Lessons from a Dozen Years of Group Support Systems Research: A Discussion of Lab and Field Findings

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ABSTRACT: During the past dozen years, researchers at the University of Arizona have built six generations of group support systems software, conducted over 150 research studies, and facilitated over 4,000 projects. This article reports on lessons learned through that experience. It begins by presenting a theoretical foundation for the Groupware Grid, a tool for designing and evaluating GSS. It then reports lessons from nine key domains: (1)GSS in organizations; (2) cross-cultural and multicultural issues; (3) designing GSS software; (4) collaborative writing; (5) electronic polling; (6) GSS facilities and room design; (7) leadership and facilitation; (8) GSS in the classroom; and (9) business process reengineering.

KEY WORDS AND PHRASES: group decision processes, group support systems, organizational role of information technology.

A GREAT DEAL OF WORK GETS DONE BY INDIVIDUALS who set their jaws, put their shoulders to the wheel, and bear down. However, many of the problems faced by organizations cannot be solved by a rugged individualist because no one person has all the experience, all the resources, or all the information needed to accomplish the task alone. And so teams form. Teams of people have successfully scaled seemingly insurmountable heights. But teamwork brings its own set of problems. Anyone who has suffered the grinding drudgery of meetings-without-end know how unproductive teamwork can be.

Many things can go wrong with teamwork [83]. Participants may fail to understand their goals, may lack focus, or may have hidden agendas (figure 1). Some people may be afraid to speak up, while others may dominate the discussion. Misunderstandings occur through different interpretations of language, gesture, or expression. Besides being difficult, teamwork is expensive. A meeting of several managers or executives may cost upwards of $1,000 per hour in salary costs alone. In *Fortune* 500 companies, as of 1988, there were more than 11 million formal meetings per day in the United States, more than three billion meetings per year. Managers spent about 20 percent of their time in formal meetings of five people or more, and up to 85 percent of their time communicating [66]. One *Fortune* 500 company reports losses in excess of $75 million per year due to poor meetings.

For all its difficulty, teamwork is still essential; for all the expense, teams will not go away. People must still collaborate to solve tough problems. And, as business becomes more global in scope and computers become more ubiquitous in the workplace, the need for collaboration—and computer-based collaboration—will surely continue to increase.

Group support systems (GSS) are interactive computer-based environments that support concerted and coordinated team effort toward completion of joint tasks. Besides supporting information access, GSS can radically change the dynamics of group interactions by improving communication, by structuring and focusing problem-solving efforts, and by establishing and maintaining an alignment between personal and group goals. This paper presents a useful model for analyzing and comparing GSS technologies. It then summarizes the lessons learned from a dozen years of developing, testing, and using group support systems.

Groupware and Group Support Systems

BEFORE WE DISCUSS GROUP SUPPORT SYSTEMS IN DETAIL, it is useful to place them within the wider domain of groupware, and to explain the diversity of contributions groupware can make to an organization. Toward that end, Groupware Grid can serve as a theory-based heuristic model for evaluating the contributions of groupware technology to team productivity (figure 2).

Team Theory and the Groupware Grid

The horizontal axis of the Groupware Grid derives from the Team Theory of Group Productivity [11]. *Webster's Dictionary* defines a team as a collection of people working together for some specific purpose. Team Theory is a causal model for the productivity of a team. It asserts that team members divide their limited attention resources among three cognitive processes: communication, deliberation, and information access. Team Theory posits that these processes interfere with one another, limiting group productivity.

Team Theory's communication construct posits that people devote attention to choosing words, behaviors, images, and artifacts, and presenting them through a medium to other team members. Team Theory's deliberation construct asserts that people devote cognitive effort to forming intentions toward accomplishing the goal and includes the classic problem-solving activities: Make sense of the problem, develop and evaluate alternatives, select and plan a course of action, monitor results,

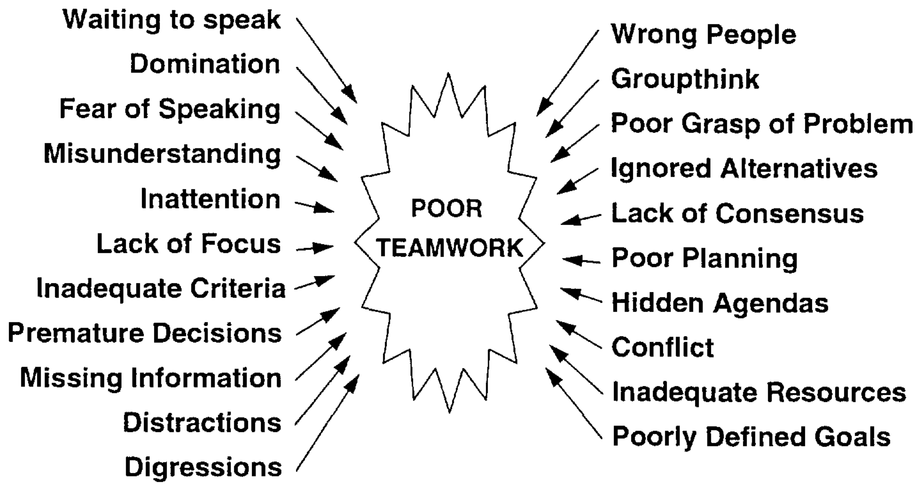

Figure 1. Teamwork Can Be Difficult

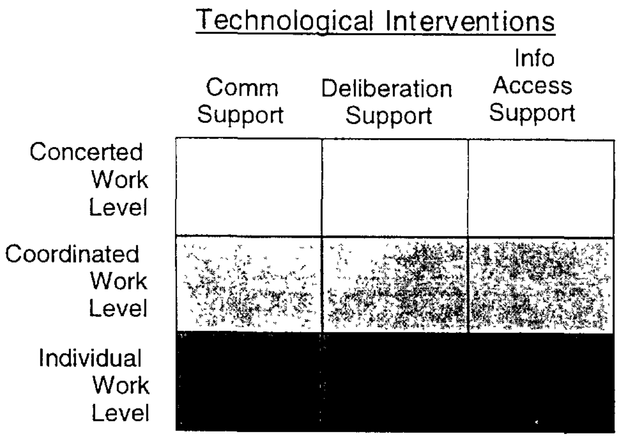

Figure 2. The Groupware Grid

and so on. The information-access construct addresses the attention demands of finding, storing, processing, and retrieving the information the group members need to support their deliberation. Team Theory posits that a key function of information is to increase the likelihood that the outcome one expects will be obtained by choosing one course of action over another. Information has value to the extent that it is available when a choice must be made, to the extent that it is accurate, and to the extent that it is complete. However, the value of information is offset by the cost of acquiring, storing, processing, and retrieving it.

Team Theory also posits that the cognitive effort required for communication, deliberation, and information access is motivated by goal congruence—the degree to which the vested interests of individual team members are compatible with the group goal. Team members whose interests are aligned with those of the group will exert more effort to achieve the goal than those whose interests are not served by the group goal. The Groupware Grid does not address goal congruence because goal congruence may have more to do with the way a team wields the technology than with the technology's inherent nature.

Therefore, the horizontal axis of the grid addresses the potential for technology to reduce the cognitive costs of joint effort. Groups may become less productive if the attention demands for communication, deliberation, or information access become too high. Groupware may improve productivity to the degree that it reduces the attention costs of these three processes.

Three Levels of Group Work and the Groupware Grid

The vertical axis of the Groupware Grid consists of three levels of group effort (figure 3). Sometimes a team may operate at the individual work level, with members making individual efforts that require no coordination. As with people in a 100-meter dash, team productivity is simply the sum of individual results. Other times team members may interact at the coordinated work level. At this level, as with a team in a relay race, the work requires careful coordination between otherwise independent individual efforts. Sometimes a team may operate at the concerted work level. As in a rowing race, teams working at this level must make a continuous concerted effort. The demands placed on the team vary depending on the level of work in which they are engaged. There is groupware technology to support teams working at all three levels.

The contributions of a single groupware tool or an entire groupware environment can be mapped into the cells of the Groupware Grid. A given technology will probably provide support in more than one cell. The potential for productivity of different environments can be compared by comparing their respective grids. For example, a team database such as Lotus Notes offers little support at the concerted work level but offers strong support for communication and information access at the coordination level. A team database offers little deliberation support at the coordination level, but a project management and workflow automation system offers strong deliberation support at that level.

The work at the University of Arizona has focused on GSS aspects of groupware. GSS offer a great deal of support for communication, deliberation, and information access at the concerted work level (figure 4). For example, the parallel input and anonymity communication interventions possible with GSS improve communication during a concerted effort. Each software tool in a GSS supports group deliberation in some unique way. A brainstorming tool, for example, prevents a group from thinking deeply, while encouraging them to diverge from familiar thinking patterns. An idea organizer, on the other hand, encourages a divergent group to focus quickly on a narrow set of key issues. Other tools might include electronic polling and voting, multicriteria evaluation, team outlining and writing, and shared drawing tools, to name but a few. GSS can support information access at the concerted work level by providing rapid access to the information in the minds of teammates, by providing permanent transcripts of past electronic interactions, or by providing an information search engine.

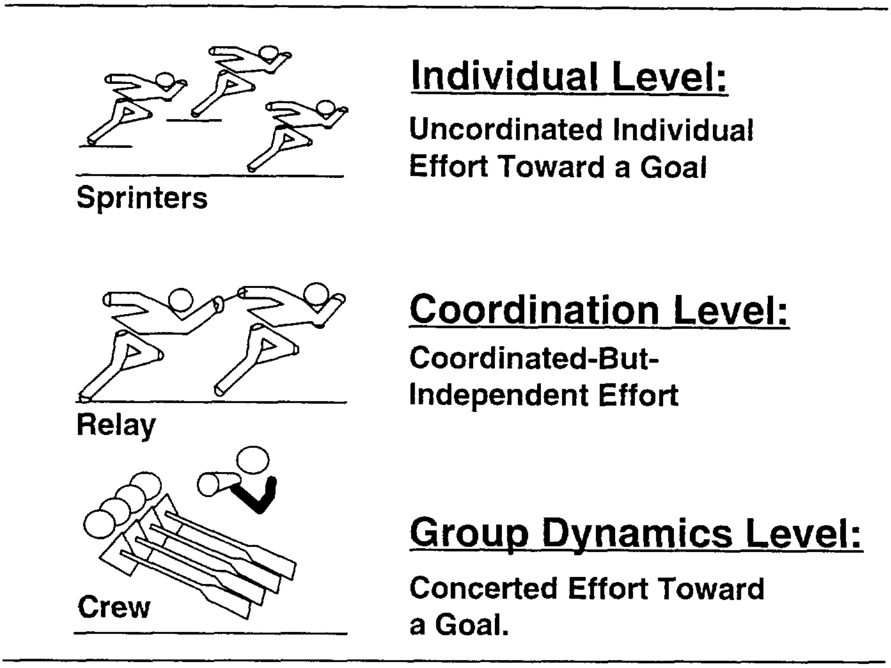

Figure 3. Three Levels of Group Work

	Productivity Processes: Communication	Thought	Info Access
Group Dynamics Level	Anonymity Parallel Contribution	Structured and Focused Processes	Session Transcripts, Automatic Concept Classification
Coordination Level	Asynchronous Communication	Schedule Matching Automated Workflow Project Management	Shared Data Stores
Individual Level	Preparing Communication Stimuli	Modelling Simulation	Info Filtering Local Data Stores

Figure 4. Classification of Benefits from Group Support Systems: Each cell contains examples of the kind of support available for a particular process at a particular level of work

This paper describes some lessons learned and the knowledge that has evolved from the building and use of GSSs at the University of Arizona over the past dozen years. The earliest GSS work at Arizona was implemented on a VAX. It focused on supporting geographically separated teams working on requirements definition for large information systems development projects. It quickly became clear, however, that these teams had no frame of reference for their on-line interactions. GSS interactions were different enough from common experience that people had no mental model upon which to base their distributed interactions. Further, because on-line interactions were so far outside the realm of normal experience, it was very difficult to explain the concept, even though the technology was very easy to use.

We therefore developed the concept of the electronic meeting room and spent a decade researching the technology and techniques to make teams productive as they interacted face to face. Building on what we learned, we turned our attention once again to supporting distributed teams. Our research center currently has twenty-two projects dealing with various aspects of distributed GSS. The problem is still difficult but it is no longer intractable. We are therefore able to summarize a great deal that we have learned in the lab and in the field about supporting face-to-face teams and also to touch on the preliminary findings of our more recent work in supporting distributed teams.

Lessons from Research

OVER THE PAST TWELVE YEARS OF RESEARCH AND DEVELOPMENT of collaboration technology, we have discovered much about the nature of the interactions among people, technology, and tasks. Our research methods have included case studies, field studies, and laboratory experiments. The findings from these studies have contributed to the understanding we have achieved over time and convinced us that the complex and multifaceted nature of group support systems requires that a variety of efforts and methodologies be called upon to address the multitude of research questions that exist. Our research philosophy is to develop systems, methods, and environments in an evolutionary, longitudinal, multimethod research program. Given this approach, we build on the theoretical foundation of prior information systems, psychology, and communications research by examining the process and outcomes of forms of group work not previously possible.

Our direct experience is based upon having worked with more than 200 public and private organizations in our own four meeting laboratories, as well as at over 1,500 sites around the world that have been built upon the meeting laboratory model established at Arizona. We have facilitated or supported over 4,000 working sessions for teams and have produced more than 150 research studies in the domain of collaborative technology.

Lessons on GSS in Organizations

While many of the initial GSS findings at Arizona, Minnesota, and other pioneering GSS centers came from the laboratory, early researchers noticed differences between lab and field findings [26]. Actual field use of GSS was producing effects that were not modeled or measured in the early lab experiments, often because real groups do not perform tasks in a void, but within an organizational context that drives objectives, attitudes, and behaviors in group meetings. While working in the field, we learned a number of lessons about GSS and organizations. Some of the following discussion stems from findings previously reported; other portions have been collected by Center for Management Information (CMI) researchers but not previously reported due to confidentiality constraints at the time of the study or other related limitations (see Table 1).

GSS and Organizational Buy-in to Decisions

The use of group support systems may increase the likelihood that participants will buy in to the final results of the group effort. For example, a task force in a large bureaucratic organization tried for over a year to draft a document detailing acceptable field procedures. In that time, they were unable to persuade both the field experts and the central administration to accept the same draft of the document, despite a long series of meetings. The team decided to bring representatives of the two groups to a GSS facility for another try. Using anonymous brainstorming, group writing, and electronic voting tools, the group quickly identified the key issues standing in the way of resolving their disputes. Within three days, the participants had negotiated their differences and rewritten the bulk of the document. The revised document was accepted and used thereafter by both sides. Because all parties worked simultaneously, a unified shared vision emerged, and key constraints from both sides could be incorporated into the document. Both sides bought in and championed the final draft with the rest of the organization.

The field studies clearly show that substantial benefits, both economic and intangible, accrue from the use of group support systems. Experience also shows that success depends on both how the tools are designed and how they are used.

Leadership

Much of what we know about GSS and leadership can be summed up in the maxim

> *GSS technology does not replace leadership.*

A GSS can move a group through a process much more quickly than is possible by conventional means. If the group is headed toward a clearly defined goal, the GSS can help achieve the goal more productively. If the group is unclear about its goal, the lack of direction will become immediately obvious when the team begins work. Undirected teams often abandon the meeting process within ten or fifteen minutes, demonstrating that GSS use does not replace leadership but it can enhance the effectiveness of a well-led team.

GSS technology does not enforce a particular leadership style. It has been appropriated in support of a variety of approaches, ranging from the democratic to the

Table 1. Lessons Learned about GSS in Organizations

- GSS technology does not replace leadership.
- GSS technology does not imply any particular leadership style.
- GSS can make a well-planned meeting better, and it can make a poorly planned meeting worse.
- Individuals must have incentive to contribute to group effort.
- GSS can reduce labor costs by more than 50 percent and project time by up to 90 percent.

autocratic; of situations, ranging from the chaotic to the static; and of organizational cultures, ranging from the fragmented to the cohesive.

GSS technology can help resolve counterproductive conflicts between leadership styles. One manager, who considered himself very democratic, presided over weekly 2½-hour planning meetings with his staff. For the first ninety minutes, he would let the staff speak but then he would grab a felt marker and move to the whiteboard with the comment, "Let me see if I understand what you're saying." He would then describe his own agenda, using words and phrases culled from the group discussion. This vice president's superiors recognized the problem and decided to try using a GSS to alter his autocratic management style. The staff was enthusiastic about the results, but he was not; he could no longer dictate the agenda and he ultimately decided to stop using the system. The staff, with the support of top management, refused to let him. Group morale rose quickly, and the team prospered under a new, shared vision.

Failure to make a meeting's objectives explicit can lead to disenchantment, particularly when participants spot phony democracy. If a leader includes a group in the decision-making process after the fact simply to "let them feel ownership," the group process breaks down. Leaders who merely want a team to understand a problem before they propose a solution should say so up front. If the objective is to develop a set of alternatives and recommendations, it should be so defined. Once the team has been commissioned to make a decision, however, a leader can contribute, advise, and argue, but the team will rebel against a leader who overrides its collective judgment.

False promises of anonymity are equally damaging. Any attempt to find out who said what in an anonymous session undermines the leader's credibility and defeats the purpose of anonymous input, which is to solicit risky, unpopular, or opposing viewpoints.

Role Clarification

Group support systems can also be used to identify those having a stake in a project and to reveal underlying assumptions. When a national library attempted to develop a computer system, it assembled a team of representatives from different departments such as circulation, cataloging, acquisitions, and computing. For several meetings, the groups tried and failed to develop a shared vision of the project. The team leader decided to use an electronic stakeholder and assumption-surfacing tool.

It turned out that the various departments had unrealistic expectations of the computer group, and the computer group had unrealistic expectations about the others. During the next few months, through vigorous and sometimes acrimonious debates, the team arrived at a common understanding and a shared vision. Until the participants engaged in stakeholder analysis, they had not even been aware that fundamental differences existed. The group support system allowed them to share critical information and correct mistaken assumptions, solving an intractable problem and fixing a major oversight in the designing process.

Any tool is only as good as the artisan who wields it. This is just as true of sophisticated group support software as it is of a screwdriver. To realize these systems' enormous potential to expand the productivity of today's team-oriented organizations, leaders must recognize both tangible and intangible benefits. The intangibles, which depend heavily on the style and quality of leadership, include greater group cohesiveness, better problem definition, a wider range of higher-quality solutions, and stronger commitment to those solutions. The tangibles, already demonstrated, are dollar savings through greater productivity and reduced staff hours to reach decisions. On the bottom line, more time is free from the demands of frequent—and often frustrating—meetings.

GSS and Participation in Organizational Activities

The members of teams that use GSS participate much more evenly and fully in team interactions than do members in conventional teams. Laboratory experiments [13] and field studies [8, 73] have shown that Pareto's law applies to conventional meetings: Fewer than 20 percent of the participants do more than 80 percent of the talking. People in GSS-supported meetings participate nearly equally and produce many more contributions than do people in unsupported meetings. Two key features of GSS may account for this increase in participation: anonymity and parallel input [62] (see Table 2).

Use of GSS, however, is not always enthusiastically welcomed by organization members. If organizational rewards are based on individual performance, information access, or specialized knowledge, persons valuing these characteristics may well resist actively participating in GSS sessions where information is shared and ideas are contributed anonymously. It is important that organizational incentives and rewards be aligned with GSS use, or GSS implementation can fail.

Lessons about Anonymity

Laboratory studies have shown that groups using GSS produce many more unique ideas of higher quality than groups using standard meeting techniques [27, 33, 34]. Further, laboratory studies have shown that teams using anonymous GSS technology contributed many more ideas when they were allowed to enter both positive and negative comments [18]. Theory suggests [29], and field experience confirms, that anonymity frees people to explore or to criticize ideas without fear of retribution from peers or superiors. Anonymity encourages people to participate in generating ideas

Table 2. Lessons about Participation in GSS Groups

- GSS can increase the number of ideas generated during a divergent process.
- Meeting participants will be active rather than passive, increasing energy and group focus.
- Anonymity is a continuous rather than discrete variable.
- Anonymity encourages GSS participants to evaluate ideas more objectively.
- Anonymous constructive criticism using GSS improves the quality of ideas generated
- GSS may increase buy-in to the final result of group effort.

without inhibition. A manager at Hughes Aircraft observed, "People who are usually reluctant to express themselves feel free to take part, and we've been surprised by the number of new ideas generated. We also reach conclusions far more rapidly."

Anonymity is a continuous rather than a discrete construct [62], and GSS facilitators have found ways to manipulate varying degrees of anonymity to achieve their goals. For example, a GSS can be used to support discussion without identifying individual comments. While some participants may believe they can identify contributors, they cannot really know for sure, and experience has shown that such guesses are most often incorrect. Partial anonymity can be introduced in a variety of ways. Participants can be asked to use an alias so that all of their comments are attributed to the same author. We often use the names of American presidents for aliases. Alternatively, participants can have their comments labeled by their subgroup membership (e.g., teachers, parents, administrators at a PTA meeting) so subgroup membership is pegged to a comment, and hence the position that participant is likely coming from, but individual anonymity is maintained.

When they first hear about anonymous input, some people express concern that the discussion will quickly degenerate into "flaming" sessions laced with four-letter words and slanderous epithets. In thousands of sessions in business and government organizations, we have seen only two instances of such disintegration. This does not mean, however, that people are not critical in electronic meetings. They are. Participants will often raise issues that would never come out in face-to-face discussions. There is less sting, however, in an anonymous electronic criticism than in a direct rebuke during a face-to-face meeting. The screen buffers the negative emotions that may accompany such criticism. Because nobody knows where a particular idea came from, people criticize the idea rather than the person who presented it. Still, we have seen bruised egos and people struggling with honest feedback.

Anonymity may also encourage group members to view their own ideas more objectively and to see criticism as a signal to suggest other ideas. "I wasn't as uncomfortable when I saw someone being critical of someone else's idea, because I thought 'Nobody's being embarrassed here at all,'" says Sam Eichenfield, president and CEO of FINOVA.

"I noticed that if someone criticized an idea of mine, I didn't get emotional about it," says the Hughes Aircraft manager. "I guess when you are face-to-face and everyone hears the boss say, 'You are wrong,' it's a slap to you, not necessarily to the idea."

Despite the safe haven it provides for most participants, GSS is not always comfortable for the leader of a project or enterprise. Sometimes it takes courage for a manager to deal with the issues that surface in an anonymous meeting. It is difficult to deal with unpleasant input, but if problems lie buried for too long, they may become intractable. In a rare incident, the founder of a very successful medical technology firm called together key personnel from multiple levels in the organization for a GSS session. Thirty minutes into the meeting, he turned red in the face and stood up. Pounding a fist on his PC for emphasis, he shouted, "I want to know who put in the comment on the problem with the interface for the new system. We're not leaving this room until I know who made that statement!" He glared around the room waiting for a response. Everyone greeted his outburst with silence. After a week's reflection, he returned sheepishly to the group and said, "I had no idea there was trouble. I guess I'm more out of touch than I ought to be. Let's try again."

Anonymity helps to separate ideas from the politics behind them. Ideas can be weighted on their merits rather than on their source. Each member of a team tends to view problems from his or her own perspective, often to the detriment of the project or enterprise. For example, in traditional meetings, engineers see engineering solutions, salespeople see marketing solutions, and production people see manufacturing solutions. In anonymous discussion and exchange of ideas from many different viewpoints, the big picture is more likely to emerge. GSS groups often achieve a unified, shared vision of problems and solutions—something that's difficult with traditional meeting methods.

GSS and Productivity

Most early GSS work focused on improving the productivity of face-to-face collaboration because the dynamics of traditional group work were already well understood and the problems were only too clear. The first field trials of GSS took place at the Oswego, NY, plant of IBM Corporation in 1986 [37]. In a yearlong study, thirty groups used GroupSystems to solve problems in production-line quality. Teams using the technology saved an average of 50 percent in labor costs over conventional methods. They also reduced the elapsed time from the beginning to the end of their projects by an average of 91 percent. The results were so dramatic that they were suspected of being anomalous, a fluke of the circumstances surrounding the study, so a second yearlong study was conducted at six other IBM sites, each with a different set of business problems. In the second study, which tracked more than fifty groups, average labor costs were reduced by 55 percent and elapsed times for projects of all types were reduced an average of 90 percent [37]

In 1991, Boeing Corporation ran an independent study to determine whether there was a good business case for the use of group support systems [71]. Over the course of a year, the company carefully tracked the results of sixty-four groups. The groups used GSS for problem definition, alternative generation, and evaluation, implementation planning, and documentation of group outcomes. The result was an average labor saving of 71 percent and an average reduction of elapsed times for projects of 91 percent. A conservative evaluation of the return on investment for the pilot project was 170 percent the first year [71].

Besides finding quantitative benefits, the IBM and Boeing studies documented improvements in the quality of results and the satisfaction levels of the participants. Since these studies, other organizations have conducted independent evaluations of the benefits of Group Support Systems. The U.S. Army reported back to researchers at Arizona a total savings of a million dollars in eight one-week sessions to design a new Armywide personnel tracking system. BellCore found a 66 percent reduction in labor costs for teams using the technology. The Army National Guard saved over 70 percent in labor costs and 90 percent in project elapsed time over three information systems documentation writing projects [58].

Lessons Yet to Be Learned about GSS in Organizations

While the Boeing case [37] illustrates a financial success using group support systems, it also illustrates some of the organizational difficulties associated with implementing new technologies. By the end of the pilot project, Boeing had documented seven-figure bottom-line benefits. Estimates of the ROI for the project rose to more than 600 percent during the second year. However, about that time Boeing's corporate structure changed. The internal consultants were reassigned from their centralized group to a number of locations in the field. Thus, no center of competence remained to support the fledgling GSS project, and so it was canceled. It was another three years before Boeing personnel began using GSS again.

A number of organizations have had difficulties maintaining a center of GSS competence for a very different reason. As people begin to use GSS to make those around them more productive, their value and visibility rise rapidly, and they are often quickly promoted, leaving nobody with the skills to run the group support system. One solution to the problem is to make sure that there are always several apprentice facilitators in training so that a promotion does not strip the company of its GSS expertise. One general in the Marine Corps adopted quite a different strategy. He insisted on being the first person trained with the GSS and ran all the early meetings himself. He reasoned that nobody would be able to claim GSS was too hard to learn. "After all," he quipped, "If the general can do it, anybody can do it." Others in his command soon acquired the skills, and GSS expertise spread throughout his organization. Minor changes in personnel could therefore not disrupt or terminate the use of GSS.

Cross-Cultural and Multicultural Issues

The interaction and influence of culture [42] in terms of patterned ways of thinking, feeling, and reacting with the use of GroupSystems for various tasks in international contexts is an emerging area of study. Hofestede applied the concept of power distance

Table 3. Lessons about Cross-cultural and Multicultural Use of GSS

- GSS can successfully support multilanguage meetings.
- Participants from different cultures may demonstrate different levels of satisfaction with GSS implementation.
- Behavioral differences across cultures occur primarily in convergent activities.

to explain behavior patterns within different national cultures. Because distributed GSS has the potential to make multicultural meetings more common, researchers have begun to explore the implications of technology mediated cross-cultural collaboration. In addition, most early GSS research used lab or field groups from North American or west European countries. More recent research has acknowledged the expanding use of GSS around the world and explored behaviors and attitudes of GSS participants from other cultures (Table 3).

Lessons from the Lab

Participants from cross-cultural and multicultural groups are able to work effectively together with a group dynamic uncommon in traditional groups. GroupSystems' ability to minimize process losses and maximize process gains [86] enables diverse groups to participate effectively and efficiently in collaborative activities with high levels of personal satisfaction.

Cross-cultural meetings introduce the problem of participants having different native languages. Participants in cross-cultural sessions can be successfully supported even when all participants are not using the same language. Because GroupSystems allows participants to contribute in their language of choice and gives them time to interpret the input of others independently and/or to use a centrally based translator, participants are able to sustain an electronic conversation that would be impossible under traditional circumstances. Preliminary development work at Arizona suggests potential for building automatic translation into future GSS.

Griffith [36] suggests that cultural differences will contribute to differences in satisfaction at the implementation of GSS technologies, with high-power-distance cultures showing more resistance to change. In addition, Griffith found generational differences in using GSS in problem-solving tasks by Bulgarian meeting participants. She hypothesized that the difference was due to the changing political climate in Bulgaria, where younger participants are more acculturated to challenging established norms.

The results with groups that do not exhibit the characteristics of groups found in real organizations tend not to be generalizable [35]. It is often tempting to use student peer groups, expecting them to assume roles and participate in group sessions emulating those that might occur in field contexts with which they have had no experience. It is especially important when using student subjects to use relevant tasks and established relationships whenever possible.

Lessons from the Field

GroupSystems is currently in use on all continents except Antarctica. Interestingly, cross-cultural use of GroupSystems is more notable for similarities than differences, especially for idea generation. Use of GroupSystems around the world tends to be fundamentally similar to its use by groups in the United States. In part, this may be a function of limited exposure and lack of opportunity to develop unique modes of use. In many countries, however, GroupSystems has been in use for over five years, which should be sufficient time for significant differences in use to surface.

Differences in cross-cultural use that do exist occur primarily in convergent activities. Here we find that cultures have different patterns of interaction. For example, groups from countries with a high power distance—that is, those with highly stratified and differentiated organizational and societal levels—tend to prefer a more clearly identified and gradual approach to convergence than do groups from countries with a lower power distance [91].

Although GroupSystems is being used in a variety of international contexts and associated cultures, there is hardly any record of practical use for multicultural teams. For the most part, relatively speaking, working sessions are being run with culturally homogeneous teams. This is likely to change as more organizations become globally focused and geographically distributed use of GroupSystems increases.

Lessons Yet to be Learned about Cross-Cultural and Multicultural GSS

Although GroupSystems is currently widely used in international contexts, little experience is recorded of longer-term projects that might provide insight into global impact. This extended use is expected to emerge, especially as organizations engage in electronic commerce and recognize the need and benefits of interactive support for groups in these contexts. The stage is set, but the data remain to be collected.

International use of GroupSystems to date has been primarily face to face. We expect to learn much as distributed groups become increasingly commonplace in terms of issues such as facilitation and technological substitution of audio and visual cues. Integration of GroupSystems with video conferencing is a special use that we expect to emerge. Virtually nothing so far is known about the need for video resolution as a function of the availability of GroupSystems features. The group and organizational benefits of combined use of video and GroupSystems are compelling but unproved.

Lessons about GSS Application Software

The core of the group support system environment is collaborative software. The collaborative software developed at Arizona is GroupSystems™. Over the years, through six generations of GroupSystems development, we have learned a number of lessons about what is important for successful GSS software in terms of structure, use, and interface (Table 4).

Table 4. Lessons about GSS Application Software

- Build GSS software as independent special-purpose modules.
- Subtle differences in user interface can make big differences in group dynamics.
- Keep the user learning curve short; use simple interfaces.
- Provide easy import and export capabilities both between modules and with external tools.
- Provide for both task and process support.

The Values of Modularity

It turns out to be very useful to build GSS software into a collection of special-purpose modules rather than as a single unit. Although it is possible to build a single tool that can be used for idea generation, idea organization, idea evaluation (polling), and idea exploration, toolkits are more flexible than indivisible systems and increase the potential for tool reuse for a variety of tasks—including new, unanticipated tasks [61]. New collaborative tools should take advantage of recent advances in distributed object architectures and make use of reusable distributed components [65].

Interface Choices Affect Group Dynamics

Subtle differences in user interfaces can make large differences in group dynamics. For instance, an idea-generation tool with a five-line limit for comment encourages concision and enables a group to explore a broad range of ideas quickly. On the other hand, an idea-generation tool that permits long comments about a few items will encourage in-depth examination of issues. Because interface choices affect group dynamics, and because group dynamics are a critical concern for group productivity, it is useful to build separate interfaces, each to support a particular dynamic [73].

Keep the User Learning Curve Short

Another reason for building separate modules is that group interfaces must be kept very simple [15]. Group members must talk, listen, think, and remember what has been said. If the computer interface poses an additional distraction, it will hurt rather than help group productivity. Individuals have only a limited amount of cognitive effort to expend: The more effort they spend on understanding the user interface, the less effort they will be able to spend on the task at hand [11]. In EMS development, we attempted to create tools that would permit groups to begin productive work with less than 30 seconds of instructions [23]. Participants are often able to begin work with no instructions at all. We accomplished a short participant learning curve by offloading much of the complexity onto the facilitator but we found over time that lengthy facilitator learning curves discouraged large-scale adoption of GSS tools and are now seeking solutions that will also shorten the facilitator learning curve.

Provide Both Structure and Flexibility

Successful meetings require both *structure* in the group's approach to its task and *flexibility* in adjusting its approach as new information is introduced. Group support systems software must provide for both faces of this paradox.

Structured techniques, the designed mapping of group processes and group interactions toward a desired outcome, provide a road map to guide a group efficiently and effectively. Group support systems support the use of structured techniques through a combination of rapid communication and structured analysis, resulting in focused discussions that enable all participants to contribute their knowledge and opinions in a minimum amount of time [25]. Electronic brainstorming, for example, inhibits participants from thinking deeply by limiting comment contributions to five lines. The activity modeler helps participants push details downward by restricting the number of activities called ICOMs (input controls output mechanisms) to six per tree level [23].

Group support systems software allows pre-planning of a meeting agenda in which each group task is mapped to a specific set of software tools. This pre-session task mapping forces the group to think through its meeting objectives more specifically than it might otherwise do. Several meeting leaders have reported that pre-session agenda building has improved their meetings [24, 55].

On the other hand, the group support system must allow the agenda to be changed on the fly should the flow of the meeting require such action. The toolkit structure of a group support system permits altering a meeting process in midstream and switching to a different tool. The GSS toolkit should have an embedded *shift* function to move data from one tool to another in real time.

Data Portability

When building an EMS in modules, it is also critical that the designer provide a simple and seamless way to move group information from one module to the next. For example, if a group spends time generating a broad set of ideas and then wants to evaluate which ideas are best, it must be possible to move the ideas to the voting module. Long or awkward transitions between modules will disrupt the group dynamics and ultimately doom group processes to chaos.

Even when people are working as a group, pieces of the work will still be done by individual members at their own desks. It is therefore desirable to integrate group productivity tools with individual productivity tools wherever possible. It is useful to be able to move information to and from spreadsheets, text editors, databases, and other individual productivity applications.

Lessons Yet to be Learned about GSS Application Design

The movement of GSS into distributed environments opens a vast array of new research opportunities and demands. As shared distributed workspaces are increasingly occupied by multiple synchronous computer users, GSS researchers need to join with the human–computer interface (HCI) community to develop truly collaborative user interfaces that seamlessly support concerted work. Much of that support will be through multimedia and virtual reality (VR) extensions to collaborative interfaces. Researchers and their colleagues in the field of communications must investigate which nonverbal behaviors are key to computer-supported concerted work and then learn to embed those nonverbal cues into the software.

Related to this is the challenge of extending VR environments to become GSS tools. Most early VR environments contain minimal task and process structuring; they are simply open-ended conversational spaces. GSS researchers must work with VR developers to embed GSS task and process structures into these environments.

Collaborative Writing

A significant body of literature describes the way collaborative groups write using conventional single-user technology [70]. These collaborative groups tend to be small (two or three members) and tend first to work independently, combining their work in an editing stage. More than two dozen computer-based group editing tools have been developed in the past decade. Sharples [82] identify three categories of group editing processes:

- *Sequential editing*: Collaborators divide up the task so that the output of one stage is passed to the next writer for individual work. Editors that support this process are called markup tools. Examples of these include ForComment, as well as recent extensions to popular word-processing programs such as Microsoft Word and Lotus WordPro.
- *Parallel editing*: Collaborators divide up the task so that each writer works on a different part of the document at the same time. Then the document is reassembled in an integration stage. Examples of these are Quilt, SharedBook, ShrEdit [64], and GroupSystems GroupWriter [58].
- *Reciprocal editing*: Collaborators work together to create a common document, mutually adjusting their activities in real time to take into account each other's changes. One example of such an editor is MULE [61].

Several group editors have been developed by GSS researchers but little literature exists suggesting how these might be used to support the creation of large documents by large groups. Olson et al. [63] used the ShrEdit text editor to support groups engaging in the task of designing a post office. However, this is essentially an alternative generation and evaluation task, not a documentation task. While the authors found that groups using their text editor generated longer recommendation documents than groups using paper, pencil, and whiteboard technologies, they found no differences in recommendation quality or in group satisfaction. Other research collaborative writing systems, such as SEPIA [38] and Flexible Diff [59], are beginning to appear in the literature. Our work at Arizona has included MULE, GroupSystems V GroupWriter, and now a Windows-based GroupWriter [58]. We have supported over a dozen synchronous collaborative writing groups, ranging in size from five to fourteen. We have supported the creation of documents from several hundred words to more than 150 pages. From this work several lessons have emerged.

Collaborative Writing Can Lead to Significant Productivity Gains

In groups that have achieved significant productivity gains through use of a computer-supported collaborative writing process, the gains seem to derive from a variety of factors. First, the technology itself —when implemented in a tightly structured process—can increase the productiviity of a team of authors by allowing all of them to write at the same time. While this may improve the overall productivity of the group, the time it takes each author to read and discuss the other authors' work minimizes the gains. Second, the act of bringing multiple authors together for synchronous writing can greatly improve the time to completion of a collaborative writing project. Much of the time normally spent during a collaborative writing effort is consumed sending drafts out for review and waiting for their return. Further, when each author individually reviews a draft, there is little chance to communicate, negotiate, and resolve issues. Multiple review passes are often required before an issue can be resolved—if it ever can be.

For example, one federal government agency team was updating a 150-page regulation document and assigned the project to a technical writer who had traveled the country interviewing appropriate team members for input. After the interviews, the writer authored a draft and sent it out for comment. Several team members disagreed with key sections of the draft and specialists in Washington, D.C., overseeing the process, had the writer insert text with which team members strongly disagreed. Eight months into the project, the team met face to face for a one-day meeting but were unable to resolve the disputes over sections of the document. Another draft was attempted but received little support or enthusiasm from team members (see Table 5).

One year into the arduous process, fourteen key members of the team were brought into a synchronous GSS collaborative writing session. Cliques had formed among team members with shared interests. There was scarcely any trust of the Washington specialists. Using a GSS, this team produced a penultimate document in three and a half days. After the session, the team estimated that in a facilitated process without collaborative technology they would have required about ten days of work to create the document, but, in reality, the three and a half days can be measured against the 365 days previously spent.

Buy-in to the Content of the Document Increases

In addition to gains in productivity, we have noticed significant gains in buy-in to the final group product. In the federal agency session discussed above, the group—which had been bitterly conflicted prior to the session—felt such a strong degree of ownership of their final document that they decided to draw a cover design for the document as a group effort on their last day of work.

Table 5. Lessons about Collaborative Writing

• GSS processes can lead to significant productivity gains.
• GSS processes can lead to significant increases in buy-in by coauthors to the final document.
• An appropriate structured process is vital to the success of a GSS collaborative writing project.
• GSS processes can prevent a group from getting bogged down over wordsmithing.

Another team of four collaborative authors, representing seven conflicted organization board members trying to write an organizational constitution and bylaws, met for an eight-hour marathon session one afternoon and evening. Their buy-in to the final document was so strong that in the end they decided to vote as a bloc when the document was presented to the full board so that the other three members would be unable to amend their work. While this action was not necessarily organizationally functional, it demonstrates the high level of shared buy-in the authoring team achieved.

An Appropriate Task Process Is Vital to the Success of the Writing Project

Early attempts at collaborative writing at Arizona used an unstructured process in which participants sat together in a GSS room and began to contribute to a document at will. The lack of structure was quickly found to be dysfunctional and frustrating for the participants. After several sessions of work, the multistage process to support the evolution of a document emerged and resulted in the productivity and attitudinal gains.

The process is based on the collaborative writing stage models already in the literature [30, 70] with proscriptive GSS interventions at each of six stages:

1. Open discussion: Develop the objectives and general scope of the document using brainstorming or parallel discussion software.
2. Generation of document outline: Develop main sections and subsections that will provide the structure for the document using a group outlining tool.
3. Discussion of content within outline: Interactive generation and discussion of document content in each section using parallel discussions in a group outlining tool.
4. Composing by subteams: These subteams may consist of a few people or in some cases may be only one person. The task is to take the content entries from a section and organize, edit, and complete the section as a first draft using a collaborative writing tool with the data from stage 3 imported from the group outlining tool.
5. On-line feedback and discussion: Using either a collaborative annotation tool or a parallel discussion tool, the team reviews each section and makes suggestions in the form of annotations or comments. The section editors accept, reject, or merge the suggestions to improve their own sections.

6. Verbal walkthrough: Using the collaborative writing tool, the team does a verbal walkthrough of the document.

Stages 1 through 3 are sequential in nature and undertaken only once. Stages 4 through 6 are circular in nature and, in some cases, multiple loops are carried out before the document is finalized. Minimal time and energy is spent on formatting the document. As synchronous group time may be limited and valuable, it is used as much as possible to add and refine document content. Formatting can be accomplished after the fact by team members or an outside editor.

The key lesson here is that GSS technology alone is insufficient to improve the collaborative writing process. However, GSS technology can be combined with a tight task and process structure to produce significant gains.

Addressing Interpersonal Issues

Disputes often arise during collaborative writing sessions The process described above helps to identify, focus, structure, and thereby to resolve disputes. Often, disputes arise when team members have incorrect or incomplete information. Occasionally, disputes arise because different team members have different philosophical approaches to an issue. To address this and to avoid pulling the entire team off track, we have placed disputing team members together on subteams. This enables them to negotiate their differences without an audience to perform for and to compromise without losing face. When such a subteam returns to the group with compromise text, the group readily accepts it, knowing that multiple points of view went into its composition.

Similarly, when individuals bog down the group process by attempting to wordsmith large sections of the document during structured walkthroughs, we have taken to assigning those individuals to ad-hoc subteams assigned to polish the text and report their results back to the full group. This gives them the opportunity to craft a document section they care about while allowing the rest of the group to proceed unhindered. When the group suspects that a wordsmith has a particular content axe to grind, we have assigned additional ad-hoc subteam members who we knew would keep the wordsmith in line.

Lessons Yet to be Learned about Collaborative Writing

Most of our synchronous collaborative writing work to date has been within one meeting room. We, and other researchers, have little to no experience yet at supporting synchronous distributed collaborative writing. At the structured walkthrough stages, which require heavy verbal and nonverbal interaction, it is currently unclear how we might conduct this work in a distributed setting.

One important measure of the success of collaborative writing is the quality of the finished document. Document quality is very subjective and difficult to measure. While we have attempted to measure perceived document quality, we have not found an appropriate way to measure direct quality. We believe that GSS collaborative writing can improve document quality, but have only very limited perceived quality measures to support this assertion.

Lessons about Electronic Polling

Researchers have, for many decades, examined ways to use computers to assist groups in decision-making processes [45, 47, 48, 51, 52, 53, 68, 77, 78, 79]. Early attempts, however, at linking computer technology with a group process, such as MacKinnon's use of an off-line FORTRAN batch process to compile votes [51], might best be labeled premature. Their failure was not due to their algorithms or their concepts, but rather to the lack of synergy in the human–computer interaction. Even today, the central problem remains enhancing the group process so that members' outputs, in real time and naturally, become inputs for computer processes and vice versa [4]. However, isolated successes [85] presage great potential for computer-based analytical tools to assist groups in arriving at a better understanding of the problem and to generate new and synergistic options for action.

The literature on voting and social choice has long attained maturity and many of its lessons can be realized in electronic voting. Consider, for example, Arrow's classic *impossibility theorem* [3], which shows that there is no fair way to form a group ranking from a set of individual rankings. However, with the advent of networked computers and algorithms, which provide real-time access to informational databases, support for pre- and post-decision group discussions, immediate feedback, and tools to fully analyze the decision process, electronic voting is now emerging as a separate stream of research, one with neoteric lessons absent from the classic literature.

In most cases electronic voting tools play a very different role from those of conventional voice or paper-ballot methods of voting. Traditional voting usually happens at the end of a discussion to close and decide a matter once and for all [41, 45, 56]. Electronic voting, however, tends to inspire a "vote early, vote often" mentality within decision groups. Because it is fast and meets the usual GSS criteria of preserving anonymity, granting equal treatment to members, and mitigating the effects of irrelevant influences, teams may use electronic voting to measure consensus and focus subsequent discussion, rather than to close debate [4]. In these ways, a more accurate term for the technology is polling rather than voting. While it can shorten discussions, saving time is not the only reason to use electronic polling tools. Teams find that polling clarifies communication, focuses discussion, reveals patterns of consensus, and stimulates thinking [67, 92] (Table 6).

The following case studies, taken from confidential research of actual events, illustrate the diversity of benefits organizations can derive from electronic voting.

Confidence Voting

A management crisis loomed for a major telecommunications company. For six months, thirty-nine senior managers wrangled about achieving an ordered ranking of

Table 6. Lessons about Electronic Polling

- GSS polling can be used to clarify communication, focus discussion, reveal patterns of consensus, or stimulate thinking.
- Anonymous polling can bring out issues that remain buried during direct conversation.
- GSS polling can demonstrate areas of agreement, allowing groups to close off discussion in those areas and focus only on areas of disagreement.
- GSS polling can be used to formally register dissenting opinions.
- GSS polling can fuse the aggregate judgment or opinions of all group members into a true group position.
- GSS polling can facilitate closure of issues that are too painful to face using traditional methods.
- Care must be taken to ensure that polling criteria are clearly established and defined.
- Polling methods in decision groups need not be democratic.

eighty-nine technical researchers on the company's payroll. When they finally completed this arduous task, a new vice president rejected the process they had used. This vice president didn't believe that the results accurately reflected the technical researchers' qualifications.

The new vice president's reaction is not all that surprising. Rank ordering gives rise to an ordinal scale. In strictest propriety, the ordinary statistics involving means and standard deviations ought not to be used with ordinal scales, for even these simple statistics imply a knowledge of something more than the relative order of data [75]. When only the rank order of data is known, we should proceed cautiously with statistics, and especially with the conclusions we draw from them [75]. Simply put, the new vice president recognized that group members had opinions that extended well beyond the ordered ranking and wanted a method that allowed a fuller expression of those opinions.

An outside consultant was hired to engineer a computer-supported voting process. The new scheme required each participant to submit both a ranking of each researcher and a measure of how strongly he or she felt about the ranking given. The senior managers then reviewed several different graphical analyses of their votes and found a great deal of confidence and consensus on some of the rankings, and a great deal of variation on others.

Subsequent discussion revealed that many managers did not know some of the people they were ranking and relied instead on second-hand information and public opinion. After much discussion and information sharing, the group voted again; this time they achieved a much stronger consensus. After the second vote, the group discussed their remaining differences and in short order arrived at an overall ranking of their technical staff with which all participants could live. They agreed that the new computer-supported voting process was much more efficient than traditional voting methods and that it inspired a more open and focused exchange of ideas. What was more important, everyone from the vice president down felt that the new rankings were more legitimate than those obtained from the earlier process. The confidence-weighted votes and graphical representations of voting patterns provided managers with a larger picture than they had previously seen.

Weighting methods have been tested in a variety of nonelectronic contexts and have seldom been found to perform much better than equal weighting as a means of improving group performance [20, 21, 81]. However, as with the current case, many GSS-supported voting experiments have found that weights improve the efficacy of the decision method [5, 45]. As Ferrell [31] points out, weighting methods may not have been tested in those situations and environments where they can be especially effective.

Getting Past Violent Agreement

Sometimes members of a team will vigorously debate issues upon which they actually agree. A startling example of this phenomenon occurred in a health-care organization that encompassed a dozen hospitals throughout a major metropolitan area. Three interest groups—doctors, administrators, and directors—set out to define a mission statement and to decide how various special services should be distributed among the hospitals. For reasons that were unclear, the process degenerated into an acrimonious battle—at which point someone noted that it had been three years since the groups had met without their attorneys being present.

The groups decided that electronic polling might be helpful in locating the source of the conflict and decided to conduct an experiment. Approximately 200 people attended a meeting where every participant was given a hand-held, radio-linked voting box. Using a large public screen, a facilitator displayed a number of policy statements such as, "When patients need emergency care it shall be given without reservation, regardless of ability to pay." Participants voted by agreeing or disagreeing with each statement as it was displayed.

Prior to the meeting, it was assumed throughout the health-care organization that doctors, as a group, were responsible for obstructing agreement and thus progress. The prevailing wisdom was that hospital administrators and directors were the peacemakers in the group, and that a good deal of their energy went into persuading the physicians to be more tractable. This assumption was shattered by the results. Analysis of the votes by subgroups revealed that, contrary to everyone's expectations, doctors and directors were in nearly perfect agreement on every issue. It was actually the staff administrators who were out of step, although for three years the administrators had been telling the directors that the doctors were causing problems.

A parallel situation occurred at a board meeting of a major nonprofit organization. As its group of twelve executives prepared a five-year strategic plan using a GSS, they reviewed funding for each activity supported by the organization. One such activity involved the broadcasting of public service announcements (PSAs). For years, PSAs represented the highest expenditure that did not directly provide a service to the organizations' constituents. However, the PSAs' role in educating the public was considered sacred. In an approval voting exercise [6, 7], the group indicated which activities, in their opinion, were worth further funding. To everyone's surprise, *none* of the twelve executives felt that PSAs deserved funding. The ensuing discussion revealed that each executive assumed that only he or she had a minority position. The board further learned that this situation had existed for many years on this issue—and others.

Maximizing Knowledge Use When Voting

Sometimes people do not consider sharing critical information until they are puzzling over a report of the spread of electronic votes. Traditional methods of measuring consensus that do not reveal group thinking patterns can prove costly. The head of a mining company used a computerized voting system for the politically highly charged task of allocating a budget across multiple corporate sites and projects. He asked a number of key executives for their opinions, but the results of the first poll were widely scattered. No one seemed to agree on budget priorities.

The president pressed his executives in order to understand why their voting patterns were so dissimilar, given that they all presumably had the good of the corporation in mind. Finally, one vice president ventured, "None of us really knows what goes on at all these places. We can't really make an informed recommendation." The president then arranged to have electronic comment cards included on the ballot, and advised the group, "If you know about a project, type in what you know. If you don't know, read what the others have typed." Within half an hour, the group had exchanged a great deal of information about the various projects and sites, and the subsequent vote-and-discuss cycle resulted in high consensus on the budget allocation. As the team left the room, one of the vice presidents pointed at an item on the bottom of the budget priority list, and commented ruefully, "We dumped $5 million dollars into that turkey last year." An eager champion had pushed the project, and when no one had information to dispute his arguments, the management council had simply taken a chance.

No More Mr. Nice-Guy

Electronic polling can sometimes facilitate decisions that are too painful to arrive at using traditional methods. A corporation with a particularly difficult budget crunch chose to use an electronic polling system to help decide the best way to downsize. In many previous meetings, the possibility of eliminating a large but ineffective division was raised but was set aside for fear of offending the division's head, who was a very personable and effective lobbyist for his employees. Although the division was generally unproductive, no one wanted to hurt the manager's feelings by pushing division's elimination. Instead, using traditional voting methods, the group consensus indicated that across-the-board cuts should be implemented. Everyone would bleed a little, sacrificing some efficiency in the interests of harmony.

When the electronic votes were tallied, however, it was clear that the most sensible and most widely supported alternative was to eliminate the ineffective division. In doing so, the organization would not have to make potentially crippling cuts to mission-critical functions, and at the same time it distributed responsibility for the decision among the participants.

Limits on Electronic Voting

Not all electronic voting sessions are successful. Occasionally, when all the votes are in, all the terms are defined, and all the hidden assumptions have surfaced, there are fundamental and irreconcilable disagreements between parties.

A savings and loan company faced a crisis that threatened its survival. During most of the discussion, people were optimistic that they would reach a consensus and proceed accordingly. Rather than converging, however, group members' views diverged as electronic voting proceeded. An analysis revealed that the group was, in fact, made up of several factions with mutually exclusive, deeply held positions. The session came to an end with an agreement to disagree. The only thing the participants knew was that, in light of the bitter disagreements they had uncovered, the viability of the current management team, and thus the company, was at stake. On the bright side, the team was now focused on the difficult problem, rather than wasting time squabbling about minor disagreements.

Lessons Yet to be Learned about Electronic Polling

In addition to making face-to-face meetings more productive, electronic voting plays a critical role in supporting geographically dispersed meetings. Remote meeting participants lack such nonverbal cues as shifting gazes, body positions, and gestures that let speakers sense when it is time for a discussion to move on.

Although many teams save time and money with electronic voting, it would be a mistake to view that as the technology's main advantage. Some groups spend more time on their deliberations when using electronic voting than with traditional methods. Research has shown that groups using structured voting schemes and response analyses to clarify communication and focus discussion consistently reach higher-quality decisions than groups using traditional voting methods [5]. Electronic tools that permit any participant to change his or her vote at any time and provide a real-time display of group voting patterns establish a different dynamic by indicating shifts in consensus. New network-based voting schemes permit a group to begin interacting long before participants arrive in the meeting room, and to extend interaction beyond the face-to-face meeting.

Lessons about the GSS Facilities and Room Design

The importance of the physical environment to the process and outcomes of technology-supported meetings has been reported in the GSS literature by several authors [62, 63, 64, 89]. GSS facilities range from the spartan to the opulent, from the inexpensive to the extravagant. An electronic meeting room need not be expensive to be successful, but we have learned from designing and using technology-supported meeting facilities that fundamental design considerations can enhance the impact of the technology on the meeting process (Table 7).

The Public Screen

Most GSS facilities include one or more public screens. A public screen is a way to give the group a common focal point, as well as a way to share public information [49]. When more than one screen is available, facilitators use the second screen to support electronic slide shows, provide a group view of a participant screen, display two different views of shared information, or bring an external document into public view. Multiple public screens displaying a single image may also improve viewing angles and shorten viewing distance for meeting participants.

Lighting Is Critical

The quantity and quality of lighting significantly affect both the performance and the satisfaction of workers [40, 87, 93]. The introduction of computer technology complicates the delivery of appropriate lighting [1, 69]. It is difficult to strike a balance between adequate lighting and the need to view a public screen. Standard office and conference space buildouts often include only fluorescent lighting, which washes out a front projected display. Optimal technology-supported meeting facility lighting balances the need for a clear bright public display with adequate workstation task lighting. And these two needs must be considered independent of the delivery of ambient lighting. The variety of tasks that occur during group support systems sessions requires multiple coordinated lighting systems in the room. There are several choices meeting-room designers can make to provide for better lighting:

- Use indirect rather than direct systems to minimize glare;
- Provide individual task lights with parabolic louvers;
- Use dark matte surfaces on countertops to reduce glare;
- Provide rheostat controls for variable dimming;
- Provide easy-to-use presets for the meeting leader.

Lighting is not only an environmental hygiene consideration; it can also be used by a meeting facilitator to focus group attention, affect group mood or energy, and communicate acceptable norms of group behavior. We often use lighting level as a nonverbal signal to a group when it is time to focus on their computer screens and when it is time to communicate verbally.

Seating Configuration

The first GSS facilities arranged participants on three sides of a rectangle with the public display at the open end. This configuration allows a reasonably good line of

Table 7. Lessons about Technology-Supported Meeting Facilities

- The public screen is important for focusing group attention; include two if possible.
- Appropriate task lighting is critical to the success of a GSS environment.
- Lighting can be used as a facilitation tool to moderate group process.
- Provide sufficient desktop space for spreading personal papers.
- Provide informal space for social interactions and personal space for reflection.
- Map table configuration to expected group activities.
- Provide for visual line of sight for participants. Nonverbal communication remains a large part of GSS meetings.
- Quiet ventilation can be supported by channeling air through the millwork to cool computers and buffer noise.

sight among participants and of the public display screen at the open end of the horseshoe It also allows the facilitator to step into the middle of the horseshoe to gain the group's attention. Several other configurations have been systematically tested in other classroom and GSS facilities with varying results [49, 50, 76].

Many GSS providers have built facilities utilizing the original arrangement of three sides of a rectangle. This focuses group attention quite well but does not allow for very large groups. With more than sixteen participants at the rectangular table, the distance between individual participants is no longer conducive to comfortable verbal conversation. Also, many participants will not be able to see other participants. Other facilities have made use of a round table with participants on every side. This focuses group attention well but places some participants with their backs to the public screen and limits effective group size to about twelve. Still other facilities have been designed as tiered auditoria. These facilities provide excellent focus toward a public screen but provide poor within-group focus. All seating configurations result in tradeoffs [32, 69]. It is important to consider the primary purposes of the facility and to decide the relative importance of group focus, access to the public display screen, and support for large group size.

Lines of Sight and the Work Surface

Some consideration must be given to the configuration of the work surface that will be made available to the participants, who must be able to see their computer screen clearly and they must also be able to see one another clearly. In some electronic meeting rooms, the CPUs sit on desktops with the monitors on the CPUs, resulting in a "Kilroy" effect. People strain to see over and around the technology. In such a setting, people tend not to engage in the proceedings; they lose interest and participation drops. Ideally, monitors should be partially recessed into the desktop so people have clear lines of site to one another. Some room designers have buried the monitors under a glass panel in the desktop, freeing the entire surface. This approach, however, is a mixed blessing because lights and windows create glare on the glass. Further, if this solution is chosen, care must be taken that shorter meeting participants have a clear line of sight to the embedded monitor once they pull out their keyboard drawer.

In recognition that it is difficult to keep the monitor viewing area free of papers and clutter during the meeting, the partially embedded monitor is a good compromise [54].

Along with space for the monitor, the work area must provide room for participants to spread out at least two full-sized sheets of paper. Despite good intentions of providing for paperless meetings, participants often need to work from documents while interacting in an electronic meeting room. We have been designing millwork to provide for at least eleven inches between the front of the workstation and the base of the monitor to allow room for a sheet of paper in front of the participant. Adequately spacing monitors gives each participant a small amount of visual privacy so that participants are less likely to view anonymous contributions typed in by other participants.

Social Space

It is often important to include social space along with the work space in a technology-supported meeting facility [57, 69]. We have built technology-supported meeting facilities to support GSS meetings that last a full day or several days. When a meeting will last longer half a day, consideration must be given to supporting both group process needs and individual needs. Most facilitators will use a variety of group process techniques during a lengthy meeting to keep a group fresh and focused. Facilitators may wish to break the group into subgroups or into individual assignments from time to time. The physical environment must accommodate such a variety of group dynamics. Further, groups will take breaks. The physical environment should allow caucuses to hold private informal conversations during those breaks. Group forming, storming, and norming activities often take place during such informal interactions. Informal negotiation and caucusing can often lead to breakthroughs that are difficult to achieve during a formal meeting protocol. The physical environment can support this by providing cozy nests, nooks, and crannies for private conversation. The physical environment can also provide white noise for acoustical privacy. One facility at Arizona has an outdoor fountain just outside the meeting room. The running water provides white noise that ensures acoustical privacy for small groups during breaks [60].

Individual needs can be supported by providing easy access to food, drink, and rest rooms. In addition, they can be supported by providing space where individuals can retreat to reflect or meditate. Some centers do this by including a garden with running water, foliage, and soft non-Euclidean shapes. Such space may provide both visual and acoustical privacy for individuals and small caucuses. Too often, technology-supported physical environment design projects are defined to be *just* a meeting room, and such vital spaces are overlooked.

Minimizing Ambient Noise and Providing Effective HVAC

Motors and fans on computers and projection equipment in a technology-supported meeting facility add both significant heat and noise to the environment. The quality of the ambient environment has been shown to have an impact on both performance [16, 80] and workplace satisfaction [16, 43, 80], and too much heat or humidity can damage computer equipment, and dust, smoke, or static electricity can damage data-storage equipment.

An effective heating, ventilation, and air conditioning (HVAC) system is critical to the success of a technology-supported meeting facility [54]. The exact amount of cooling required for a given facility will depend upon several factors, including the size of the facility, the specific equipment chosen, and the amount of sunlight or other external heat sources present. Design solutions include a stand-alone HVAC system, using air filters in an existing system, and installing antistatic carpet. While a stand-alone HVAC system may be expensive, it offers the advantage of remaining functional even if the central building system is down, as well as providing for finer tuning of meeting-room temperature and humidity controls.

Whether it is centralized or stand-alone, the HVAC system may actually contribute to problems of ambient sound. HVAC systems often include fans to move air and may produce significant ambient noise. One strategy used at Arizona to reduce this noise has been to place the HVAC returns beneath the computer millwork. Fresh cool air is dropped from the ceiling, as cool air naturally falls. Vents in the millwork accept the cool air, which then falls past the computer equipment and is sucked into floor ducts beneath the millwork. The heated air is removed from the environment without ever passing the meeting participants. In addition, much of the ambient noise generated by the computers is taken out along with the air.

Lessons Yet to Be Learned about GSS Facilities and Room Design

Much of the GSS physical environment research completed to date has been from an engineering orientation. We have built different types of rooms and millwork and then observed how participants behave in the completed space. We have not yet addressed the theoretical question of why participants behave as they do in technology-mediated collaborative space. While there is a rich environmental psychology literature to draw from, most of this territory remains uncharted, but environmental psychology will become vital to designers of virtual GSS environments We cannot build VR artifacts to support information communication structures in technology-mediated space until we know how the physical artifacts affect interaction in physical space.

Lessons from Facilitators and Session Leaders

The person who chairs an electronic meeting is the leader or facilitator. This person may be the group leader, another group member, or a separate, neutral individual who is not a group member. Using a nonmember enables all group members to participate actively rather than giving up one member to serve as chair. A nonmember can be a specialist in GSS and group work but may lack the task and group knowledge of a regular member. The meeting leader/facilitator provides four functions: First, he or she provides technical support by initiating and terminating specific software tools and functions and guiding the group through the technical aspects necessary to work on the task. This removes one level of system complexity and thereby reduces the amount of training required of group members. In some cases technical support is provided by an additional technical facilitator or technographer. Tandem facilitation can be beneficial with GSS technology since it is necessary to pay attention to both the group and the technology, sometimes simultaneously [10] (Table 8).

Second, the meeting leader/facilitator chairs the meeting, maintains the agenda, and assesses the need for agenda changes. The leader may or may not take an active role in the meeting to improve group interaction by intervening to provide process structure in coordinating verbal discussions, for example. This person also administers the group's knowledge. In a GSS designed without support for meeting leaders/facilitators, any group member may change or delete the group memory. When disagreements arise, competition among members for control can create dysfunction. While this is manageable for small collaborative groups, it is much less so for larger groups with diverse membership or where competitive political motives and vested interests exist. With GSS, members can view the group memory and add to it at their own workstations. On the other hand, when desirable, only the meeting leader/facilitator can modify and delete public information

Third, the meeting leader/facilitator assists in agenda planning by working with the group and/or group leader to highlight the principal meeting objectives and develop an agenda to accomplish them. Specific GSS tools are then mapped to each activity. Finally, in an ongoing organizational setting where the meeting leaders/facilitators are not group members, the meeting leader provides organizational continuity by setting ground rules for interaction, enforcing protocols and norms, maintaining the group memory repository, and acting as champion/sponsor. The roles of the meeting leader/facilitator may also change over time. For example, after a group has some experience using GSS, the need for technical support and agenda planning advice may diminish. Through both facilitation research and organizational practice, several lessons for GSS facilitators have been accumulated.

Plan the Agenda Carefully in Advance

The most basic principle for successful use of electronic meeting systems is that the task must be very clearly defined and meaningful to the group and the activity in which its members engage must obviously advance them toward accomplishing that task. Whereas a conventional meeting may wander for three or four hours before people realize it is off track, a GSS meeting can resemble a train wreck in a small fraction of an hour if it is not well planned. If the participants believe that the technology is wasting their time in irrelevant activities, they will quickly grow hostile or dysfunctional and refuse to continue [12].

The importance of pre-session planning cannot be overemphasized [25, 55]. Prior to a GSS session, the group leader must define exactly what concrete deliverables the group will create—be it a problem statement, a list of possible solutions, a documented decision, a plan of action, or whatever. Defining a deliverable can in itself be a difficult

Table 8. Lessons about Facilitation and Session Leadership

- Thorough, explicit pre-session planning is critical.
- The group must always see where they are headed and how each activity advances them toward the goal.
- Rehearse all GSS keystrokes so that meeting focus can be on the group rather than the technology.
- Small changes in tool setup make big differences in group dynamics.
- Expect that ideas generated will change the plan and the agenda.
- Mix modes between electronic interaction and verbal/oral interaction. Change locations and alternate between large and small groups every few hours to minimize burnout.
- Be aware of nonverbal communication behaviors among participants. Even small cues tell a lot.

task, but without it an electronic meeting is likely to founder. The group leader and facilitator must decide on a process for achieving the deliverable. This requires awareness of the GSS tools and the different dynamics each can produce. Having mapped out a process for achieving the goal, the leader must also be sure that the appropriate people are invited to—and will attend—the meeting. Any group that has a stake in the outcomes can and should be represented. This is much more feasible with electronic meetings than with conventional meetings because GSS meetings can include many more people without hampering group productivity and can also provide support to minimize political dysfunctions that might occur as a consequence of bringing hostile groups together.

Alternate Styles of Group Interaction

One source of group fatigue is the monotony of repeating the same kind of activity *ad infinitum*. This work strain can be reduced if the agenda allows the group to alternate among different interaction styles. One dimension for such alternation is electronic and oral interaction. Another is to move participants every so often from full-group activities to subgroup activities, and vice versa. Changing the work environment in these ways reduces monotony, which in turn improves productivity. Further, by varying the kinds of interaction, it is possible to stimulate different modes of communication that may produce synergies or break logjams of conventional thinking. GSS enable groups to be distributed among different modes of interaction in that the software can be used to blend parallel work into a single group repository. In addition, GSS can provide for easy and effective ways for each subgroup to report their work back to the full group and for the full group to evaluate what the subgroup has done.

Control of Participant Interaction

The facilitator can influence the amount of online discussion among participants with subtle verbal cues and with switch selection choices in the GSS software. For example, if the facilitator wants participants to respond to one another, the GSS discussion tools can be instructed to number all participant comments and he or she can explain and demonstrate how easy it is to respond to a comment by referring to its number. On the other hand, if the facilitator wants participants to focus attention on developing ideas already presented and to discourage cross-discussion, he or she can turn off the comment numbering function.

Nonverbal Communication

It is important for the facilitator to remember that the use of electronic communication technologies does not eliminate the power of nonverbal communication in the meeting room. The facilitator must be careful about delivering nonverbal cues. Position in the room, posture, eye contact, and gestures are all important ways the facilitator guides the group. In return, the attentive facilitator can receive significant nonverbal information from the group. For example, facilitators can learn to gauge group energy and interest in a GSS discussion session simply by listening to keyboard clicks. The noise level in the room will tell an experienced facilitator when the process is producing diminishing returns and it is time to move on.

Verbal Communication

Even though much of the group discussion takes place online during a GSS session, participant-to-participant online verbal communication can have a huge impact on the results of a session. A facilitator can use the amount of humor reflected in online communication to determine whether a group is anxious or bored. When a group is focused on the topic at hand, conversation should only show a moderate amount of humor. When the level of humor noticeably increases, the group is ready to move on.

A facilitator can implement structure and training choices during a meeting to affect the degree to which participants' verbal input is conversational in tone. If the facilitator wants participants to brain-dump ideas into the shared group memory, he or she can structure the GSS to include many parallel topics in tandem. If the number of topics is more than one-third the number of meeting participants, it will be difficult for participants to focus on what other participants are saying; they are then likely primarily to dump their own ideas into the repository. In addition, if the facilitator wants to stress interactive discussion among participants who are novices at GSS, he or she can take them through a two-stage training—first submitting a comment for discussion and then, in lock step, finding a comment and responding to it directly.

A facilitator can affect the quality of participant argument by probing and encouraging further development of arguments in online discussion [10]. Facilitators can also use the anonymity features embedded in GSS to encourage risk-free exploration of position rationale and argument development. Facilitators can encourage participants to play the devil's advocate (or do so themselves) to push for stronger supporting constructs to arguments.

Facilitator cues can have a great impact on group performance. One recent experiment [84] found that the facilitator could boost group performance in an idea-generation task by an average of 30 percent simply by changing two phrases in the instructions to the participants. Performance increased if the facilitator adopted a jocular tone and urged participants to "kick butt" rather than to "try," and suggested the participants would be "brain-dead" instead of "below average" should their performance flag. This small example illustrates a key point: GSS meeting tools, like the tools of a craftsman, must be used with skill and understanding. The success of the technology depends on both the quality of the system and the quality of the processes in which it is used.

Lessons Yet to Be Learned about Leadership and Facilitation

Much work in using technology to leverage facilitator productivity and facilitator knowledge in GSS sessions remains to be done. For example, the expert systems tools might be introduced into the session-planning process to help facilitators design meeting agendas and choose GSS tools. Software wizards might be introduced to guide the facilitator in real time during meetings at tool selection or group process awareness. Additional tools could monitor online group processes and provide facilitators with feedback on group productivity measures.

Currently, GSS facilitators are trained through apprenticeships that take several weeks to several months for even an experienced facilitator to become comfortable leading a GSS session. This has inhibited several classes of facilitators from actively embracing GSS technology. In particular, classroom instructors have been reluctant to incorporate GSS into their classroom processes, in part because of the heavy learning curve required. While making GSS facilitator interfaces simpler should help address this problem, researchers must develop methods to train facilitators more quickly.

Distributed facilitation is still a largely unexplored area. As more GSS are implemented as distributed systems, more facilitators will be called upon to lead distributed meetings. Little research has yet been undertaken to understand and improve the process of distributed facilitation. A vast amount of work will be required to address this issue.

Lessons about GSS in the Classroom

Over the past three years, a number of researchers have begun to explore the use of GSS to support learning. Early studies tended to be experimental and focused on automating standard classroom activities. For example, instructors lectured, then posed questions to students. All students responded simultaneously through the GSS [2, 13]. Class participation rose dramatically, and student interest increased substantially, but learning improvements were only marginal (Table 9).

Substantial benefits, however, accrued when researchers began to use GSS to enable new classroom dynamics that were impossible with standard methods [14]. A series of one- and two-year field studies explored ways to improve learning with GSS [14, 90].

New Technologies Enable New Pedagogies

The successful approaches required a fundamental change in the role of the instructor. Rather than being the "sage on the stage," delivering information, the instructor became the "guide on the side," leading students through the problem-solving process and directing them toward useful information The problems were framed such that the students perceived a vested interest in the resolution. The instructors chose problems carefully so students had to learn what the teachers wanted them to know in order to get what they wanted. Using the GSS, the students engaged one another online. This liberated the instructor from the podium and able to work with learners one-on-one as the class sought a solution.

At Orr Elementary School in Anacostia, Washington, DC [12, 90], 64 percent of the learners in this inner-city school were dropping out before finishing high school. Interviews with the learners revealed that they did not believe they would get good jobs or that they would be able to attend a university. They were concerned about surviving the urban environment from day to day; to them, school was irrelevant. The instructors reasoned that they might be able to reengage the disaffected by having them work on problems they themselves considered real and important. Solving real problems typically takes more time than a standard classroom allows, so it is usually not an option. With GSS, however, the instructors could choose not to lecture and could implement a cooperative learning process using real and salient problems. The learners were engaged and energized to find information for themselves, in the classroom, in the library, and online.

One teacher, who wanted the students to learn letter-writing skills, did not begin with a lecture on letter writing. She hung up a poster of proper letter formats and asked her twenty-two students if they would like to try to persuade Michael Jordan, the famous basketball player, to visit their school. The students jumped at the chance. The instructor guided the students through the process of solving that problem. They used electronic brainstorming to generate reasons why Jordan might be persuaded to come. The instructor's writing activity showed on a public screen at the front of the room. This modeled the letter-writing process for the students. Then the instructor asked the students to draw from the same idea pool to compose individual letters to the athelete. The students enthusiastically proceeded to write.

Their first efforts were technically atrocious. The instructor, who had still not lectured on letter writing, asked the learners to evaluate how persuasive they thought their first efforts would be. The learners determined that they were not very persuasive. The instructor pointed out the letter-writing poster on the wall and suggested that the learners help one another edit their letters. The learners worked for another hour and a half kneading their letters into acceptable form. The instructor circulated to help learners who had difficulties. The instructor then wrote a cover letter and mailed the bundle to the Michael Jordan.

The students did not persuade Jordan to come to their school, but subsequent efforts did bring an astronaut and a Marine Corps general to their classroom. Throughout the year the learners continued to use the GSS for team and individual writing on subjects

Table 9. Lessons about GSS in the Classroom

- GSS enables cooperative learning pedagogies that were not previously practical to implement.
- Using real problems that students find salient energizes participation and learning.
- The most at-risk learners can become the classroom leaders.
- Teacher–user interfaces must be simple so that teachers can attend to their students instead of the computer.

they considered important. Their reading and writing scores advanced two grade levels more than those of their peers in other classes.

The pedagogy in this case was radically different from the standard approach. The instructor did not deliver information. She offered problems the students considered important and guided them as they sought solutions. She suggested where they could find information (the poster) and helped them apply the information to their problem. The slowest learners in the class were not left behind by a fast-paced lecture. The brightest students were not held back by the slow pace of other learners. All participated fully. The new pedagogies did not depend on the GSS technology but would have been too time-consuming and unwieldy to implement without it. Therefore, GSS enabled new approaches to learning that engaged at-risk learners in ways not practical under standard methods.

Researchers tested the application described above in other case studies at the grammar-school, junior-high, high-school, and undergraduate levels. Pupils at all levels engaged successfully in the problem-based learning strategy. Their reading, writing, argumentation, problem-solving, and teamwork skills improved substantially; and a number of practical lessons emerged.

Vested Interest Motivates Cognitive Effort

The approach described only works when students perceive the problem to be real and pertinent. GSS tools typically allow for anonymous input. When asked to work on contrived problems, learners at all levels quickly resort to flaming and buffoonery. *Flaming* is when participants launch vitriolic personal attacks full of swear words and obscenity. *Buffoonery* is jocular off-task comments meant to disrupt or distract the group.

Several strategies for reducing flaming emerged. One instructor empowered all learners to delete contributions that offended them. Another asked all students to tag their contributions with a matriculation number. This identified the learners to the teacher, but not to one another. Several teachers made an extra effort to raise the students' awareness of their vested interests in the problem. In the end, however, it became clear that the GSS was only an effective tool when the learners valued the work it supported.

The Most At-Risk Learners Can Become the Leaders

The most disruptive and disengaged learners often became the leading contributors to projects they cared about. Several factors may account for this. First, these were the learners who had decided school was irrelevant and they were willing to take action on their belief. When they decided the online activities were relevant, they may have chosen to act on that belief. Second, these learners tended to be older than their peers, having been held back one or more grades, so they may have brought more developmental maturity to the tasks in which they engaged.

New Technology Can Be Tough on Teachers

Students in these studies had no problems with the new technology. Teachers, on the other hand, faced several difficult barriers. First, teachers already have a very demanding job, yet it often fell to them to build and maintain the computer networks upon which the technology ran. Their schools were not attuned to the need for technical support. It became clear over time that teachers do not have enough time both to run their classes and to maintain networks. Long-term solutions will require that the functions be separated. Systems must be configured so that teachers can bring their students into collaborative environments effortlessly.

For some teachers, their own assumptions constituted a barrier. Some had difficulty not thinking of themselves as information-delivery specialists but thinking of themselves instead as mentors to learners on a quest toward goals important to the learner. Only after they gained experience with GSS did they begin to understand that newer, more powerful roles were available to them. It is therefore important not to place the technology in a school and leave it. During the first year, a person with a good grasp of the new pedagogies must be in residence and available to help teachers plan online activities.

Teacher Interfaces Must Be Simple

It has long been the goal of GSS developers to make interfaces so simple that novices can begin work with less than a minute of oral instruction. One technique developers have used is to offload much of the complexity from the participant interface to the leader interface. Classroom teachers, however, have more demands on their attention than do managerial facilitators. In addition to attending to the learning content, they must also monitor their students' cognitive development and deportment. Field experience revealed that teachers needed interfaces that impose substantially lower cognitive loads than do the facilitators of managerial meetings.

Lessons Yet to Be Learned about GSS in the Classroom

While early studies suggest that substantial benefit may be derived from the use of GSS in the classroom, little is known about how best to integrate the technology into the physical classroom environment. What is the best arrangement for tables, chairs, screens, and keyboards to support cooperative learning? What changes should be made to lighting and windows? What other resources should be readily available?

It is also not entirely clear what would be the best way to help teachers learn to wield the newest tools in their kit. Day-long, week-long, and month-long training courses have been ineffective. Only year-long partnerships between novice teachers and teachers knowledgeable about GSS have been effective. The main difficulty for teachers new to GSS is not with running the technology—that they appear to learn in three or four days. It is that they face a new teaching paradigm that has no support from past experience, textbooks, manuals, activity books, or any other resources that would help them figure out what to do with the GSS. It is far too expensive to put trainers in every classroom for a year. New methods and approaches will have to be developed before widespread rollout can begin.

Much remains to be learned about other possible uses for GSS in the classroom. Existing studies constitute early forays close to the frontier. As fieldwork continues, new methods and techniques should emerge.

Business Process Reengineering

Business process reengineering (BPR) and its cousin, business process improvement (BPI), are often applied to ascertaining how an organization can transform itself to meet its future needs. Over the past five years, the University of Arizona has used GSS tools and methodologies with numerous government and private organizations seeking to accomplish BPR/BPI (Table 10).

GSS Supports Large Heterogeneous Reengineering Teams

One of the most consistent lessons we have learned is that both large and small groups whose members come from all organizational levels can successfully accomplish BPR/BPI. Using GroupSystems in combination with specially designed facilitation protocols enables diverse and often antagonistic groups to deal efficiently and effectively with the issues and complexities associated with BPR/BPI [23]. With GSS, groups with as many as thirty participants have been able to work effectively. These groups are too large for traditional BPR/BPI facilitators to work with effectively. Large groups allow consideration of more subject-matter expertise and ultimately increase the degree of members' buy-in to the proposed new processes. It is possible to introduce large groups to the BPR/BPI by using parallel subgroups at various stages of the model-development process.

With large heterogeneous teams working on BPR/BPI, the results of various sessions and subgroups will have to be summarized and integrated. It is easy to develop a relatively complete product with consensus and buy-in of subgroup members in a session that does not *travel well* beyond the subgroup context. It is also possible for the full group to develop a product that does not *travel well* to the organization as a whole. Consequently, BPR/BPI opportunities can become insulated and fail to be

Table 10. Lessons about GSS for BPR/BPI

- GSS supports larger, more heterogeneous BPR/BPI teams.
- Special-purpose modeling and graphical GSS software is desirable.
- GSS can reduce the time required to complete a modeling process.
- GSS can aid in data collection from subject-matter experts, but the experts still require facilitation in organizing data relationships.

implemented. Special care must be taken to provide briefing packages that session participants can use to promote change.

Special-Purpose GSS Software Is Advisable

BPR/BPI modeling processes require structures that do not exist in most GSS software packages. A desirable feature is specific tree and network structuring with rule or consistency checking. Graphical representation of this information is also extremely helpful. Special modeling tools to structure participant input and graphical displays of results are recommended to sustain a group dynamic and facilitate the process. Without such tools, a group is unable to successfully participate in modeling, does not make maximal use of effort, or may develop a "compost heap" of processes that serve neither the needs of a group nor the needs of system developers. Several special-purpose tools have been built at Arizona specifically to support the BPR/BPI process.

BPR/BPI Requires Both Facilitators and Modelers

The group dynamic associated with BPR/BPI is different from other group support sessions and requires a combination of modeling and facilitation. This marriage is difficult to achieve and frequently requires session support beyond what is normally supplied for group sessions. Successfully supported groups, however, develop a sense of buy-in and support that is otherwise rare in BPR/BPI activities [23].

It is difficult to combine modeling and facilitation techniques in a way that results in a defined organizational role. The key to success seems to be recognizing the intersection between the modeling and facilitation roles and establishing a team approach to supporting groups and organizations. By so doing, it is possible to establish self-sustaining organizational support without need for a consultant.

GSS Can Reduce Model-Building Time

Groups using GSS tools for BPR/BPI were able to create process models up to seven times faster than groups using traditional (non-GSS) facilitated techniques. This was thanks to a bottom–up approach to model building. However, because it became difficult and time-consuming to reconcile errors in these bottom–up models, a more traditional top–down approach was developed that was still two to three times faster than traditional facilitated techniques [22]. Field studies have demonstrated that GSS promote very fast data collection from subject-matter experts, but these subject-matter experts require significant facilitative help at organizing relationships among the data elements [46].

One unanticipated benefit has emerged during field studies: At a particular government agency, non-GSS BPR/BPI sessions often lasted eight weeks. For this reason, managers often sent their less vital or less proficient staff members to modeling sessions—those whom they could more easily spare for so long. This meant, however, that new work processes were often engineered by the least vital, least experienced, or least competent workers. The GSS BPR/BPI sessions allowed the same model-building work to be accomplished in about two weeks, and managers were consequently more willing to assign their more vital employees.

Lessons Yet to Be Learned about GSS and Business Process Reengineering

Despite many and varied successes in laboratory and field settings, the use of GroupSystems tools remains relatively rare in comparison with the total number of BPR/BPI sessions. It remains to be learned how to successfully capture the attention and secure the commitment of consulting groups and organizations actively to incorporate GroupSystems technology in BPR/BPI.

There is also much we have yet to learn about facilitating distributed BPR/BPI sessions. It is not uncommon for organizations to be unable to successfully assemble an optimal set of stakeholders for any length of time. Stakeholders who are invaluable to BPR/BPI activities are generally also invaluable to other organization activities. An ability to involve remote participants actively and successfully remains to be documented.

The extension of GroupSystems technology beyond static modeling to support simulation and animation is expected to be especially helpful with participants who need to validate complex models as well as in evaluating alternative "to-be" scenarios. If as successful as anticipated, animation could provide a value-added component to BPR/BPI activities.

Conclusions

RESEARCHERS AT THE UNIVERSITY OF ARIZONA HAVE LEARNED a great deal about successful GSS collaboration but a great deal remains unexplored. The field is growing rapidly in many different directions. A dozen years from now, when we look back on today's technology, it may look like it was in a horse-and-buggy stage. GSS will continue to evolve with improvements in both technology and processes. Some problems will still be so intractable that no single person can solve them. Technology will still improve communication, still structure and support thinking processes, and still provide access to information.

With all the research that has been done, we have barely scratched the surface of GSS research. For example, we know that on-line communication must be much more explicit than verbal interactions; geographical separation amplifies the need for explicitness an order of magnitude. What can be done to ease communication losses for a geographically separated team? A great deal of research has been done on electronic brainstorming and idea generation, yet idea generation is only a small part of the overall effort of a team engaged with a GSS. Little research has been done to examine processes for converging quickly on key issues, or for exploring key issues in depth. Far less is known about the organizational changes engendered by GSS. Almost nothing is known about GSS adoption and diffusion. How and why does power shift within organizations using GSS? How can teams make sense of the vast quantities of information now available to them on-line? The next decade will likely bring some answers, and many more questions.

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