail or local expertise.

We believe that the students did not complete the projects because the goals we set (the project scope) were too ambitious. In our first TeleMentoring trial, we saw TeleMentoring as the ''*Deus ex Machina*'' in teaching undergraduate computer science labs. Unfortunately, reality intruded and the ambitious goals were not achieved. One positive note is that the more successful team of students (XXXX and YYYY, above) were sufficiently enthused to continue working on their projects with the TeleMentors. They will complete the projects this summer.

As this was a trial run, and the equipment was entirely experimental, and was somewhat unstable, the concerns about equipment problems are real. It has been our observation with other new technologies that reliability is paramount; unreliable technology distracts attention from the application of that technology. Since the TeleMentor's time was volunteered, the student demands on it had to be structured and prioritized with respect to research responsibilities. We expect that experience and better scheduling of TeleMentoring with respect to CSE371 course requirements would improve the comfort level.

Finally, with respect to advantages over local expertise, we ''shot ourselves in the foot''. To guarantee that the equipment was as reliable as possible, and interactions went as smoothly as possible, one of us (Traw) served as the Teaching Assistant of CSE 371 in charge of TeleMentoring. However, this made the T.A. capable of helping with problems that we presumed only the TeleMentors should have been able to handle (that was a major argument for TeleMentoring - remote expertise unavailable locally). The students thus saw less need for TeleMentoring.

Having absorbed these lessons, we intend to adjust our next trials of TeleMentoring to better couple the video-conferencing and other networking support to our coursework.

7.4. Next Steps

We intend to broaden our experiments next year, to include more advanced students, independent studies, senior theses, and a few trials of a ''distributed seminar'' with colleagues at MIT.

First, the hardware has become more robust and more reliable. In the course of this first experiment, we moved from ''Cheap Video I'' to ''Cheap Video II''. Cheap Video I was somewhat cumbersome, as we used a speakerphone for voice; Cheap Video II solved this by including a voice facility. In our second set of trials, the improved hardware and operational experience should make the facilities much less intrusive on the educational effort.

Second, we have to adjust the relationship between the course and the interactions with the TeleMentors to better prepare the students for interaction with senior engineers. It seems that a major difficulty was that the student schedules, questions and need for interaction mismatched with the TeleMentors. We now feel that students working independently (who would otherwise be on their own, e.g., in a senior design) are better suited to TeleMentoring. They would be at a level where they could begin taking advantage of the interaction immediately, rather than only in the last month of the term. Seminars also offer an environment where distant interaction is desirable.

8. References

[1] U.S. Congress, Office of Technology Assessment, ‘‘Advanced Network Technology - Background Paper,’’ OTA-BP-TCT-101, U.S. Government Printing Office, Washington, DC (June 1993).

[2] Israel Cidon and Inder S. Gopal, ‘‘PARIS: An Approach to Integrated High-Speed Private Networks,’’ *International Journal of Digital and Analog Cabled Systems* **1**, pp. 77-85 (1988).

[3] David D. Clark, Bruce S. Davie, David J. Farber, Inder S. Gopal, Bharath K. Kadaba, W. David Sincoskie, Jonathan M. Smith, and David L. Tennenhouse, ‘‘The AURORA Gigabit Testbed,’’ *Computer Networks and ISDN Systems* **25**(6), pp. 599-621, North-Holland (January 1993).

[4] David D. Clark, Bruce S. Davie, David J. Farber, Inder S. Gopal, Roch Guerin, W. David Sincoskie, Jonathan M. Smith, and David L. Tennenhouse, *The AURORA Testbed Annual Report III*, Available from Corporation for National Research Initiatives, 1895 Preston White Drive, Reston, VA June 1993.

[5] J. Giacopelli, J. Hickey, W. Marcus, W. D. Sincoskie, and M. Littlewood, ‘‘Sunshine: A High-Performance Self-Routing Broadband Packet Switch Architecture,’’ *IEEE Journal on Selected Areas in Communications* **9**(8), pp. 1289-1298 (October, 1991).

[6] William S. Marcus and C. Brendan S. Traw, ‘‘Audio/Video ATM Transmit And Receive ,’’ DSL Technical Report (1994). in preparation.

[7] Craig Partridge, *Gigabit Networking*, Addison-Wesley, Reading, MA (1993). ISBN 0-201-56333-9

[8] Jonathan M. Smith, Susan B. Davidson, David J. Farber, Insup Lee, and Ira Winston, *TeleMentoring: A Novel Approach to Undergraduate Computer Science Education (NSF CDA-92-14924)*, University of Pennsylvania (1993). DSL Technical Report