Collaboration in the Large:
Using Video Conferencing to Facilitate Large Group Interaction

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ABSTRACT

This chapter discusses the social, organizational and technical challenges and solutions that emerged when facilitating collaboration through videoconferencing for a large, geographically dispersed research and development (R&D) organization. Collaboration is an integral component of many R&D organizations. Awareness of activities and potential contributions of others is fundamental to initiating and maintaining collaboration, yet this awareness is often difficult to sustain, especially when the organization is geographically dispersed. To address these challenges, we applied an action research approach, working with members of a large, geographically distributed R&D center to implement videoconferencing to facilitate collaboration and large group interaction within the center. We found that social, organizational and technical infrastructures needed to be adapted to compensate for limitations in videoconferencing technology. New social and organizational infrastructure included: explicit facilitation of videoconference meetings; the adaptation of visual aids; and new participant etiquette practices. New technical infrastructure included: upgrades to video conference equipment; the use of separate networks for broadcasting camera views, presentation slides and audio; and implementation of new technical operations practices to support dynamic interaction among participants at each location. Lessons learned from this case study may help others plan and implement videoconferencing to support interaction and collaboration among large groups.

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INTRODUCTION

Collaboration is a strategic component of many research and development (R&D) efforts because challenges resulting from the need to solve complex problems may often be best addressed by collaboration among experts who apply complementary knowledge from different disciplines, or specializations within disciplines. Indeed, national agencies, such as the US National Science Foundation (NSF) and the National Institutes of Health (NIH), have established grant programs, such as the Science and Technology Center program, Industry-University Research Center program, and the National Computing Research Resource program, that provide funding to large multi-disciplinary and multi-institutional R&D groups to address complex problems. Typically centers funded by these national agencies have 50 to 100 or more participating faculty, undergraduate and graduate students, postdoctoral fellows and industry members. These groups are often geographically distributed and not all members may have worked together or even interacted with each other previously. Therefore, it is often challenging to establish and maintain collaboration. Awareness of the activities and potential contributions of others is fundamental to initiating and maintaining collaboration, yet this awareness is difficult to sustain.

To address these challenges, we have been studying structures and processes within the NSF Science and Technology Center for Environmentally Responsible Solvents and Processes (NSF STC-ERSP) using an action research approach (Stringer, 1999; Whyte, 1997). Our approach investigates social, organizational and technical aspects of large group collaboration, and iteratively recommends and evaluates mechanisms to facilitate collaboration among group members. Thus, our action research approach builds on existing social and technical infrastructures, and continually explores new ways to facilitate collaboration. The approach is evolutionary in nature in that we are observing the development of the collaboration within the center over time. This chapter describes these efforts in connection with one collaboration awareness mechanism, large group videoconferences. Our efforts have focused on both social and technical infrastructures that are required to enable and empower collaboration. We have conducted 25 interviews with center members and observed approximately 50 videoconference meetings over 12 months. Through these interviews and observations we have identified "best practices" for collaboration in the large.

Problems of transition from co-located to multi-site meetings using videoconferencing will occur in most organizations and the benefits of broader participation may only be realized when time and resources are invested to notice what does not work, or what is not happening, and to explore and evaluate alternatives. This requires investigating and exploring ways that the social infrastructure of the organization and the technical infrastructure at the participating locations can better facilitate large group collaboration. At the NSF STC-ERSP our investigation yielded new social and organizational best practices, including: facilitation before, during and after videoconference meetings; the adoption of visual aids to match videoconference technology constraints; and the adaptation of participant, or audience, etiquette. It also yielded new technical practices including: upgrading of video conference equipment; using separate networks for broadcasting camera views, presentation slides, and occasionally voice; and implementing new technical practices to support dynamic interaction among participants at each location. These new practices have enhanced the effectiveness of videoconferencing, leading to its adoption within the center and enabling frequent, needs-based meetings across distances.

Table 1: Previous studies on socio-technical aspects of videoconferencing

		Research Setting	
Research Focus:	***Pairs***	***Small group (3-7 people)***	***Large group (more than 8 people)***
Interpersonal Interaction	Masoodian, et al. (1995) Heath & Luff (1991)	Sellen (1992) Ruhleder & Jordan (2001) Barefoot & Strickland (1982)	Rice (1993) Isaacs, et al. (1995) O'Conaill, Whitaker & Wilbur (1993)
User Satisfaction	Nodder, et al. (1999)	Tang & Isaacs (1993) Kies, et al. (1996) Patrick (1999)	Finholt, et al. (1998) Mark, Grudin & Poltrock (1999) Gowan & Downs (1994) Ruhleder, Jordan & Elmes (1996)
Work Outcomes & Process		Nardi, et al. (1993) Olson, Olson, Meader (1995)	

BACKGROUND

Previous studies investigating videoconferencing vary in terms of their focus, setting, and technical system. We developed a matrix to highlight some ways of viewing videoconferencing (see Table 1) in order to raise issues that we needed to consider in our study. In the table, we categorized studies by the nature of the research setting (pairs, small groups of three to seven people, and large groups that include more than eight people) and the focus of these studies, i.e., the impact video conferencing has on interpersonal interaction, work outcomes and processes, and participant, or user, satisfaction.

In sum, lessons learned from these studies are as follows:

- audio is crucial (Tang & Isaacs, 1993; Whittaker, 1995)

- video adds some value especially when it is used as data (Nardi, Schwarz, Kuchinsky, Leichner, Whittaker, & Sclabbassi, 1993)
- video sometimes does not affect task performance, but increases participant satisfaction (Kies, Williges, & Rosson, 1996; Olson, Olson, & Meader, 1995; Tang & Isaacs, 1993)
- video use reduces certain kinds of interactions compared to face-to-face partially because of a lack of turn taking cues (Cadiz, Balachandran, Sanocki, Gupta, Grudin, & Jancke, 2000; Ruhleder & Jordan, 2000, Isaacs, Morris, Rodriguez, & Tang, 1995; Sellen, 1992), and
- the adoption of video conferencing includes both social and technical aspects (Gowan & Downs, 1994; Finholt, Rocco, Bree, Jain, & Herbsleb, 1998; Ruhleder, Jordan, & Elmes, 1996; Patrick, 1999)

In the following, we highlight some of the studies that are particularly relevant to our study.

Interpersonal Interaction

Various studies have examined how video influences interpersonal interaction. Reflecting on some of those, Barefoot and Strickland (1982) note that there have been three positions regarding the impacts of media on interaction. One position is that media may facilitate interaction because it enables interaction that otherwise may not occur. A second position is that media may impede interaction because media eliminate, or destroy, some of the cues available in face-to-face interaction. A third position is that media may have no influence on interpersonal interactions. Heath and Luff (1991) also suggest that the form of communication access that works best depends on the nature of tasks and type of sociality that are desired. In studying the impact of videoconferencing on interpersonal interactions all four positions have found some support.

Masoodian, Apperley and Frederickson (1995) found no statistical difference in speech duration, number of utterances and turn taking, and duration of mutual silence between pairs working face-to-face, with audio only or with video and audio. The pairs worked on a problem-solving task that had a correct answer. Sellen (1992) found similar results with respect to speech duration and turn taking. However, Sellen reports that there was more simultaneous speech in the face-to-face condition and that study participants found it more difficult to take control of the conversation in the video condition. Ruhleder and Jordan (2001) report similar findings, and conclude that delays inherent in videoconferencing technology today cause these problems, especially when the delay is apparent only to participants at one location.

Barefoot and Strickland (1982) further conclude that video often impedes expressions of conflict and disagreement during discussions. When comparing face-to-face interaction with video (television) mediated interaction, Barefoot and Strickland found that ‘conflict’ was more prevalent in the face-to-face group and, as a result, face-to-face groups produce better integrated solutions to the change of work procedure problem they were addressing.

Similarly, Rice (1993) found that participants in an R&D organization ranked (desktop) video fourth after face-to-face, telephone, and meetings in the appropriateness for "exchanging information, negotiating or bargaining, getting to know someone, asking questions, staying in touch, exchanging time-sensitive information, generating ideas, resolving disagreements, making decisions, and exchanging confidential information" (p. 458). Video also ranked low in appropriateness for exchanging confidential information. However, (desktop) video ranked third in appropriateness for staying in touch.

Another related study by Isaacs, et al. (1995) compared the delivery of presentations via (desktop) videoconferencing and face-to-face lecture. They found that speakers tended to prefer giving lectures in face-to-face mode because they felt more comfortable and closer to audiences, whereas audience members tended to prefer receiving lectures through desktop videoconferencing because of convenience. In terms of interpersonal interaction, their study found that presentations in face-to-face settings seemed to allow richer interactions than through the desktop videoconferencing. Audiences were inclined to ask questions one after another, and speakers tended to stimulate more audience involvement when lectures were given in person. In a similar vein, O'Conaill, Whittaker and Wilbur (1993) examined the nature of spoken communication in order to identify reasons for unsuccessful videoconferences. One of their findings is that audiences were likely to interrupt less often in videoconferencing systems than in face-to-face meetings, thus reducing the interaction between speaker and the audience.

These findings suggest that video conferencing may work fairly well in situations where people are separated across physical distances and a face-to-face meeting is not possible, or where visual information needs to be shared and acted on. These findings further suggest that there is something about physical distance among participants that is maintained by the video medium that inhibits discussion, and thus video conferencing, as it is presently constituted, may not be appropriate for brainstorming and conflict resolution.

Participant Satisfaction

Based on a tradition of usability engineering, several studies have investigated participant, or user, satisfaction with specific aspects of videoconferencing technology. Nodder, Williams and Dubrow (1999) describe how they conducted iterative usability evaluations on a videoconferencing (and shared application) software application to increase participants' satisfaction with the application. Tang and Isaacs (1993) confirm that high quality audio is crucial for supporting remote collaboration among small groups. Kies, Williges and Rosson (1996) report that low video frame rates did not affect task performance in distance learning situations but did negatively affect participant satisfaction. Patrick (1999) also makes recommendations for session organizers to improve videoconferencing sessions, such as providing appropriate visual information by considering video bandwidth for a particular session, paying attention to lighting, camera placement, and camera move, providing high quality audio, and evaluating in advance whether tasks are appropriate for videoconferencing. Moreover, Patrick's recommendations for software developers include developing tools to distinguish between non-interactive and interactive uses and to support informal communication, user feedback on running a videoconferencing session, and conference organizing features such as polls.

In addition to investigating specific aspects of video conferencing technology, Tang and Isaacs (1993) surveyed participants' attitudes about (room-based) video conferencing systems. Participants reported that the advantages of using room-based videoconferencing included availability of visual contacts with their collaborators and time and travel savings. The disadvantages included difficulty in scheduling a room for videoconferencing, poor audio quality, and poor visual materials. The participants were also asked to suggest new capabilities that would make the current videoconferencing systems more satisfying. The suggestions included a shared drawing surface, a larger screen, and the ability to access multiple sites.

Tang and Isaacs (1993) also developed a prototype desktop videoconferencing system to support remote collaboration. They used this prototype to compare participants' use and satisfaction with conventional communication tools, the desktop videoconferencing prototype system, and the prototype system without video capabilities. Their findings indicate that desktop videoconferencing did not affect the amount of communication, was used more frequently with video capabilities, and was considered by its users to be an adequate replacement for face-to-face and room-based videoconferencing. They concluded that, despite previous research that found no significant effects by adding video, users preferred to use video because it helped collaborators understand each other better as a richer set of cues was available.

Finholt, Rocco, Bree, Jain and Herbsleb (1998) report on a three-month field trail of desktop video conferencing in a 125 person software development organization. Study participants reported a low use of the technology but moderate satisfaction. In addition, they reported the system was slow and the organizational technical infrastructure did not at first adequately support the technology. However, participants also reported novel uses of the system, including using the desktop videoconferencing as one might use a room-based system to connect multiple participants in one location to multiple participants in another location.

Videoconferencing is also successfully used at Boeing (Mark, Grudin & Poltrock, 1999). There was wide participation in meetings held via videoconferencing, saving participants time and stress related to travel. Meetings that had a formal structure or a facilitator who knew both how to fix technical problems and ways to engage remote participants were most satisfying. Similarly, Gowan and Downs (1994), Ruhleder, Jordan and Elmes (1996) and Patrick (1999) found that group members in an organization found it difficult to schedule, set up and use videoconferencing technology; learning to use the technology is a social, group learning process.

From these studies, we find that participants are often satisfied or moderately satisfied with video conferencing technology. Participants tend to use the technology in limited, but sometimes novel, ways, finding its most appropriate use for their context. Both a technical and social infrastructure can facilitate the adoption and use of video conferencing.

Work Outcomes and Processes

Few studies have focused on the impact that videoconferencing has on work outcomes and processes. Until recently, video was shown to have no effect on the quality of work unless the work involved negotiation (Short, Williams & Christie, 1976). However, Nardi, Schwarz, Kuchinsky, Leichner, Whittaker and Sclabassi (1993) report that video, which shows data that otherwise could not be viewed by team members, does increase the quality of work outcomes. Olson, Olson and Meader (1995) show that people accomplished assigned tasks through video as well as face-to-face and slightly better than audio-only in terms of the quality of the output. However, they find that video is less effective for supporting some work processes. The groups using video spent more time setting up initial stages to clarify each other's points compared to the face-to-face groups.

In conclusion, Gale (1992) suggests that videoconferencing research has been focusing too much on formal communication, while ignoring social factors, such as the difficulty of access to videoconferencing equipment and "a lack of understanding of the way in which people work" (p. 520). Tang and Issacs (1993) stress the importance of conducting research in work settings. As Kling (1996) notes, "people and organizations adopt constellations of technologies and configure them to fit ongoing social patterns" (p. 19). In the case of videoconferencing this suggests the need to incorporate videoconferences in the ongoing social systems of organizations, and investigate its impact on interpersonal interactions, participant satisfaction and/or work outcomes and processes. One way to begin doing this is by employing a socio-technical approach (Eason, 1988) to actively involving participants in the planning and conduct of such videoconferences, so that the sessions meet the specific needs of the participants. This paper presents one such case study that incorporates a socio-technical action research approach to evolve large group video conferencing practices to facilitate collaboration in a geographically distributed R&D organization, the STC-CERSP. We first discuss the social and organizational infrastructure that has evolved to increase the effectiveness of video conferences for participants, and second discuss the technical infrastructure that has evolved to provide innovative video conferencing capabilities.

SOCIAL AND ORGANIZATIONAL INFRASTRUCTURE

Social and Organizational Setting

The STC-ERSP consists of four geographically dispersed universities including the North Carolina Agricultural and Technical University, North Carolina State University, University of North Carolina at Chapel Hill, and the University of Texas at Austin. At each university, there are approximately 10 to 37 undergraduate and graduate students and postdoctoral fellows, and 6 to 10 faculty who are members of the center, for a total of

110 members. These members do not work full-time for the center as students are enrolled in degree programs and must take courses, etc., and most faculty teach as well as conduct research outside the auspices of the center.

At the time we began this work, the center was organized into four physical science research teams. Each team consisted of six to nine faculty members, and three of the four teams had faculty members from each university. Each team also had 6 to 29 student and postdoctoral fellow members. Many students and postdoctoral fellows were asked to be members of two teams, and each team had student members from each university.

Similar to other centers and organizations, there was limited interaction among center members before the center was established. For example, data reported in a sociometric survey completed by members (60% response rate) indicated that only 22.9% of center members had interacted with other center members prior to the establishment of the center. Thus, the center is a large, geographically distributed group whose members are not full-time participants and who may have previously had little or no interaction with each other. In this respect the center is typical of the emerging genre of federally funded, university-based research centers.

Figure 1. A center-wide videoconference meeting

Types of Video Conferences

Three types of meetings in the STC-ERSP are held using videoconferencing: center-wide meetings, group meetings, and faculty (principal investigator) meetings. *Center-wide meetings* are held infrequently (e.g., once every 6-8 months); these meetings include all members at all universities and have been used to share information among all center members (see Figure 1.) For example, a center orientation meeting was held that introduced the center's mission, organizational structure and center-wide activities several months after the center was established. A recent all-center meeting introduced a new team-based organization as well as an update of the center's mission, vision and objectives. At these large meeting, as with most large meetings, interaction among members is somewhat limited due to the number of participants and time limitations.

Group meetings are held weekly; all center members are invited to attend these meetings. However, students and postdoctoral fellows are strongly encouraged to attend these meetings when the presentations are given by members of their team. Each meeting typically lasts 1.5 to 2 hours, and includes 20 to 30 participants. During this time, members (primarily students and postdoctoral fellows to date) present and discuss their work. Students are required to present their work once or twice per year at these meetings. In addition, these meetings have been used to present outreach activities and opportunities and to illustrate the use of videoconference related technologies. Each presentation during these meetings typically lasts 20 to 45 minutes with integrated discussion. Thus, these meetings are a vehicle for bringing people together to share, learn, raise problems, offer solutions, and perhaps achieve other, as yet undetermined, outcomes. As faculty and student members reported:

> *I always learn something. Even if everything in [the other] group meeting isn't interesting to me, I can … read a manuscript and still listen to things that seem separate from what I am interested in and I will pick up something that I didn't know.*

> *By attending these conferences and listening to explanations from other people, I [began to] understand research much more clearly.*

Faculty, or principal investigator (PI) meetings, occur on an as needed basis, typically once every 4 to 6 months. These meetings are typically used to plan upcoming projects and activities and are organized by the center directors or by faculty. Initially these meetings were held using audio conferencing only, but faculty members are beginning to hold these meetings using videoconferencing.

Facilitation of Videoconferences

Irrespective of the type of meeting being held via videoconferencing, each meeting has a facilitator or moderator. For the group meetings, a student from each project group is assigned the role of facilitator. This responsibility rotates among the students approximately every six months. While the center directors, in consultation with faculty and students, determine policy for the student presentations, student facilitators schedule the presentations as well as perform the following responsibilities:

(a) Compose an e-mail message to all center members announcing the upcoming meeting topics. Abstracts for the presentations are included in this message when available. Other center-wide announcements and norms regarding the video conferencing may be included in this message.

(b) At the beginning of the meeting, welcome everyone, verify that audio and video communications are working from the audience's perspective, and ask if there are any general announcements.

(c) If there are any technical problems at any time, the facilitator is responsible for informing the videoconference technical staff and relaying the status of the technical problems to all locations. Often, the technical staff is located in an adjacent control/operations room, and the facilitator may use a dedicated headset to talk with the staff.

(d) Introduce each presenter; manage the question/answer period as needed.

(e) Provide a 10 to 15 minute break between presentations. The break also allows participants who cannot stay for a subsequent presentation to leave with minimal interruption as well as informal discussion of completed presentations.

(f) Close the meeting, thanking participants.

(g) After the meeting, the facilitator publishes the highlights of the meeting. These are one to two paragraphs in length and are sent to all center members via e-mail and published in a secure discussion forum area of the center's web site.

It can be tempting for facilitators (and presenters) to forget that there are people at other locations who want to participate in the discussion. The participants at remote locations may need to be reassured that they are part of the meeting and encouraged to speak. Speakers have, consequently, been requested to stop periodically and ask if there are questions.

Initial ideas regarding these responsibilities emerged from observations of videoconferences and discussion with center members and technical staff at each location by the authors who are members of the social science research team of the center. As Gowan and Downs (1994) recommend, facilitation of a videoconferencing meeting leads to an efficient meeting. Further, a meeting was held between the social science research team staff and the student facilitators and technical staff to discuss and refine these practices. Thus students and staff participated in their formulation.

Participants have responded positively to the practices that were developed. For example, the e-mail announcements and summary messages facilitate interaction in several ways. Because some topics cross project team boundaries, these announcements make it possible for anyone who is interested in the topic to know when to attend. They also allow center members to get a bird's-eye view of research progress within the center, increasing their awareness of center activities. As one participant reported:

> *The beauty of the videoconferences is the way they send the titles out in advance and then you can go to different [group meetings]*

and see what you want to see. That helps so much. If you don't know what the titles are going to be then you might… only go to [your] own [group meeting]. So if I'm a simulator and I see somebody's giving a talk in one of the other [group team meetings regarding] something I'm interested in I just go [to that video conference.]

Furthermore, the facilitator role provides students with an opportunity to practice leadership and meeting facilitation skills—skills sought by prospective employers. It also fosters interaction among the student facilitator and presenters. While this interaction is relatively minor in nature as, in this context, students are not co-located and have previously never interacted with one another, these types of formal interaction mechanisms are a first step towards more meaningful and sustained interaction as they promote awareness of expertise and provide a foundation for future collaborative relationships.

Adaptation of Visual Aids

Visual aids, such as slides, are important as they can aid in the retention of the material being presented as well as help participants understand what the presenter is saying when, for instance, the audio is a bit garbled. However these aids often need to be adapted for use in videoconference settings due to constraints imposed by the technology. Use of TV monitors in video conferences, for instance, instead of the large screens commonly used for the display of overhead slides or a PowerPoint presentation in conference or classroom settings make a difference—text and graphics that are very readable on a large projection screen may be difficult to read on a monitor, where the monitor is some distance from those trying to read the screen. Guidelines for Microsoft PowerPoint presentations/transparencies typically suggest a minimum of 20-point for headlines and 16-point for other text (Ross & Dewdney, 1998). While this works well in most presentation situations, it is too small for the TV monitor situation. We consequently advised presenters to go bigger. We found that 28-point text was readable from the back of our videoconference rooms.

For text on the screen, we advised using keywords or short phrases over sentences. That is, presenters are asked to avoid including everything that they wish to say on the display. We found that all UPPER CASE TEXT was harder to read than lower case (with capitalization as appropriate) on the screen. Size was an issue for graphics too. Many presenters included multiple charts, graphs, etc. on a slide. This can be an effective way of placing related views of data together to show the 'shape' of what happened in an experiment comparatively. It is not an effective way of communicating details. By moving from overview to details—that is, a larger full screen view of a single graph, the audience can better see the details (e.g., units of measure). This effect could also be achieved by zooming in on the details of a graph or creating follow up screens that blow up the details.

The traditional black text on a white background of many presentations is not as effective a color scheme as a dark background with text in a light color. A dark blue background with yellow header and white text is a color scheme that provides better visual clarity, especially on a TV monitor, than black and white. Red text tends to look blurry on a TV monitor. A template for slides with these guidelines in mind was developed and distributed to center members through e-mail and included on the center's web site. However, printing slides from this template, especially in black and white, can be problematic. Although Microsoft PowerPoint has an option to view slides in "black and white," some slides may require modifications to produce a quality "black and white" print version. Also, some participants felt that printing in color was inappropriate due to its expensive and environmental concerns.

Before electronic white boards were installed (see section 3.2 below) we found that paper copies of slides worked better than transparencies when the overhead camera was used to project the slides because they minimized the reflection from the lights. The use of the overhead camera also allowed the presenter to zoom in to details of a paper slide, something that is not possible with an electronic presentation.

Participant Etiquette Practices

Because videoconferences differ from face-to-face meetings, a set of participant videoconference etiquette practices was developed. We expect these practices to evolve further over time.

One practice focuses on self-identification. During videoconferences, it is not always possible for the presenter and other audience members to see who is asking a question because anyone can ask a question and camera operators can not always switch camera focus and video displays fast enough to show who is asking the question. Knowing who posed a question sometimes provides clues regarding the best response and provides the presenter the opportunity to later follow up with the questioner at their discretion. Thus, we developed the common practice of questioners first saying their name and location, i.e., "This is Reto from UNC at Chapel Hill." Initially others in the audience, including the facilitator, would prompt participants if they forgot to say their name and location. Now this practice is widely used without prompting.

There is also a need to explicitly communicate problems to videoconference technical staff. If a participant (usually the facilitator) reports a technical problem, they give their location and state what the problem is and where it is coming from, e.g., "*This is Chapel Hill and we have no sound from Texas*." This is the type of information our technical staff told us they need to investigate and solve problems.

Another practice focuses on microphone awareness. In most videoconference rooms, the microphones are always on; almost all sounds in one location can be heard in other locations. This includes whispers or side comments, munching on chips, sneezes and page turning. In response to this constraint, participants cover the microphone closest to them when sneezing, etc., and limit their page turning and other activities not directly related to the meeting.

In the frenzy of preparing a presentation a presenter may fail to realize that the presentation is an opportunity to advance their research. Thus, the main purpose of the presentation for many presenters may at times be to get it over with as quickly as possible. Yet, when this happens it is an opportunity lost, as this was an occasion to get help as the presenter helps others learn. One possibility is to encourage those present to consider problems encountered by the researcher by saying: "*Here is something that I've been struggling with. Do you have any suggestions?*" Similarly, it may be encouraging to those who aren't initiated in the mysteries of a particular experimental method or instrumentation to stop and say: "*Would anyone like me to discuss why we are using this experimental approach?*" or to help those in the audience who don't want to interrupt the flow of the presentation to say: "*Are there any questions*?" It is helpful to give the participants some time to respond along with these opportunities as it often takes a bit of time to formulate responses. Similarly, participants at remote locations need to have an opportunity to offer feedback to let the presenters know when they are lost, cannot see important details on the screen, or would like a more detailed explanation.

In some sense, these practices are simple and intuitive, making them relatively easy to implement. However, they were not self evident at the beginning. As a center, we had no common experiences with videoconferencing, and we first applied our standard, face-to-face meeting practices in videoconference situations. Frequently this was not effective because the constraints of videoconferencing differ from those in face-to-face meetings. For example, Heath and Luff (1991) found that a gesture is comparatively not effective over video. We needed to experience and learn about these constraints to find ways to modify our practices to better cope with them. This sort of reflection in practice (Schön, 1983) is fundamental to organizational learning (Cohen & Sproul, 1996).

Evolution and Dissemination of Practices

Initially videoconferencing was met with reluctance from some center members and technical staff because it required people to do familiar things differently and the social and technical infrastructure was in a beginning stage of development. As one member reported:

> *Early on I thought [the videoconference] was a complete waste of time.*

An important thing to realize is that problems of transition from the one site to multi-site video presentation can be overcome and the benefits of broader participation realized. However, returning to the reflection in practice idea, participants need to invest some time to notice what does not work or what is not happening and use what is not working to suggest alternatives. Videoconference participants were, consequently, encouraged to reflect and offer constructive feedback.

The videoconference meetings are a particular kind of communicative event (Saville-Troike, 1989). Among the center's communication structures, it is a vehicle for bringing together people with a broad common interest in one of the thrust areas to share, learn, raise problems, offer solutions, and perhaps achieve other as yet undetermined outcomes. If what is happening is not what the administrators, presenters or other participants wish to happen, it is within their power to raise that as an issue and seek solutions. For example, when discussing ways to utilize videoconferences in the future a student commented:

> *Maybe I can discuss my [research] problems through the videoconferences if I encounter any.*

Changes to group practices need to be discussed with all participants. We have done this in various ways, including presentations and discussions at meetings, publication of group practices on the center's web site, the inclusion of "tips" in announcements of meetings, and training sessions to illustrate and teach the use of videoconferencing technology. Center management also took a lead role in facilitating the adoption of these practices by consistently using these practices in meetings and encouraged others to do so.

Overall, there is a need to avoid letting videoconference technology get in the way of what needs to happen for both the purposes of the participants and center in general. A well-organized and managed meeting can be effective despite the technology; however, technology cannot make a poorly managed meeting better (Schwartzman, 1989). The videoconferences can be whatever the participants wish them to be, but only with reflection and constructive action.

TECHNICAL INFRASTRUCTURE

Technical Setting

Each university participating in the center has video conferencing facilities that were established to primarily support distance education programs. Each facility is maintained and operated by a combination of full-time staff and part-time (student) staff, and there is variation with respect to technical capabilities between the facilities. The staff is trained to support distance education courses that primarily use a lecture-based format and are broadcast to locations within the university's state.

Three of the four universities, located in the same state, participate in a statewide educational videoconference communications network. The network is centrally controlled/operated, and uses proprietary analog technology to provide video and audio links among universities (and community colleges and high schools) in the state. As a result, most videoconference technical staff at the universities in this state primarily interacts with the centralized staff.

We decided to take advantage of existing university video conferencing facilities, and work with the videoconference technical staff to purchase additional videoconferencing equipment and establish new operational practices to enhance the technical quality of videoconferences. In this way, we leveraged our funding dollars, and provided some benefits to everyone who uses videoconference facilities at the participating universities.

Patience and persistence were sometimes required in working through administrative procedures that were originally established to support distance education courses broadcast from a single university location. For example, at several of the participating universities, courses are given priority in scheduling the use of large videoconference rooms, and the course schedules are often planned 3 to 5 years in advance. A workaround involved establishing one and no credit courses for the weekly group meetings and to schedule as many of these weekly meetings in advance as possible. Of course, each university has it owns scheduling process. Coordinating scheduling across four universities is not necessarily a trivial matter.

An alternative approach includes establishing and maintaining a separate, independent videoconference facility at each university. This approach would provide more control over the design and use of each videoconference facility. However, establishing and maintaining an independent facility will typically cost more in terms of equipment purchases and ongoing operating expenses. In addition, unless there are sufficient funds to staff technical support personnel at each location, quality, customized and advanced videoconference capabilities that currently require more than turning on a switch to operate could not be supported.

Video Conference Room Layout

Figure 2 illustrates a physical layout typical of many of our videoconference rooms. This layout was developed in collaboration with university videoconference technical staff and has some commonality with the videoconference layout developed at Argonne National Labs (Childers, Disz, Olson, Papka, Stevens & Udeshi, 2000). To provide a maximum view of participants, two large screens are used. At one location these screens are 120" large (along the diagonal) and are wall mounted. To reduce noise, the LCD display projectors for these screens are ceiling-mounted. Typically, one screen has a quad-split screen display that shows three of the remote locations. The other screen is a large display of another location; each location is periodically displayed, however, when the presenter is at a remote location, typically more time is devoted to show the presenter and the presented materials.

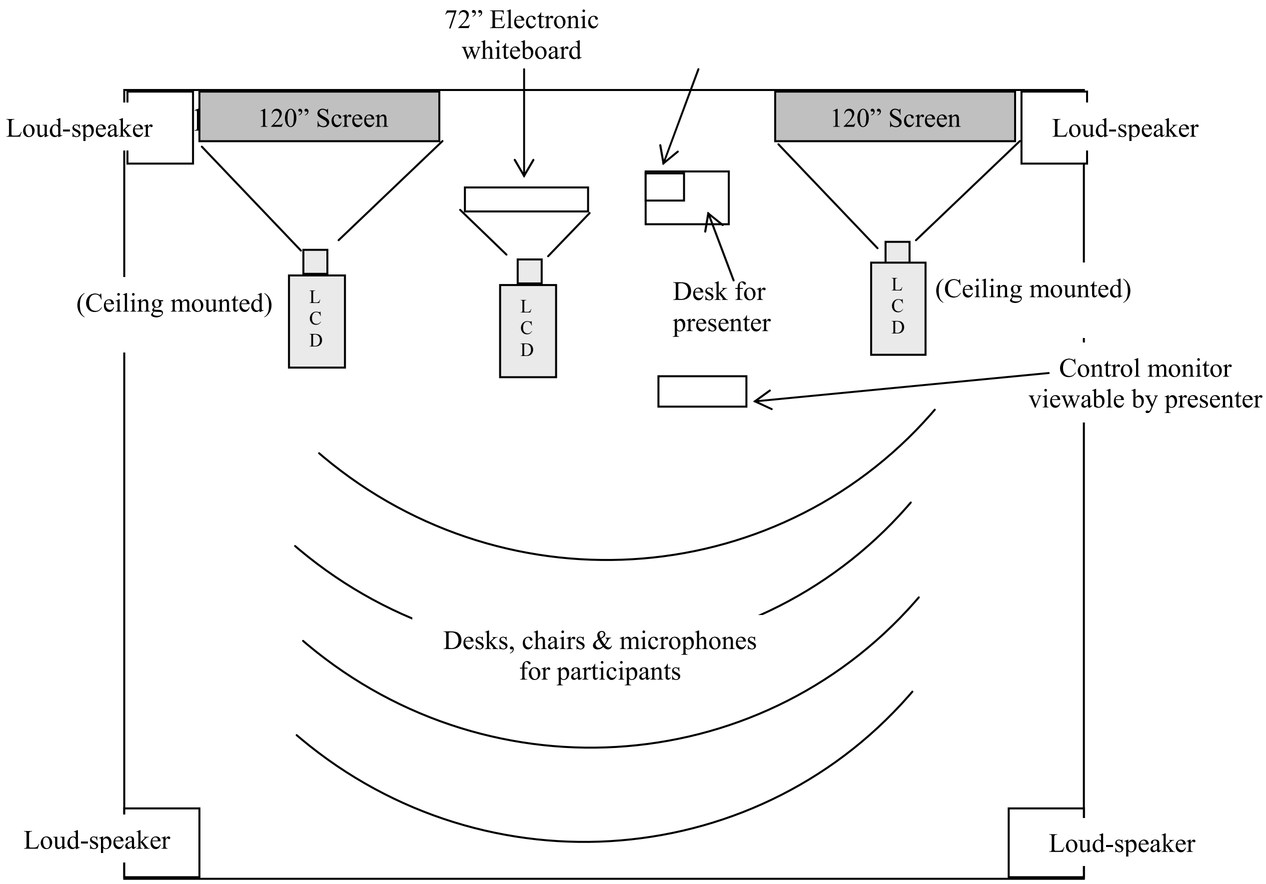

Figure 2. Example of a Videoconference Room Physical Layout

Figure 3. A student using an electronic whiteboard during a videoconference

In addition to these large screen displays, a large touch-sensitive electronic whiteboard is used to display the presenter's slides. The presenter, and anyone in the audience at any location, can write on their local electronic whiteboard and the result is transmitted to all locations (see Figure 3.) This allows participants to highlight aspects of their slides, create notes in real time, and to save these notes for later reference. Our locations use a SmartBoard from Smart Technologies and an LCD projector connected to a personal computer (PC) to provide this capability. Alternative technologies include rear projection systems that eliminate projector shadows and plasma displays that operate more quietly than projectors. We currently do not use rear projection systems due to cost and space constraints, and we do not use plasma displays due to current size limitations of the technology.

Two to four speakers strategically placed around the room broadcast sound. Each presenter uses a wireless microphone, and microphones to capture comments from the audience are typically installed on every other desk. The microphones on the desk are always on, and, sometimes, unintended whispers and sounds from paper shuffling are broadcast.

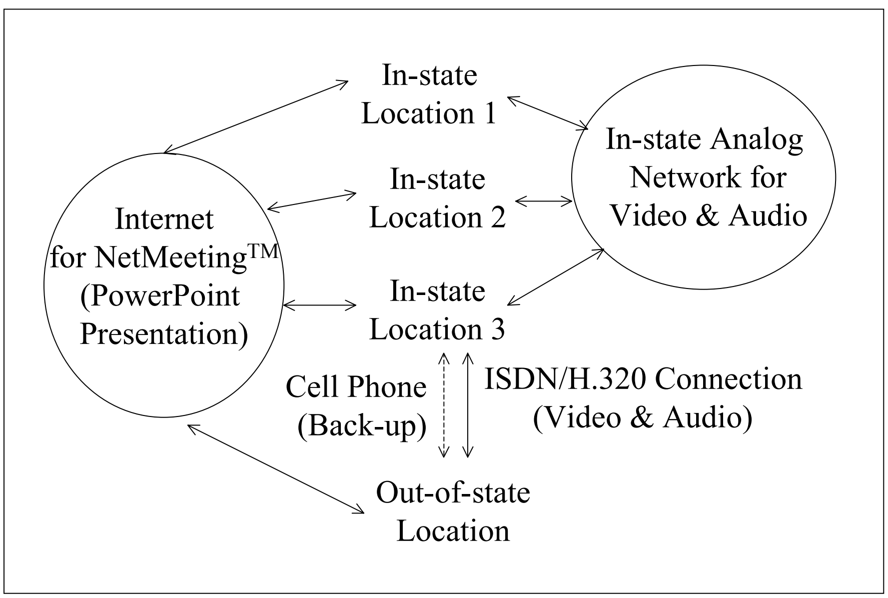

Figure 4. Current Telecommunications Network Configuration

Telecommunications Infrastructure

Several network communications technologies are used to support the videoconferences (see Figure 4.) As previously mentioned, a centralized statewide videoconference network is used among the three North Carolina locations. This network uses proprietary analog microwave technology. The University of Texas at Austin uses ISDN videoconference communications technology. This ISDN signal is transmitted to UNC at Chapel Hill and is broadcast to the other two North Carolina universities.

The audio signal is sent together with the video signal over these networks. This does not always work well; audio quality can be poor and audio can be lost completely. As research has indicated (e.g., Olson, Olson, & Meader, 1995; Patrick, 1999; Tang & Isaacs, 1993), audio quality is typically more important than video quality so poor quality or no audio is not conducive to effective meetings. We have been working with videoconference staff to resolve this problem. An ISDN conference phone has been purchased in an effort to upgrade audio quality, and cellular/digital phones with speakers have also been purchased to provide auxiliary audio capabilities when needed.

Most presentations during meetings use PowerPoint slides running on a PC connected to an electronic whiteboard and the Internet. This allows a Microsoft NetMeeting session to be established among the PCs at all locations. PowerPoint and other applications as needed are executed within this NetMeeting session. Access is controlled by IP addresses, i.e., only computers with the pre-specified IP addresses can participate in the NetMeeting session. Previously the PowerPoint display was first processed through a scan converter and then broadcast over the video network described above. However, the (NTSC) video picture resolution is only 525 lines, or 500 x 400 pixels, and this low resolution is problematic in large rooms. We achieve a higher resolution using NetMeeting over the Internet. Transmission delays due to Internet traffic variability have not as yet been a problem because we are only broadcasting slides that do not change frequently.

Technical Operations

As mentioned previously, we collaborate with each university's videoconference technical staff. From the onset, we asked them to work with each other and us to do whatever what necessary to make the videoconference meetings successful. This requires "buy-in" from technical staff at every location. A common pitfall to avoid is the attitude: "You're not from my department - I'm just doing you a favor letting you use my videoconference room." Specifically we asked the technical staff, in some instances for the first time, to manage multiple types of audio and video signals, provide and maintain high quality audio and video among all locations throughout the entire meeting, dynamically operate cameras, and add or upgrade technology in their videoconference rooms.

Multiple Types of Signals

In most distance education courses, the outgoing broadcast is typically a view of the instructor and their teaching materials, and the one incoming broadcast is typically a panoramic view of the remote classroom. Thus typically technical staff only need to manage one incoming video and audio signal, and the camera operation is primarily a "point and focus" task with occasional monitoring. Our needs required that they manage multiple incoming video and audio signals to allow each other location to see and hear the remote locations.

Furthermore, in our setting most distance education courses are in-state courses that utilize the centralized network. A single protocol and standard operating procedures are used throughout the network. Our center videoconferences required the addition of a new network connection with a different telecommunications protocol. This required new equipment and introduced more complex operating procedures. For example, some equipment had to be re-positioned so that an operator could effectively reach the new combination of switches in the time allotted when managing a videoconference.

High Quality N-way Audio and Video

"High quality" in our setting is defined by low latency, clear n-way audio among all locations, and "reasonable" n-way video among all locations. Both audio and video should persist throughout the duration of the videoconference.

As other studies have illustrated (e.g., Olson, Olson, & Meader, 1995; Patrick, 1999; Tang & Isaacs, 1993), audio is more important than video for effective interaction during most meetings. Individuals can, for the most part, compensate for lack of video if audio is available; however, video cannot make up for the lack of audio. Furthermore, we require high quality audio throughout the duration of the meeting because participants at any time from any location may wish to ask a question or make a comment. Audio quality has been problematic. As one member reported:

> *We had a lot of problems with the sound…if that were a little smoother it would be nicer.*

To address this, technical staff now does a sound check with no one in the room 10 minutes before each videoconference. This check helps to identify and resolve any problems. Because many of our sound problems occur with the ISDN connection, we have begun using an ISDN videoconference phone and have a cellular phone as a backup at the location connected via ISDN.

Dynamic Camera Operation

To facilitate interaction among participants irrespective of their location, we would like all meeting participants to be able to see whoever is talking as much as possible. For example, if Sue is presenting at one location and Bill asks a question at that same location, the outgoing video should show Sue when she is speaking and switch to Bill when he is speaking. This requires constant active camera operation (or sound-activated camera control) throughout the videoconference. This was not a standard operating procedure when we began videoconferencing. It is generally common practice for technical staff to set up a camera with a wide shot of the audience, do a microphone check and then leave the scene completely. This has disastrous effects for spontaneous, interactive discussions.

Interestingly, the etiquette practice of speakers identifying themselves and their location helps technical staff to provide this capability. Those short preferences alert staff to the need to change the camera view and give them a few extra seconds to accomplish the task.

Equipment Modifications

As discussed previously, each university had videoconference facilities before the center was established. We have worked and continue to work with the technical staff that manage and operated these studios to upgrade and provide new equipment that can facilitate our video conferences and be used in other video conferences that take place in these studios, creating a win-win situation. These upgrades and new equipment purchases have ranged in scope from upgrading PCs to support current versions of NetMeeting and PowerPoint to buying and installing SmartBoards and LCD projectors. Several universities have also "matched" these purchases, providing additional components needed such as 120" screens.

CONCLUSION

Facilitating collaboration among a large geographically dispersed group whose members may not have met previously and whose membership changes is a complex challenge. The NSF STC for Environmentally Solvents and Processes approached this challenge by investigating and implementing both social and organizational practices and technology, with an initial focus on large group, interactive videoconferencing. Our work has been evolutionary and collaborative in nature. Social and organizational practices or infrastructure, such as the role of a facilitator during a videoconference, use of visual aids, and participant etiquette, have evolved with insights from the literature and reflection on our experiences. Providing effective, interactive videoconferences among multiple sites has also required the implementation of different technologies and, perhaps more importantly, the evolution of new technical operation practices, including active camera operation and high quality n-way video and audio.

The STC has one full time technical staff member who spends approximately 60% of his effort working with university technical staff to develop and coordinate the technical infrastructure and working with social scientists and center members to implement social infrastructure practices. The social scientists (two faculty members and one postdoctoral fellow) observe meetings and interview participants to suggest new practices with respect to videoconferencing, in addition to conducting other action research initiatives in the center. Costs to upgrade university videoconference rooms have ranged from several hundred dollars to $15,000. Our universities do not charge the center for use of videoconference facilities when the in-state network is used or when the videoconference is part of a course as in the case of the center's weekly group meetings. Otherwise, the cost for an ISDN connection ranges from $50 to $75 per hour; however, this type of charge can vary widely between telecommunications companies.

Future efforts include investigating strategies to help make the weekly group videoconference meetings less formal. Students have reported they feel that their talks at these meetings must be well rehearsed and thought out, which is not necessarily a bad thing, though this situation becomes problematic when presenters avoid pointing out difficulties and their own questions due to their emphasis on a polished presentation. Others have reported that they feel uncomfortable asking tough questions because they do not want to embarrass the presenters, when the asking of such questions might help presenters overcome difficulties in their research or become aware of relevant matters that they were not aware of or had not considered. Additional exposure and use of the technology may help reduce these perceptions of formality; however, this alone may be insufficient. One strategy is to have key faculty (i.e., recognized experts) present work in progress and have colleagues add their constructive comments. This modeling may show by example that informal discussions are both appropriate and helpful in this venue. Another strategy includes having time allocated during the weekly videoconference meetings for individuals and groups of individuals to discuss topics. For example, faculty and students interested in a particular type of instrumentation could use this time to share recent experiences and ask for advice. These types of informal information exchange require trust among participants and furthermore that trust must in large be part created and maintained using technology not previously used (Jarvenpaa & Leidner, 1999; Iivonen & Huotari, 2000).

Future technical efforts include streaming the meetings over the Internet to allow interested individuals at corporations and national labs to participate in some videoconferences from their desktop. To achieve this several challenges exist. For example, security practices must be implemented to restrict viewing to designated individuals, and full screen video viewing on PCs is required for slides and other details to be easily seen. In addition, telephone calls from each individual at a remote corporation or lab would have to be patched into, or merged with, the video conference audio to enable those individuals to interact during meetings.

We also plan to conduct an evaluation of the videoconference meetings. Ideally, the evaluation will be an ongoing activity that will help guide the evolution of our social and technical infrastructure. Examples of questions to ask in the evaluation include:

What impact, if any, have the videoconference group meetings had directly on you, your research work/your academic progress/your learning/your research team/the center?

Do you see ways that the videoconferences might better support, or facilitate, your research [or studies] -- and the aims of the center?

How do the videoconferences compare with other approaches to sharing information among group members?

We have received requests to extend the videoconference capabilities to include additional locations, such as funding agencies, corporate sponsors, national labs and universities whose scientists collaborate with center members. We envision that technical and social challenges will continue to emerge throughout this expansion effort. For example, expectations regarding participant etiquette may need to be shared with first-time participants who, in turn, may suggest new practices.

In summary, many challenges emerge when facilitating collaboration among a large, geographically dispersed group. Reflecting on and learning from our experiences and sharing that learning is one way to advance our understanding of these complex challenges. These new practices have enhanced the effectiveness of videoconferencing, leading to its adoption within the center and enabling frequent and needs-based meetings across distances.

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References

Arapis, C. (1999, November). Archiving telemeetings. *Proceedings of ACM 1999 Conference on Information and Knowledge Management*. (pp. 545-552). Kansas City, MO.

Barefoot, J. C., & Strickland, L H. (1982). Conflict and dominance in television-mediated interactions. *Human Relations, 35 (7),* 559-566.

Cadiz, J.J., Balachandran, A., Sanocki, E., Gupta, A., Grudin, J., and Jancke, G. (2000, December). Distance learning through distributed collaborative video viewing. *Proceedings of ACM 2000 Conference on Computer Supported Cooperative Work*. (pp. 135-144). NY: ACM Press.

Childers, L., Disz, R., Olson, R., Papka, M., Stevens, R., & Udeshi, T. (2000). Access gird: Immersive group-to-group collaborative visualization. *Proceedings of the Fourth International Immersive Projection Technology Workshop.*

Cohen, M. D., & Sproull, L. S. (1996) (Eds.). *Organizational Learning*.
Thousand Oaks, CA: Sage.

Eason, K. (1988). *Information Technology and Organizational Change*. London: Taylor & Francis.

Finholt, T.A., Rocco, E., Bree, D., Jain, N., & Herbsleb, J.D. (1998). NotMeeting: A field trial of NetMeeting in a geographically distributed organization (PDF file). *SIGGROUP Bulletin*, *20*(1), 66-69. NY: ACM Press.

Gale, S. (1992). Desktop video conferencing: technical advances and evaluation issues. *Computer Communications, 15 (8),* 517-525.

Gowan, J. A., & Downs, J. M. (1994). Video conferencing human-machine interface: A field study. *Information & Management, 27*, 341-356.

Heath, C., & Luff, P. (1991). Disembodied conduct: Communication through video in a multi-media office environment. *Proceedings of CHI'91, ACM Conference on Human Factors in Computing Systems*, (pp. 99-103). NY: ACM Press.

Herring, S (1999). Interactional Coherence in CMC. *Journal of Computer Mediated Communication,* 4 (4) June. [Online]. http://www.ascusc.org/jcmc/vol4/issue4/index.html

Iivonen, M., & Huotari, M.-L. (2000). The impact of trust on the practice of knowledge management. *Proceedings of the ASIST Annual Meeting*, *37*, 421-429.

Isaacs, E. A., Morris, T., Rodriguez, T. K., & Tang, J. C. (1995) A comparison of face-to-face and distributed presentations. *Proceedings of CHI '95, ACM Conference on Human Factors in Computing Systems,* (pp. 354-361). NY: ACM Press.

Jarvenpaa, S. L., & Leidner, D. E. (1999). Communication and trust in global virtual teams. *Organization Science*, *10*(*6*), 791-815.

Kies, J. K., Williges, R. C., Rosson, M B. (1996). Controlled laboratory experimentation and field study evaluation of video conferencing for distance learning applications. *Hypermedia Technical Report HCIL-96-02*. [Online]. Available: http://hci.ise.vt.edu/lab/htr/HCIL-06-02/HCIL-96-02.html

Kling, R. (1996). Social controversies about computerization. In R. Kling (Ed.) (2d ed). *Computerization and controversy: Value conflicts and social choices* (pp, 16-21). San Diego, CA: Academic Press.

Kling, R. (2000). Learning about information technologies and social change: The contribution of social informatics. *The Information Society, 16 (3)*. [Online]. Available: http://www.slis.indiana.edu/TIS/articles/kling16(3).pdf

Masoodian, M., Apperley, M., & Frederickson, L. (1995). Video support for shared work-space interaction: An empirical study. *Interacting with Computers, 7* (3), 237-253.

Mark, G., Grudin, J. & Poltrock, S. (1999). Meeting at the desktop: An empirical study of virtually collocated teams. *Proceedings of ECSCW'99* (pp.159-178.). Lyngby, DK: Technical University of Denmark.

Nardi, B. A., Schwarz, H., Kuchinsky, A, Leichner, R., Whittaker, S., & Sclabassi, R. (1993). Turning away from talking heads: The use of video-as-data in neurosurgery. *Proceedings of INTERCHI'93, ACM Conference on Human Factors and Computing Systems,* (pp. 327-334). NY: ACM Press.

Nodder, C., Williams, G., & Dubrow, D. (1999). Evaluating the usability of an evolving collaborative product – changes in user type, tasks, and evaluation methods over time. *Proceedings of GROUP'99, ACM Conference on Supporting Group Work*, (pp. 150-159). NY: ACM Press.

O'Conaill, B., & Whittaker, S. & Wilbur, S. (1993). Conversations over video conferences: An evaluation of the spoken aspects of video-mediated communication. *Human-Computer Interaction, 8*, 389-428.

Ochsman, R. B., & Chapanis, A. (1974). The effects of 10 communication modes on the behavior of teams during co-operative problem-solving. *International Journal of Man-Machine Studies, 6,* 579-619.

Olson, J.S., Olson, G.M., & Meader, D.K. (1995). What mix of video and audio is useful for small groups doing remote real-time design work? *Proceedings of CHI'95, ACM Conference on Human Factors and Computing Systems,* (pp. 362-268). NY: ACM Press.

Patrick, A. S. (1999). The human factors of MBone videoconferences: recommendations for improving sessions and software. *Journal of Computer Mediated Communication, 4* (3). [Online]. http://www.ascusc.org/jcmc/vol4/issue3/patrick.html (January 4, 2001).

Rice, R. E. (1993). Media appropriateness: Using social presence theory to compare traditional and new organizational media. *Human Communication Research, 19 (4),* 451-484.

Ross, C. S., & Dewdney, P. (1998). *Communicating Professionally: A How-to-do-it Manual for Library Applications*. New York: Neal-Schuman.

Ruhleder, K., & Jordan, B. (2001). Co-constructing non-mutual realities: Delay-generated trouble n distributed interaction. *Computer Supported Cooperative Work, 10*, 113-138.

Ruhleder, K., Jordan, B., & Elmes, M. (1996). Wiring the "New organization": Integrating collaborative technologies and team-based work. *Annual Meeting of the Academy of Management.* http://alexia.lis.uiuc.edu/~ruhleder/publications/96.academy.html

Saville-Troike, M. (1989). *The Ethnography of Communication*. New York: Basil Blackwell.

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

Schwartzman, H. B. (1989). *The Meeting: Gatherings in Organizations and Communities*. New York: Plenum Press.

Short, J., Williams, E., & Christie, B. (1976). *The Social Psychology of Telecommunications.* London: Wiley.

Stringer, E. T. (1999). *Action Research*. (2nd ed). Thousand Oaks, CA: Sage.

Sellen, A. (1992). Speech patterns in video-mediated conversations. *Proceedings of CHI'92, ACM Conference on Human Factors and Computing Systems*, (pp. 49-59). NY: ACM Press.

Tang, J., & Isaacs, E. (1993). Why do users like video? Studies of multimedia-supported collaboration. *Computer Supported Cooperative Work, 1,* 163-193.

Whittaker, S. (1995). Rethinking video as a technology for interpersonal communications: theory and design implications. *International Journal of Human-Computer Studies, 42* (5), 501-529.

Whyte, W. F. (1997). *Creative Problem Solving in the Field: Reflections on a Career.* Walnut Creek, CA: AltaMira Press.