Taxonomy and Theory in Computer Supported Cooperative Work

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Abstract

In the mid-1980s, when most hands-on computer use was still confined to one person and one computer, a group comprising social scientists and technologists began convening under the label Computer Support Cooperative Work to discuss how technology could support groups, organizations, and communities. The resulting research, presented in annual conferences and journals, has had to adjust to the extraordinary growth of activity as the Internet and World Wide Web have transformed work. In this chapter, we examine the evolution of the participants and topics covered in CSCW, the frameworks and typologies that have been used, and we discuss the diverse if somewhat limited roles that theory has played in guiding CSCW research and application.

Keywords: Computer Supported Cooperative Work, CSCW, Human Computer Interaction, HCI, technology, typology, framework

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Introduction

Computer Supported Cooperative Work (CSCW) is a community of behavioral researchers and system builders. They reside primarily in human-computer interaction (HCI) groups in computer science departments, information schools, and industry research laboratories. CSCW generally focuses on software developed for widely-available platforms and directly used in end-to-end support of communication, collaboration, and coordination tasks.

Individual tool use may contribute indirectly to such tasks, but its study is left to other HCI disciplines. For example, a project management system in which every team member enters status information would be considered a CSCW system, whereas if one person collects and enters the data, it would not. Typically, CSCW software includes a representation of group participants or tasks. A typical database that strives to treat each user in isolation is not within the scope of CSCW; one that supported communication among its users could be.

Given its preference for platforms in widespread use, CSCW had a narrow but growing focus through the 1980s and 1990s. Inspiration was drawn from early writers and prototype builders who foresaw a future of discretionary computer use in group settings. A celebrated instance is Douglas Engelbart's public demonstration of email, videoconferencing, and other novel hardware and software on December 9, 1968 in San Francisco.

Social science has always been part of CSCW, but the research has primarily resided in Computer Science departments and industry research labs that had the infrastructure support and technical skills to build experimental prototypes. A notable if not ultimately successful exception was work on electronic meeting rooms, central to *Group Decision Support Systems*, carried out in Management Schools. Product developers also contributed to early research. Recently, some CSCW research has migrated to Information Schools as they have become more open to system development as a facet of research.

In this chapter, our principal goal is to provide a guide to what is in the CSCW literature, what is not found there, and a sense of where CSCW research is headed. In the abstract, a broad span could be envisioned, but in reality CSCW is a research niche determined by forces that act on and around the contributing disciplines. Since 1990 we have given survey tutorials on CSCW at most major HCI and CSCW conferences, requiring continual examination of technology development and the research literature. Grudin and Poltrock (1997) and Grudin (1994; 2012) are sources for some of the history and participation discussed in this chapter.

The next section is a high-level view of CSCW technologies and social research, concluding with descriptions of two published analyses of the CSCW literature. Then CSCW precursors, its emergence in 1984-1986, and its subsequent evolution are detailed. A critical and often under-emphasized aspect of the history is the dramatic change in the power and capability of the underlying hardware over the thirty years. The instability resulting from technology change profoundly affects the prospects for developing useful theory in this field. Different paths taken by North American and European CSCW are also described. We then present framing models of technology development and use, followed by descriptions of many of the taxonomies and typologies found in the CSCW literature. These typically include a mix of technical, behavioral, and activity characteristics. We review uses of theory in CSCW research and practice. We conclude with a description of research issues and directions that we anticipate or encourage.

In this chapter we cite some journal articles and many conference papers. Curious readers from journal-oriented disciplines must understand that most North American Computer Science research is found in its final form in highly selective, widely-accessible conference proceedings. This is the case for CSCW.

Overview of CSCW

In this section we describe the technologies spanned by CSCW research, closely following the outline of a recent handbook chapter by Gary and Judy Olson titled *Groupware and Computer-Supported Cooperative Work* (Olson & Olson, 2007). We then cover the potential and realized social science contributions, drawing on a 2003 book chapter by Robert Kraut, and finish by describing two analyses of the CSCW literature. A comprehensive view of CSCW origins is found in Ron Baecker's collection *Readings in Groupware and Computer-Supported Cooperative* Work (1993).

Technology Overview

Olson and Olson (2007) begins with a discussion of infrastructure requirements. This was once a core consideration, but with the near-universal presence of the Web and client-server architectures, it is now generally taken for granted. A 1999 volume with chapters by several leading CSCW researchers, now available online, has contributions titled "architectures for collaborative applications," "groupware toolkits for synchronous work," "group editors," and seven others (Beaudouin-Lafon, 1999).

When CSCW emerged in the mid 1980s communication tools were its first focus and have remained central. Email was first and is occasionally a topic of research today. Weblogs and microblogging sites such as Twitter are recent foci, as is the use of other social networking sites. In between came voice, video, and text conferencing, coauthorship support, instant messaging, and text messaging. Studies of prototype desktop video systems have been prominent in CSCW, with waves of research in the late 1980s, mid-1990s, and early 2000s. If video communication finally blossoms, CSCW studies covering a range of social and interface issues, some quite complex, could contribute (Poltrock and Grudin, 2005).

Tools that support coordination include meeting support systems and group calendars, which were prevalent in the first decade. Awareness indicators became prominent in the second decade. Workflow management systems garnered attention despite a weak track record. Characteristic of the skeptical view of CSCW toward the relatively inflexible workflow approach is Bowers, Button, and Sharrock's (1995) nice description of problems that arose during a significant deployment of workflow technology in a large printing enterprise.

Computer supported cooperative learning is a conceptually relevant field predominantly published in other venues, but with a few papers in the CSCW literature. Artificial intelligence was briefly present at the origin of CSCW but is now represented mainly in work on recommender systems, which themselves are reported on more extensively in other venues such as the Intelligent User Interfaces conferences.

Information repositories are another technology focus. They range from document management systems to wikis. Today, Wikipedia is a mountain of freely-accessible information with a complete edit history over which an army of graduate students swarms, analyzing it in different ways. Papers by CSCW researchers, published at CSCW conferences and related tracks at other conferences, include studies of conflict through history flow visualizations (Viégas, Wattenburg, & Dave, 2004), image contribution and editing (Viégas, 2007), Wikipedia administration (Bryant, Forte, & Bruckman, 2005; Burke & Kraut, 2008), and incentive systems (Kriplean, Beschastnikh & McDonald, 2008).

The creation of virtual spaces or places in which to interact has been a thread of CSCW research beginning with the *media spaces* first explored at Xerox PARC in the early 1980s. Research into virtual environments, such as multiuser simulations and virtual worlds, has, like desktop video, waxed and waned in interest and representation. The most ambitious efforts are collaboratories developed to support large-scale multisite efforts, primarily in scientific research, engineering, and education. The Olsons and their colleagues have been at the heart of this work (Olson & Olson, 2007).

Social Research

In an excellent review 15 years after CSCW emerged, Kraut (2003) outlines how social psychology might contribute to the design and use of tools to support groups in novel ways or to enable novel forms of collaboration. Kraut (2003) notes the value of understanding factors that contribute to effective group processes and factors that lead to social loafing and process losses, and that these could differ for collocated versus distributed groups.

Kraut (2003) then explains why social psychology has not contributed much to this engineering discipline. Contextual and motivational factors that are typically abstracted away in experiments are crucial in the settings of interest to CSCW researchers. For example, the experiential and motivational heterogeneity of real-world groups can yield variability that swamps the experimental effects of studies conducted with small groups of psychology or MBA students.

CSCW formed precisely when research into group and team behaviors shifted from social psychology to organizational psychology. Circa 1985, emphasis on interpersonal interaction and performance gave way to research into what groups do and how they do it (Kozlowski & Bell, 2003). Social and organizational psychologists initially participated in CSCW, but the organizational psychologists who focused on technology use had alternative publication outlets and soon left. CSCW in North America only slowly recapitulated the progression noted by Kozlowski and Bell (2003). It took time for the allure of small-group solutions that might be independent of organizational context to yield to studies embedded in particular contexts. When it came, this evolution did not mark the return of organizational psychologists to CSCW, but resulted from the contributions of ethnographers studying technology use in industrial settings. These scholars were more academically marginalized and open to participation in CSCW. Some of these disciplinary shifts are described in surveys such as Grudin (2012). In addition to living through the changes, we have retrospectively analyzed participation on program committees and conducted interviews of participants.

Sciences generally strive for frameworks that are independent of technology, which is consigned to engineering. With CSCW, engineering and other contextual factors cannot be extricated because they affect the frameworks that emerge from behavioral studies. For example, Kraut (2003) divides group size into these units: individual, dyad, small group/team, organization, and society. CSCW technologies do not readily span these group sizes. The limitation of viewing digital information on small displays and the early development of software tools to support large software development projects motivated different unit sizes. Desktop video software could only comfortably support three or four simultaneous participants, who do not need mechanisms for controlling who speaks, whereas other applications support larger groups who do need these control mechanisms. Quite different considerations arose in supporting units larger than a group but smaller than an organization.

Two Analyses of the CSCW Literature

The CSCW conference held in 2006 marked 20 years since the first open conference. Two papers marked this anniversary by analyzing and summarizing the conference papers published from 1986 to 2004 (North American conference only). Jacovi, Soroka, Gilboa-Freedman, Ur, Shahar, and Marmasse (2006) analyzed the citation graph of all 465 papers to identify the core and major clusters within the field. They identified eight clusters, of which the two largest correspond roughly to social science (83 papers) and computer science (82 papers). The social science cluster includes papers about theories and models, ethnography, and user studies. The next largest cluster (43 papers) comprises meeting/decision support, shared media spaces, and conferencing. A fourth cluster comprises 12 papers on instant messaging, social spaces, and presence. The fifth is seven papers on the use of computer tools such as email in the workplace. The remaining clusters (each of five papers) were groupware design and workspace awareness; management of computing and information systems; and video-mediated communication and shared visual spaces. The computer science cluster was relatively stable over 20 years, but the others evolved considerably. The current social science cluster was a collection of much smaller clusters that coalesced. The 47 core papers identified by the authors are listed at http://en.wikipedia.org/wiki/CSCW.

Convertino, Kannampallil, and Councill (2006) categorized each paper by type of institutional affiliation, author's geographical location, its level of analysis (individual, group or organization), type of contribution (theory, design, or evaluation), and type of collaboration function investigated (communication, coordination, or cooperation). They reported that 60% of authors are from academia and 40% from industry, and although most are from North America, European and Asian participation has grown. About 80% of the papers are about small group collaboration and nearly all of the rest have an organizational focus. The proportions of design (corresponding roughly to the computer science cluster of Jacovi et al., 2006) and evaluation (corresponding to the social science cluster) are about equal, although in any given year one or the other may dominate. At the first three conferences about 30% of the papers offered a theoretical contribution, but with the flight of MIS researchers this subsequently declined to fewer than 10%. Throughout the history of the conference the preponderance of research has focused on communication. In early years relatively few CSCW papers discussed coordination, but now about half the papers address this topic. Fewer than 20% of recent papers address cooperative work by their measure.

In the next section, we consider crucial historical forces, including one omitted from most accounts: technology change.

Historical Context and Evolution

In 1980, an era was ending. For 15 years, business computing had been dominated by huge, expensive mainframe computers sold by Burroughs, Control Data, IBM, Sperry, and others. Mainframes were acquired to support key organizational goals. The principal users were executives and managers, who read printed output. Few people interacted directly with the technology, which was generally too expensive to be used for interactive tasks such as email or word processing.

The 1980s would see the rise and fall of minicomputers. Supplanted by PCs and largely forgotten today, minicomputers catapulted companies such as Data General, Digital Equipment Corporation, and Wang Laboratories into prominence. The PDP series culminating in the VAX made Digital the second largest computer company in the world in the mid-1980s. Dr. Wang was briefly the fourth wealthiest American. Minicomputers changed the way many people thought about computers and work. This included the research community, which embraced their use.

Minicomputers, a fraction of the size and price of a mainframe, were acquired by small businesses or to support departments and groups within large organizations. Minis ran productivity applications such as word processing, business graphics, spreadsheets, and email. Use of these *office information systems* was hands-on and interactive. *Office automation* was an explicit goal and in the name of four conference series and symposia first held between 1980 and 1982, one affiliated with a large tradeshow.

In 1984, two office-automation researchers, Irene Greif of MIT and Paul Cashman of Digital Equipment Corporation, coined the acronym CSCW for an invited workshop of technologists and social scientists focused on supporting or understanding workplace collaboration. Email use was a major topic—at the time, email was poorly designed, not interoperable across products, and bereft of social norms to govern use. An account of the workshop, titled "Computer Supported Cooperative Groups," was given at the 1985 Office Automation Conference (Greif, 1985). The first open CSCW conference was held the next year. By 1988, the minicomputer industry was collapsing, the office automation conferences had dissolved, but CSCW had seized the baton. Beginning that year, CSCW was sponsored by the Association for Computing Machinery Special Interest Group on Computer-Human Interaction (ACM SIGCHI), the psychologist-heavy enclave within the principal professional organization of computer scientists. The era of client-server PC networks was getting underway.

The term *computer-mediated communication* was used prior to the arrival of computer-supported cooperative work, and continued to be used by some researchers with that specific focus. *Groupware* was commonly used to describe the technologies by 1990, but lost currency a decade later, when group support features could appear in virtually any application.

The introduction of technology to support teams had several consequences. First, digital technology revealed and often left a persistent record of previously ephemeral group activity. This facilitated study of group behavior. Second, designing, marketing, introducing, and using these technologies created new challenges for vendors and purchasers, focusing their attention on the activities to be supported (or automated). Third, over time, use of the technologies altered aspects of group work.

In theory, computer supported cooperative work could be broadly construed to cover any aspect of work in which digital technology plays a role. In practice, the CSCW research field is what it is, constrained by severe technological limitations in its early years, and by the shifting backgrounds and interests of the researchers who contribute to CSCW conferences, journals, and books. It includes some research that ranges broadly, emphasizing collaboration without computers. It includes useful methods that could be applied beyond group settings. It includes study of entertainment and play. In addition, research that conceptually fits under the label is not covered in the conferences or in CSCW surveys; it may be reported in other conferences and journals, or its absence may reflect different interpretations of the scope, such as how extensive the representation of groups or group processes should be in the software to be considered.

Technology Change

Work is the core noun, revealing a strong commitment to a focus on behavior. The North American conference series typically has parallel tracks on technology use and technology design. However, the common view of CSCW as a figure with one foot firmly planted on human nature and behavior and the other on digital technology is misleading. The two foundations differ dramatically in their stability

Human nature and social organization change slowly—the management of pyramid builders and Roman legions may differ from that of shopping center construction and infantry battalions today, but perhaps not by much. In contrast, technology has been changing at a pace unparalleled in the history of tool-building.

The stability of human nature provides the time and incentive to build and test models or theories that govern individual, social, organizational, and cultural behavior. In contrast, the name *computer supported cooperative work* has been a constant, but the computer of 1985 has scant resemblance to the computer of today. A 10 megabyte memory drum cost several thousand dollars then. Today, 10 terabytes—a million-fold increase—is less expensive, smaller, faster, more reliable, and easier to install and use. On various dimensions, computer hardware capability increased two orders of magnitude each decade, giving rise to major new platforms and human-computer interaction research disciplines (Figure 1).

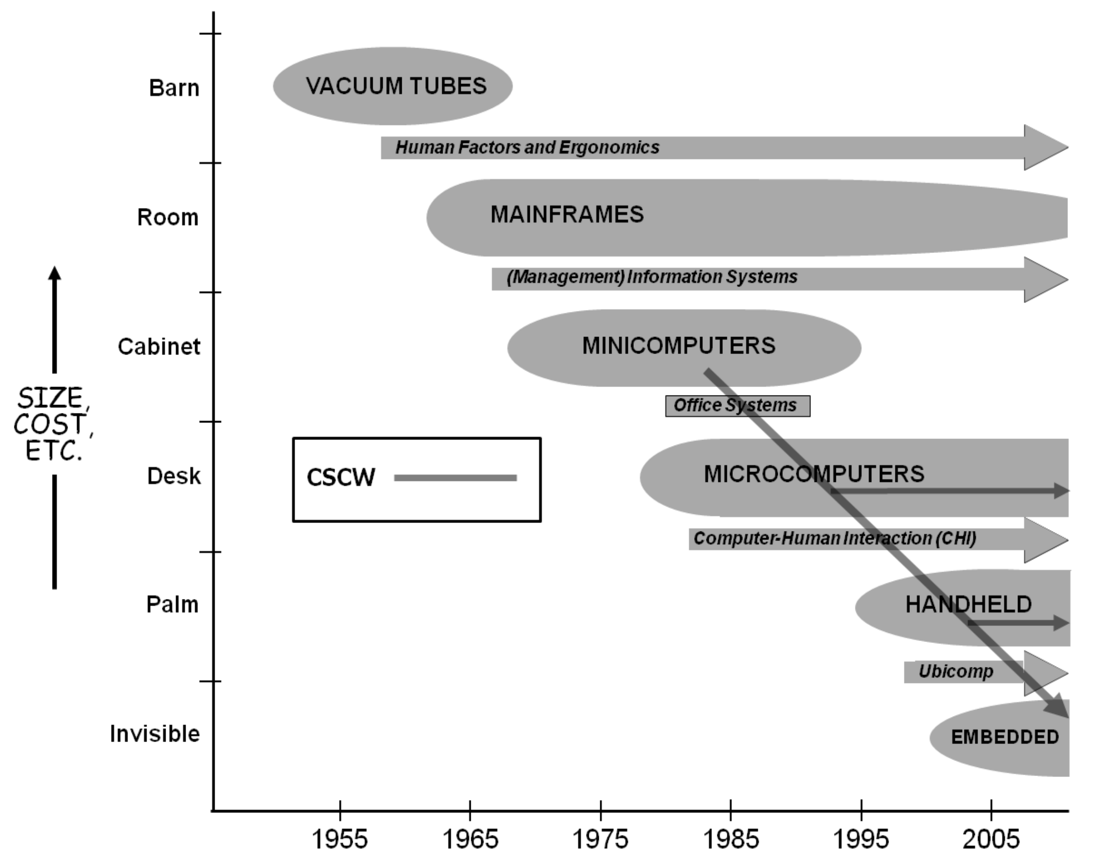

Figure 1. Hardware platforms, HCI research fields, and CSCW. CSCW is represented by the branching arrows that start with and descend from Minicomputers

Successive waves of technology and falling prices enabled new applications, brought computation into new domains, and supported activities at ever finer granularities. It made geographically distributed teams and global organizations more manageable, affecting social behavior in workplaces.

The role of technology change is often overlooked. For example, in his 2003 survey, Kraut wrote that the CSCW research community coalesced out of dismay at the individual user focus of human-computer interaction research and development. But prior to 1985, technology at affordable prices was hard pressed to support a single user, much less a group. Many of the people involved early in CSCW were cognitive psychologists who realized that the single-user focus, although useful, was increasingly limiting. The telecommunications companies were an exception: With their focus on communication, often dyadic, they had from the outset hired social psychologists, including Kraut himself.

To see the impact of technology change on social research in CSCW, consider studies of the ongoing *awareness* that people have of the activities of distant collaborators. For many years, people were aware of what collaborators sent them, and little else. Passive awareness was technically difficult, and no papers with *awareness* in the title appeared in the first five CSCW conferences. At that point, local and wide area networks were becoming robust, and from 1992 through 1995 there were three papers with *awareness* in the title. By 1995, the World Wide Web was taking hold, and *awareness* appeared in the titles of 12 papers from 1996 through 1999.

Equally interesting is a marked shift in the stances taken toward the phenomenon of remote awareness. The first paper, "Awareness and Coordination in Shared Workspaces" (Dourish & Bellotti, 1992) was a widely-cited celebration of the achievement and potential utility of this new capability. Several years later, post-Web, the focus shifted in no small measure to risks of *too much* awareness, as in "Techniques for Addressing Fundamental Privacy and Disruption Tradeoffs in Awareness Support Systems" (Hudson & Smith, 1996). In 1992, early desktop video prototype builders could write in defense of allowing people to surreptitiously watch their colleagues: "One-way connections have advantages we are unwilling to give up. Glances allow us to maintain our awareness of colleagues without actually engaging in interaction with them… Video provides an excellent means to gain awareness unobtrusively; enforcing symmetry for the sake of privacy would undermine this functionality" (Gaver et al., 1992).

This view retreated slowly. A novel technology elicits efforts to maximize its use and tolerance for rough edges. A subsequent system provided an audible notification that one was being watched, but no indication of who was looking. Eventually, the desirability of invitation and reciprocity in collaboration among peers was established. Research also identified designs that worked or did not; for example, people reacted poorly to an intuitively simple feature of inviting someone to a video conference by dragging his or her icon into your office on a floor plan map.

Impact on Theory

Instability wrought by technology change undermines theory-building. A researcher has no sooner staked out theoretical turf and started to farm it then a wave of innovation washes the shoots out to sea. This affects CSCW, but is a broader problem.

Researchers still alive once worked at packing information more efficiently on 80-column punch-cards. In the early 1980s, command-line interfaces dominated interactive computer use. Cognitive psychologists at the forefront of HCI research worked on command naming as part of a theoretical framework that would enable us to design from principles. The commercial success of the graphical user interface (GUI) in 1985 rendered the project moot, to the dismay of those who expected their work to be a foundation for future research and development. Other theoreticians worked rigorously on effective representations of information on static, monochrome monitors. Color monitors and animation swept in, rendering that work irrelevant before it was complete.

Closer to social technologies is the case of language understanding, the holy grail of human-computer interaction. Billions of research dollars were spent developing computational models of linguistic theory. Careers were built on topics such as anaphoric reference. But it went slowly, and when technology made possible the rapid processing of huge text corpora, statistical approaches to language understanding largely supplanted linguistic theory. The researcher-editor of a special issue of *Communications of the ACM* on natural language understanding railed against changes underway, but then seemed resigned to the idea that "it would be bags of tricks and not theory that would advance computational linguistics in the future" (Wilkes, 1996).

Interpersonal messaging systems offer another example. Studies of email conventions were prevalent in office automation and early CSCW research, but email as a medium changed radically over time. Throughout the 1980s, memory was too expensive to save messages, so email was initially an informal, ephemeral medium, in which spelling and grammar were not important. Email did not support attachments, so printed or typed documents were distributed. The business value of email was uncertain: A 1992 CSCW paper argued from the perspective of organizational theory that email undermined productivity (Pickering & King, 1992).

Then technology changed everything. Standards enabled the reliable exchange of documents, spreadsheets, and slide decks, and email became mission-critical for managers. Memory costs fell, spelling checkers appeared, and archived email became formal records. Early data and theory about email use no longer applied at all, it was outdated soon after publication. Perhaps it could have had an afterlife when Instant Messaging (IM) spread in the early 2000s, lauded as the informal, ephemeral, attachment-free alternative to email. But the lessons had not been learned. Corporate IM etiquette guides appeared; analysts counseled organizations that IM was a threat to productivity, and the cycle repeated.

Four examples follow of major research conclusions that ignored or were quickly reversed by dynamic changes in technology. In some cases, mainstream media picked up the original report but not the subsequent about-face. Some are by CSCW leaders and published in other venues. Others were published in *Communications of the ACM*, received by all ACM members, which evolved from being a journal to a serious professional magazine over these years.

Example 1. A well-executed study of Internet use suggested negative effects on social development (Kraut et al., 1998), whereas subsequent data suggested that changes in experience, technology, or the Internet itself had erased this effect (Kraut et al., 2002). Although data were carefully analyzed and speak for themselves, they were shifting sand, not a promising foundation for theory construction.

Example 2. The "productivity paradox" debate of the 1980s and 1990s was given prominence by a 1987 observation of Nobel laureate economist Robert Solow. Analyses indicated that organizations were not realizing benefits commensurate with IT investments. A decade later, new analyses appeared claiming to refute this. For example, Brynjolfsson (1993) presented the paradox and Brynjolffson and Hitt (1998) refuted it. There is evidence, though, that IBM had recognized in the 1960s and 1970s that its customers were getting not productivity but prestige and a reputation for being forward-looking (Greenbaum, 1979). And, in fact, both sets of analyses could have been accurate—not discussed is the fact that decade after decade, many cost components dropped and capability increased sharply—especially in the 1990s. Hardware costs dropped, fewer companies had to develop all software internally, and with computer savvy rising among employees new and old, less training was required.

Example 3. Hoffman, Kalsbeek, and Novak (1996) reported that flawed sampling by Nielsen had created a 30% exaggeration in Internet participation. This was described as significant for market planning. But no one disputed that Internet participation was doubling annually, ergo a 30% exaggeration was insignificant—it was an *underestimate* by the time the study was reported. This example points to the lack of understanding of the implications of rapid change. In a similar misreading of supralinear growth, earlier studies that showed a high number of inactive Internet nodes were taken as a sign that Internet use might collapse. As long as the number of nodes doubled annually—and this did not stop—the rate of abandonment was inconsequential.

Example 4. The possibility of obsolescence always looms, threatening even results that seem established. Consider geographically distributed teams. Studies indicated that to perform effectively, they should initially and periodically meet face to face. But now consider the millions of multi-player game enthusiasts. Game quests can require up to three dozen participants with different skills and roles, who must show up at a set time and execute well for an hour or more, or the beast will win. They do not meet face to face, disproving the truism. We do not know which factors might be critical, but we do know that those players enter the workforce in growing numbers and may establish different approaches to distributed team formation and motivation (Brown & Thomas, 2006; Reeves, Malone, & O'Driscoll, 2008).

Forays into theory are covered in a later section, but CSCW largely eschews theory-building and experimental hypothesis testing. Many CSCW researchers are wary of fields such as Information Systems that dwell on such approaches. Many of them (including the authors of this chapter) were trained in experimental approaches, but moved to qualitative studies and the natural quasi-experiments that waves of technology deployment make feasible. A technology could be adopted by projects in different lifecycle phases, teams with different compositions and cultural norms, or organizations facing different external pressures. Temporal and contextual variables that are present in workplaces but not in controlled experiments can prove more important than factors that are feasibly manipulated. Widespread technology adoption enables patterns to emerge, or not, across organizations of diverse natures, rewarding qualitative study.

It is easy to underestimate the value of descriptive and other pretheoretical contributions to science. Mendeleyev constructed the periodic table based on patterns in observed properties of elements. He had no theory, just as Linnaeus had no theory behind his classification of plants and animals or Brahe behind his organization of celestial observations. But their work was crucial to the theorists Bohr, Darwin, and Kepler. Theoreticians were active before these frameworks were constructed, but most were alchemists, theologians, and astrologers who retarded science more than they advanced it. Taxonomies and typologies that have been used in CSCW despite being pretheoretical in this sense are addressed in a later section.

North America and Europe

Since 1988, CSCW conferences have alternated between ACM-sponsored conferences in North American and European conferences (ECSCW). The series began with different emphases, but participation overlaps and some differences attenuated over time.

North American CSCW began with participants from psychology, software engineering, sociology, anthropology, management information systems (MIS), organizational theory, and AI (artificial intelligence, in particular multiagent systems; Greif, 1988). AI was riding high in 1984 with well-financed responses to the Japanese *Fifth Generation* effort, but by 1990 an *AI winter* had set in and AI disappeared from CSCW. The psychologists and software engineers were mostly CHI researchers expanding their focus from individuals to small groups. The relevant MIS and organizational theory research resulted from scaling down from an organizational focus to large groups that less expensive systems could support. Group Decision Support System research had begun in MIS departments in the early 1970s, continued through the 1980s, and in 1990 two start-ups and IBM brought them to market, albeit without much success.

In North America, and in Japanese and other Asian countries in the 1990s, CSCW comprised mainly young researchers and practitioners, the latter employed by large computer and software vendor companies. With the success of single-user applications such as word processors and spreadsheets in mind, these companies sought *killer apps* that supported groups. Powerful workstations emerged in the late 1980s that enabled CSCW research to extend beyond email and computer-controlled analog video to applications such as collaborative writing and knowledge management.

In contrast, Europe lacked an intensely competitive software product industry. The IT focus was on computer use in government and industry. The European CSCW community had an organizational perspective, but in contrast to the managerial bias of MIS, it was political and focused on empowering workers. This provided common ground with the young North Americans focused on pleasing consumers, but significant differences in research orientations stemmed from organizational versus small-group foci.

Research method biases differed, at times sharply. Although North American researchers largely avoided experimental studies and social theory, they engaged in user studies to quickly identify probable flaws in interaction design. Many ECSCW researchers eschewed laboratory studies altogether due to the salience of contextual factors in organizational behavior. European research often supported long-term development: a system might take ten years to design, build, and deploy. Accordingly, a European paper might only describe requirements analysis or a theoretical justification for a system. With far shorter product development cycles the norm for North American CSCW efforts, papers were expected to cut to the chase and include use data, for at least a prototype system. Participatory Design, involving eventual users as active participants in development, fit the European context of in-house organizational development, especially in the egalitarian Scandinavian countries where researchers explored it. It did not transfer easily to the production of mass-market applications.

Until recently, neither CSCW nor ECSCW embraced quantitative approaches, sociological analysis, network analysis, or data mining. With Participatory Design and small-scale user studies in the beginning and ethnography in later years, researchers favored specific or qualitative approaches. With the emergence of accessibility of high volumes of behavioral data on the Internet, Web, and other networks, this is changing. It is still rare to see work that employs both quantitative and qualitative methods, despite a sense that the future lies there.

An influential development in North America was ACM's decision in the early 1980s to archive conference proceedings. They were initially available by mail order after conferences as inexpensive hardcopies, and later in a digital library. As U.S. conferences shifted from a community-building role to quality gate-keeping, rejection rates to 75%-85%. This, in turn, reduced the incentive to progress CSCW conference papers to journal publications.

Interviews indicate that the conference focus was a factor in driving MIS research out of CSCW. To write a paper that met the standards of an ACM conference required almost the effort of journal publication in a field that valued the latter more. In contrast, European conferences proceedings were not generally accessible after the conference. There the emphasis remained on journals, and the 1992 formation of a research journal *Computer Supported Cooperative Work* was an all-European effort. No U.S. journal followed. (Several of the ECSCW proceedings were published as expensive books by Kluwer, and they are now available online.)

Both branches of CSCW welcomed ethnographers. The design-oriented North Americans favored broad observations and the Europeans leaned toward ethnomethodology and sociology. More Europeans embraced action research and overt political objectives; North Americans reaching for mass markets saw such considerations as tangential or unscientific.

Over time there was convergence, arguably mediated by the United Kingdom. In particular, Xerox established a CSCW-oriented basic research laboratory in the UK that interacted with its sibling Xerox PARC. Comprising a mix of ethnographers, sociologists, and technologists, it played strong roles in both conference series. Researchers came to appreciate different perspectives, at least more than they had previously.

Incoming waves of technology helped wash away differences by promoting fresh starts. Organizations that once built systems from the ground up and thus could afford insular perspectives increasingly relied upon commercial applications. The desire to support activities in ever-finer detail pushed small-group researchers to greater consideration of organizational and community contexts.

Consequences of Technology Evolution

Between 1988 and 1996, ten or more books with Computer Supported Cooperative Work in their titles were published. The most significant technology-driven shift was the growth of the Internet and emergence of the Web around 1995. CSCW did not take the lead in research in these consumer-driven areas, and attention shifted. Essays looking to conceptualize CSCW as a field were no longer published, and to our knowledge Ackerman, Halverson, Erickson, and Kellogg (2008) is the one book in English with CSCW in its title.

A striking effect of the rapid advance of technology was that each of the terms in the CSCW acronym has lost applicability.

Computer. The computer was a sensible focus in the 1980s. Digital technology is now embedded in many devices not called computers, the design and use of which is part of CSCW.

Supported. Twenty-five years ago, computation was brought in to *support existing activities.* Today much work is *centered* on digital information. Computation is in a focal role, not a support role.

Cooperative. This word reflected the small-group product focus that dominated in North America. Designers of a coauthorship system, for example, are happy if it succeeds with cooperative coauthors. This word displeased organizational behaviorists from the outset. In a CSCW 1988 conference panel, Rob Kling challenged the assumption of cooperation, noting that organizational behavior is more complex: “Why not computer supported conflictual work? Coercive work?” Other suggestions were collective, coordinated, or collaborative work, the latter marred by lingering associations to World War II collaborators.

Work. Well into the email era, use of computation to support group activity was restricted to workplaces. The cost of sending a single email message was greater than the price of a postage stamp (Panko, 1981). PCs and Macintoshes were difficult to network until around 1990. Today, the CSCW research community engages a full range of consumer activity, including play.

Reflecting this shift, in 2009 the Springer CSCW book series changed its title to the more playful *Collaboration, Sociality, Computation and the Web*. CSCW 2010 adopted this as a tagline.

Models of Technology Development and Use

Figure 2 depicts a model that we find useful. We begin at the top with people collaborating, perhaps with digital technology, perhaps not. That is the core issue. People collaborate. A fundamental premise in CSCW is that technology could help them do so more efficiently or effectively or enjoyably. This is not always true, but with advances in power and scope, digital technology can often support activities, and in ever finer-grained detail. Where does that technology come from? Following the diagram clockwise from the top, someone must determine the requirements for a technology that could help people collaborate. Second, research or investigation may be needed to find the technology if it exists, or to define a new technology and a process for making it. Third, the technology must be developed and made ready for people to actually use. Then one of two things must happen, depending on who has created the technology. If it is made by a company for its own internal use, it is deployed to the employees. If made for others to use, people must be persuaded to acquire it, and, therefore, it must be marketed. Finally, people must adopt it. They must decide to use it and figure out how to do so.

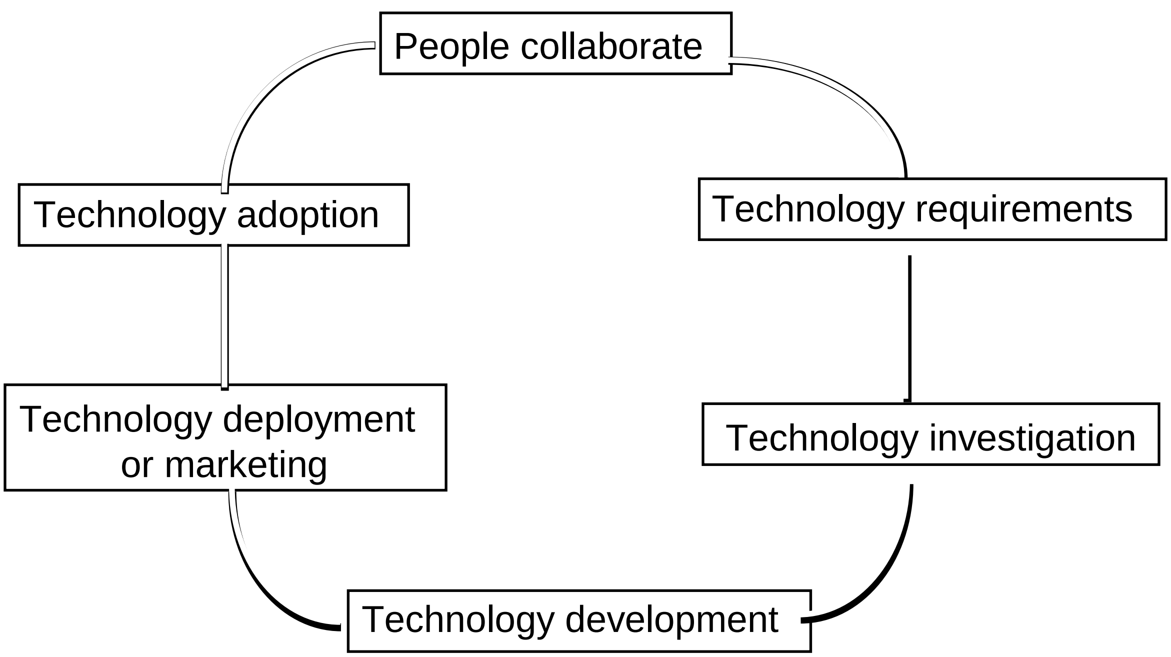

Figure 2. A model of collaboration and technology introduction.

We are then again at the top of Figure 2. People may or may not use the technology as envisioned, and over time their use evolves as the technology is understood better or is used alongside other new technologies or processes. And then, in no small part because of the shifting price and power of digital technology, it may be time to begin the cycle again, by gaining a deeper understanding of current use and considering requirements all over.

Each step in Figure 2 constitutes a domain of human activity for which methods or theories have been developed or adapted. Social scientists in the CSCW community explore how people collaborate in various settings, define high level requirements, and investigate adoption patterns. Computer scientists explore technology requirements and investigate and develop new technologies. Technology deployment or marketing have received relatively little attention within the CSCW community.

Maturation of Technology Use

In a field of invention and rapid maturation, not all design and assessment follows the same course. Figure 3 shows stages that often occur as a technology matures, with rows for the users of a technology, the priorities of the interaction models or user interfaces (UI), and typical research approaches at different points. A novel technology or application faces shifting considerations as it matures. Use begins with hobbyists and researchers, often moves to routine use in business where kinks are worked out, then to adoption by consumers delighted to be able to afford it, and finally to sophisticated use marked by a desire for personalization. Watches began with inventors, were later used by railroads, eventually reached broad markets with inexpensive identical Timex watches, and later came Swatches as fashion statements. This is seen in everything from washing machines to word processors, although steps may be omitted or the progression may be more complex.

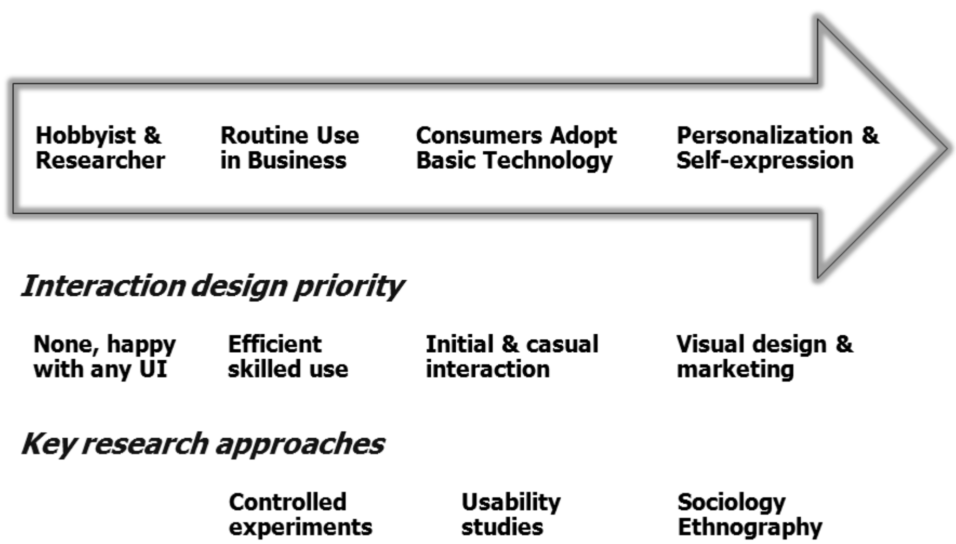

Figure 3. Adoption of new technologies.

Consider the computer keyboard and monitor. Little consideration was given to their design or usability until businesses hired data entry personnel, such as airline reservation agents or telephone operators. Then keyboards were carefully optimized for efficiency. With consumers came the need to support initial or casual use, leading to greater simplicity, such as dedicated function keys. Eventually, personalization arrived, with keyboards that differ in color, sleekness, and ergonomic considerations.

CSCW's focus on widely used platforms with minimal expectation of training means that progression from initial encounter and casual use to personalization can be relatively rapid. Students became early adopters who shaped technology use, despite lacking the money usually required, because government underwrote many expensive university computers. The technologies of interest to students were primarily those supporting communication and personal information management, such as email and word processing, and not, for example, databases.

The flow of novelty means that at any point in time, different technologies are at different points of the Figure 3 progression. This affects research and application. Email had reached wide use when IM made its first inroads into business. Digital videoconferencing moved slowly from research into business, and is likely to become a successful consumer product. Products in mature technology areas, such as the Blackberry and the iPhone, compete through design.

Maturation of Technology Design

A technology can be disruptive or can represent an incremental change. For example, the first wiki introduced into an organization could represent a fundamentally different way of looking at collaboration. When anyone can enter information and edit others' contributions, issues of authority and accountability are raised. After these issues have been resolved, a new and improved wiki will encounter different constraints on design, introduction, and use. In Figure 4, steps from Figure 2 are shown with bar heights as rough, schematic representations of the relative significance of steps in each context. For an innovation intended for use by hobbyists, early stages require attention; for a new version of a mature product, later stages get more attention. The key point is that the literature contains many descriptions of both mature and innovative system development and use that do not call attention to differences that lead to the use of different methods, frameworks, and emphases.

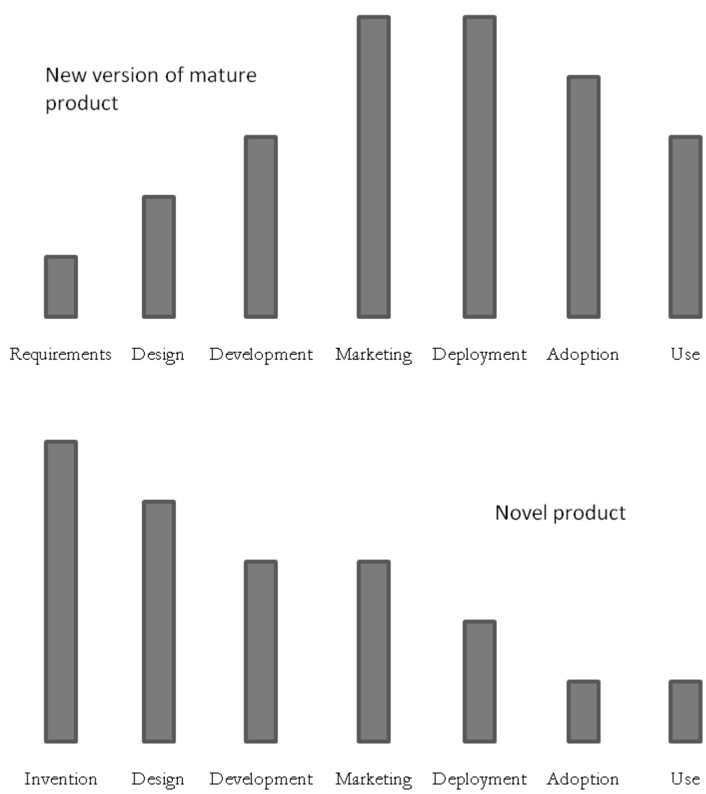

Figure 4. Schematic illustration of development phases in two technology categories. The y- axis depicts the significance of the activity.

Figures 2 through 4 are intended to guide thinking about the frameworks and theories that follow and the CSCW literature in general. The application/conceptual frameworks, research methods, and development approaches differ greatly according to phase of development and use. The link often is not spelled out in specific papers. In surveying the literature, readers are encouraged to give thought to when a paper was written, its author's field, maturity of the technology, the context of intended or actual use, and the points in the collaboration and technology cycles that are under consideration.

Taxonomies and Typologies Used in CSCW

Taxonomies and typologies in CSCW are pretheoretical constructs that characterize cooperative work and identify the technologies that support different types of work. Especially in the early years, technical features were often explicitly tied to their position within one of the frameworks we will describe.

Johansen's Four-Square Map and a Nine-Square Extension

The simplest and most widely cited taxonomy is the *Four-Square Map of Groupware Options* proposed by Robert Johansen and his colleagues in the late 1980s (Figure 5a). It inspired researchers and developers to reflect on the dimensions that influence collaboration and different ways of supporting group activities.

		Place	
		Same	Different
Time	Same	Electronic meeting room	Application sharing
	Different	Shift work, team rooms	Email, newsgroups

Figure 5a. Four-Square Map of Groupware Options from Johansen et al (1991).

Interaction can occur synchronously or asynchronously, and it can be collocated or distributed. Representative applications illustrate the different cells. People unfamiliar with CSCW technologies could quickly grasp this framework and apply it to their work environments. Indeed, it provides a convenient way to pigeonhole new technologies. Spatial and temporal differences translate into different technical requirements. Well into the 1990s, technology limitations often forced applications to focus on activity residing in only one cell, such as support of a real-time face-to-face meeting.

A subtle issue was the degree of predictability of a digitally mediated interaction. An activity can be carried out in a single place, in multiple locations known to the participants (e.g., email exchanges), or in numerous places not all of which are known (messages posted to a netnews group). Activity can be carried out in real time, asynchronously yet predictably or constrained, as with email sent to a colleague, or at times that are highly unpredictable, as in open-ended collaborative writing projects. In 1991, we extended Johansen's framework by subdividing the *different place* and *different time* categories, shown in Figure 5b. Of course, a task type may not fit uniformly into a cell—for example, one collaborative writing project could take place in a single session, another could involve a large set of people assembling a major piece of documentation over time. And research was not uniformly extensive across cells; support for work shift handoffs and team rooms was of less concern.

		Place		
		Same	Different but predictable	Different and unpredictable
Time	Same	Electronic meeting room	Desktop video-conferencing	Multicast events
	Different but predictable	Work shifts	Electronic mail	Newsgroups
	Different and unpredictable	Team rooms	Collaborative writing	Workflow

Figure 5b. Distinguishing predictable and unpredictable differences in time and place from Grudin and Poltrock (1991).

Groupware Taxonomy Based on Organizational Research

MIS researchers who examined organizational support saw that the one-person-per-office assumptions of most distributed work experiments did not fit organizations, where interaction was often among collocated groups at different locations. Nunamaker, Dennis, Valarich, Vogel, and George (1991) proposed the taxonomy shown in Figure 6 that distinguishes a single collocated group, individual participants at different locations, and multiple collocated groups. In conformance with the constraints imposed by display size, they distinguish groups of up to seven from larger groups. Display technology has *not* changed rapidly. If a long-predicted breakthrough in displays materializes, another wave of innovation is likely.

A Developer's Taxonomy

Ellis and Wainer (1994) proposed a conceptual model to guide developers, which has seen some use. It integrated aspects of technology with basic characteristics of use. Its three components were an ontology of groupware, the temporal coordination or organization of activities, and the user interface. The ontology covers the data structure supported by a groupware system and the operations that it supports. For example, a collaborative drawing program comprises objects such as polygons and operations for creating and modifying them. The coordination model describes how participants' interactions with the system are managed. A system could permit simultaneous interaction with the same object or permit only one person at a time to interact with it. The user interface model describes how actors interact through the system. Interaction may be achieved by displaying attributes of the objects manipulated by other participants, by displaying representations of other participants, or by displaying shared context, such as progress toward an objective.

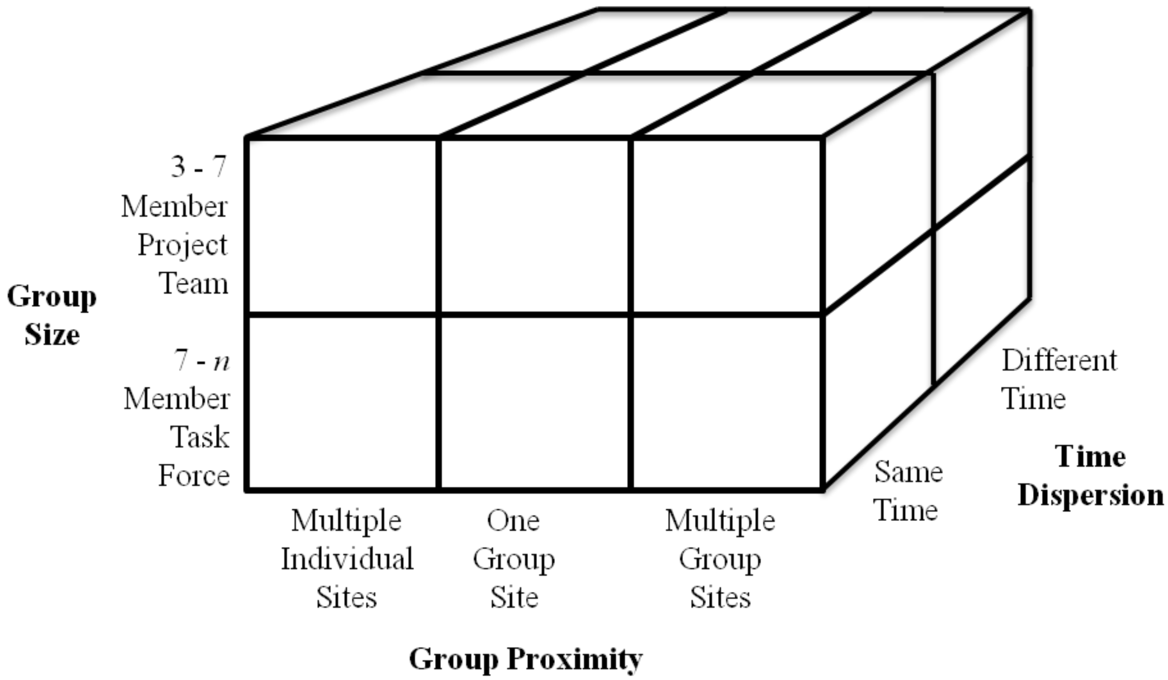

Figure 6. Taxonomy of groupware from Nunamaker et al (1991).

Two Recent Activity-Based Taxonomies

In tutorials on CSCW and Groupware over 15 years, we used many of the aforementioned taxonomies before settling on the framework shown in Figure 7a. It retains the temporal dimension, adds an activity dimension, and includes a social structure dimension that is hidden in the figure but emerges as overlays. The core activities are communicating, sharing information, and coordinating. Features of a technology can support any combination of these activities performed synchronously or asynchronously. In practice, people collaborating face-to-face in real time, as in meetings, often have little interest in using technology to coordinate their contributions. Instead, they rely on formal or informal social protocols, such as Robert's Rules of Order or the lessons learned when playing together as children. Because the social protocols often rely on nonverbal information that is not communicated by a technology, support for real-time collaboration across distance, such as teleconferences or application sharing, requires features such as floor control and session management to facilitate coordination.

When people collaborate, it is generally in the context of (a) small groups or teams, (b) organizations, or (c) large-scale communities. Communities in the online context only rarely have a geographic element. When groups of more than around seven work together, they generally establish subgroups and an organizational structure to coordinate the work. These different social structures rely upon different sets of cells of the Figure 7a framework. Small groups or teams are likely to work together in real time, communicate informally and share information, and they have minimal need for coordination technologies. Organizational collaboration involves the coordinated activity of different groups or teams to achieve common goals. Asynchronous collaboration is the dominant mode for large organizations, and information sharing and coordination are critical. Most communities have fewer explicit shared goals and thus do not require coordination technologies. Community members want to communicate and share information asynchronously with each other.

	Real time	Asynchronous
Communication	• AV conferencing • Telephone • Chat, messaging • Broadcast video	• E-mail • Voice mail • FAX
Information sharing	• Whiteboards • Application sharing • Meeting facilitation • MUDs and CVEs	• Document management • Threaded discussions • Hypertext • Team workspaces
Coordination	• Floor control • Session management	• Workflow management • Case tools • Project management • Calendar & scheduling

Figure 7a. Modes of collaboration from Poltrock & Grudin (1998).

Okada (2007) proposed an ambitious, multilayered hierarchical framework, the result of a decade of analysis of experience with a range of systems (Figure 7b). This framework posits that the experience of collaboration is strongly influenced by the degrees of assertion and cooperation exhibited by participants. Low levels of both result in compromise, more assertion than cooperation results in collision, more cooperation than assertion results in concession, and high levels of both result in coordination. This collaboration layer is supported by sharing: sharing views and opinions through communication, sharing knowledge and information, and sharing work and operations. The sharing layer, in turn, is supported by awareness of other human participants, the environment in which the work occurs, and the objects and tools that are involved. Finally, awareness is affected by the temporal and spatial factors that were the focus of earlier taxonomies.

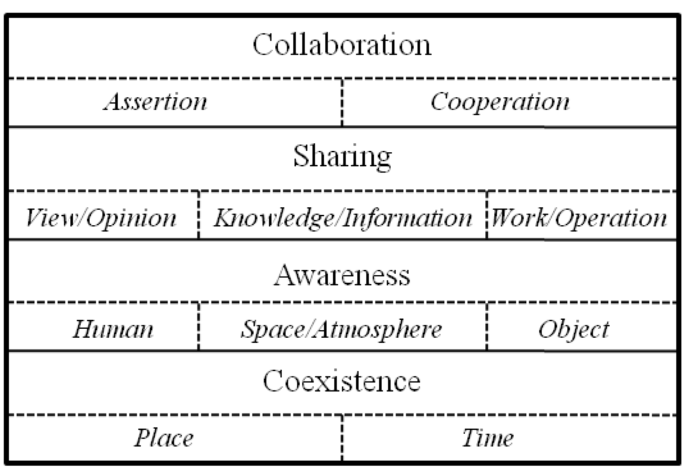

Figure 7b. A hierarchical collaboration model from Okada (2007).

The DeSanctis and Gallupe Taxonomy

In 1987, MIS researchers DeSanctis and Gallupe proposed the first taxonomy, specifying three dimensions that they felt should drive the design of groupware (Figure 8). Physical location and group size were dimensions picked up by others, but we introduce this taxonomy here because their third dimension, task types, bridges to typologies that did not originate in CSCW but which have proved very useful in understanding CSCW research findings. Specifically, their task types were based on McGrath's framework (1984), which is discussed below and appears in Figure 9b.

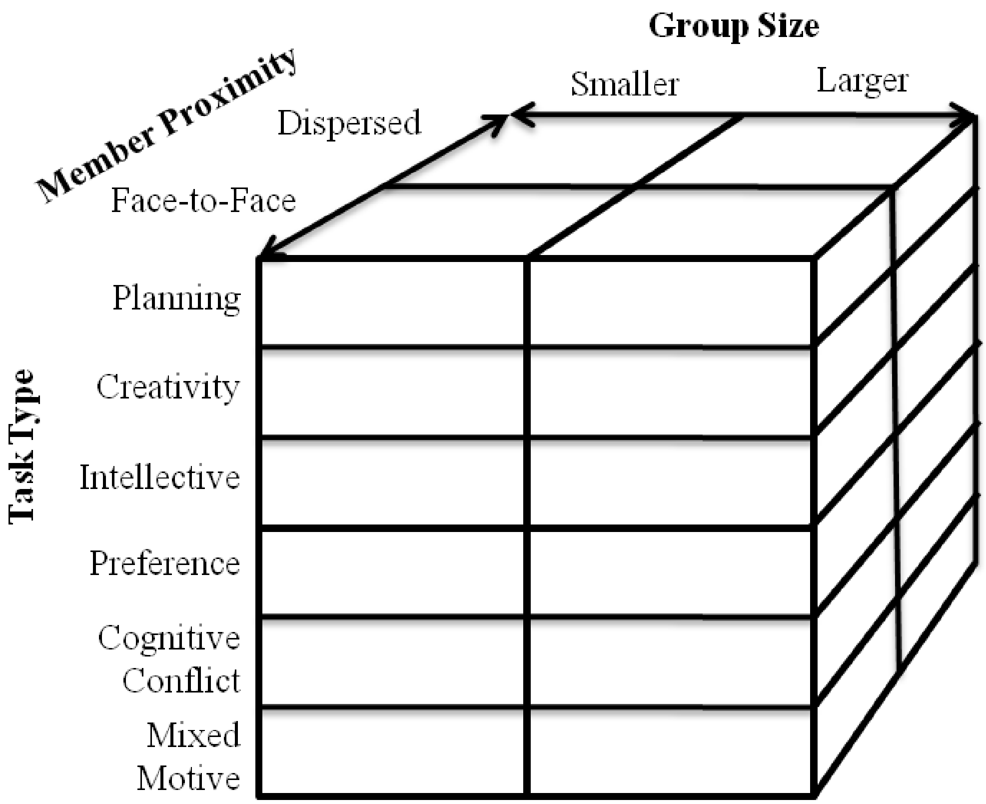

Figure 8. A taxonomy representing group size, member proximity, and task types from DeSanctis & Gallupe (1987).

Why was the focus on task types dropped from taxonomies that found favor over the next twenty years? The answer lies in the historical context outlined above. CSCW is an engineering discipline, driven by technology-producing companies and academic computer scientists with common interests. They sought lowest-common-denominator tools that would be useful in as many contexts as possible. Email was the quintessential success case, yet it had little representation of social context. CSCW researchers generally avoided special cases (such as *mixed motive*). When MIS researchers ceased participating in CSCW, pressure to consider such factors subsided. Perhaps this enabled more focus and progress in some directions, but overlooking these considerations slowed the recognition of some patterns that were emerging.

A more recently-developed taxonomy (Bolstad & Endsley, 2003) includes elements of all the taxonomies above, including task types. Its dimensions include tool category (e.g, video conferencing, email), collaboration characteristics (i.e., time, predictability, place, and interaction), tool characteristics (i.e., recordable, identifiable, and structured), information types (e.g., verbal, textual, video), and processes, which are similar to the task type dimension of DeSanctis and Gallupe (1987). The purpose of this taxonomy was to guide the development and selection of tools to support the military, not the common-denominator tools of interest to CSCW researchers and developers.

McGrath's Typologies of Team Behavior

We conclude this section with two social science typologies: Joseph McGrath on the functions and modes of activities in groups or teams, and Henry Mintzberg's analysis of the forces at work in different parts of organizations. Neither author focused on technology use, but the potential relevance of their work has become clear.

McGrath (1991) described team behavior in terms of three functions and four modes, shown in Figure 9a. This typology may seem evident, yet it can be a revelation, because studies of technology deployment and use focus almost exclusively on a single cell of this framework: performance, combining the production function and execution mode. The holy grail of *return on investment* translates into short-term measures of productivity (Grudin, 2004b). Even when a specialized technology focuses on another mode, such as a negotiation support system, policy resolution becomes the performance measure.

	Production	**Group well-being**	**Member support**
Inception	Production demand and opportunity	Interaction demand and opportunity	Inclusion demand and opportunity
Problem-solving	Technical problem solving	Role network definition	Position and status achievements
Conflict resolution	Policy resolution	Power and payoff distribution	Contribution and payoff distribution
Execution	Performance	Interaction	Participation

Figure 9a. Functions and modes of team activity from McGrath (1991).

Activities that support group health and support group members are common in organizations, but they often occur without conscious consideration or are overlooked as tangential to the task at hand. This tendency to focus on the production function explains some apparent mysteries in the literature. Dennis and Reinicke (2004) found evidence that the absence of support for group and member well-being explains the lack of commercial success of group support systems with proven ability to increase performance. Anonymous brainstorming may work well in studies, but the identity of a speaker may be crucial in the work place, and credit for their contributions may motivate participants. One participant in a meeting conducted using a group support system told us that it was the most unpleasant meeting he had experienced in his life, despite its success at accomplishing its stated objective. Video is a second example: Decades of studies showed that it provided no performance advantage over audio, but more recently video had significant effects in problem-solving and conflict-resolution tasks (Veinott, Olson, Olson, & Fu, 2001; Williams, 1997).

McGrath's (1984) circumplex in Figure 9b has three task dimensions: conceptual versus behavioral, conflictual vs. cooperative, and whether the focus is on generation, selection, negotiation, or execution. Once again, most CSCW research and application focuses on a single cell, executing performance tasks. Although this figure has impressed many CSCW researchers and students, the field's performance focus seems to hinder using it to advantage. The narrow focus can mean that users of resulting systems struggle to find ways to use them to support activities in other cells, or may abandon use altogether.

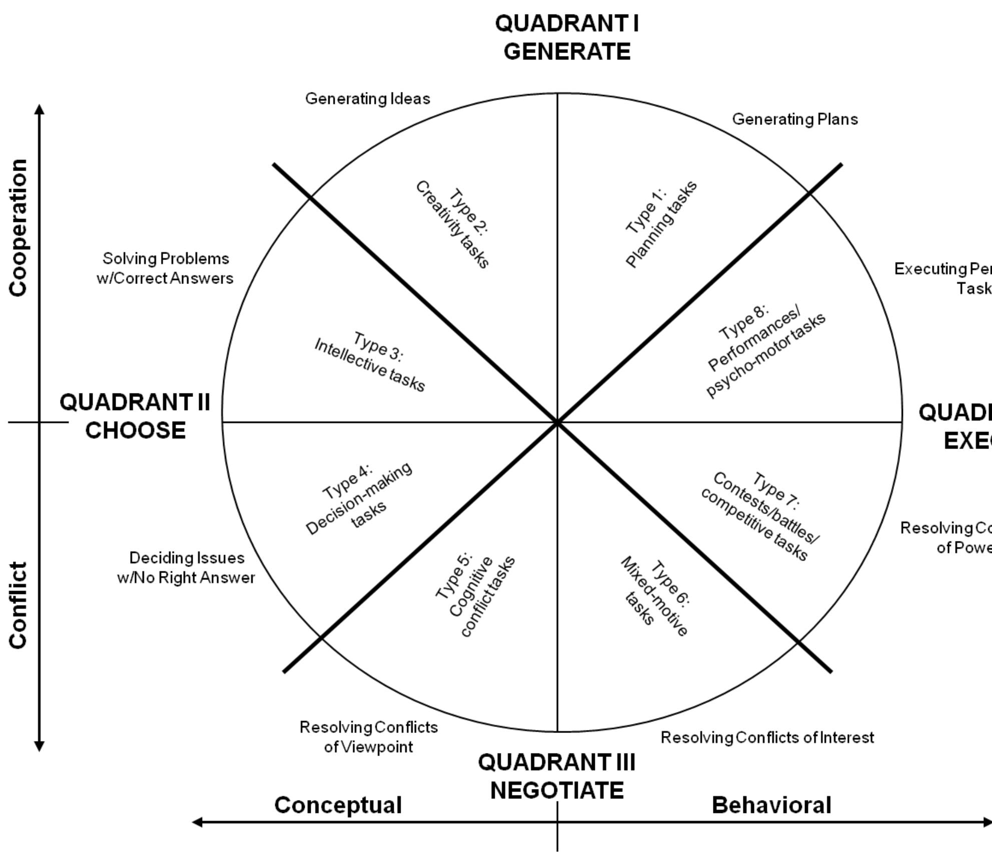

Figure 9b. McGrath's Typology of Tasks from McGrath (1984).

Mintzberg's Typology of Organizational Parts

A consistent finding in the CSCW literature, perhaps first appearing in Perin (1991) for email, is that organizational stakeholders often have radically different responses to an application. Perin (1991) noted that in the mid-1980s email solved problems for individual contributors and created them for managers. Subsequently, many studies have found differences consistent with Henry Mintzberg's elegant dissection of organizational parts (Figure 10). Executives (strategic apex), managers (middle line), individual contributors (operating core), the people formulating work processes (technostructure), and the support staff often have different approaches, constraints, opportunities for action, and competing priorities.

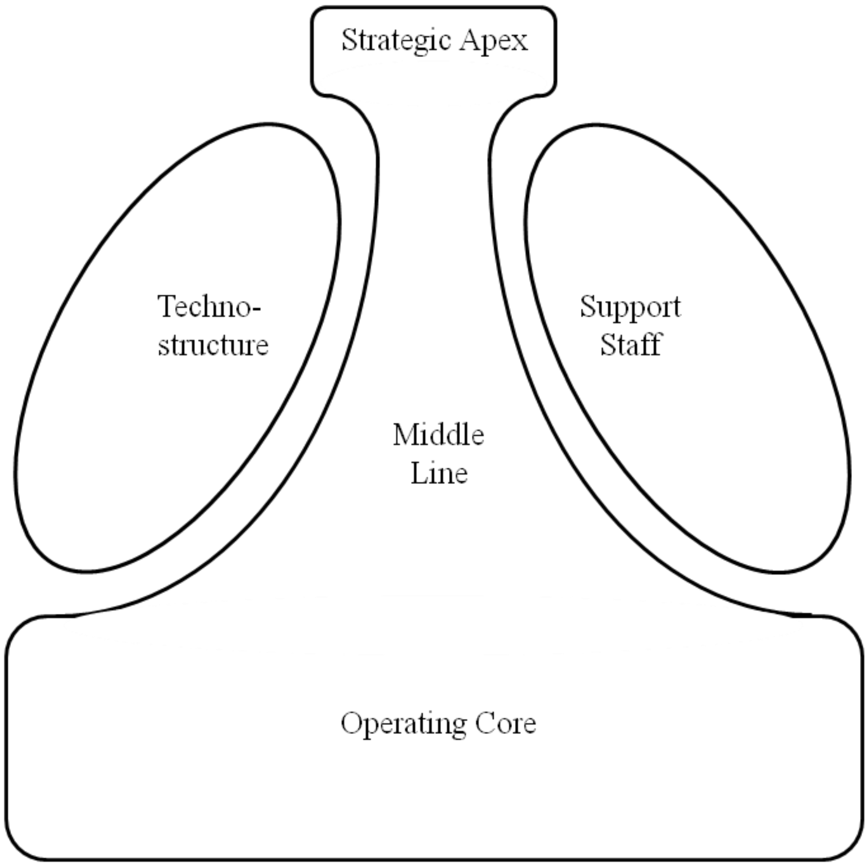

Figure 10. Central parts of an organization from Mintzberg (1984).

Individual contributors who make up the operating core are typically heavily engaged in communication, managers focus on sharing structured information in the form of documents, spreadsheets, and slide decks, and executives focus on coordinating activity of different groups. Note that these foci constitute one dimension of the Figure 7a framework. Executives' time is heavily scheduled with meetings, managers' less so, individual contributors' least. The ability to delegate work correlates with level in the organization, as does the sensitivity to public disclosure of one's work activities. The three groups have very different structures to their work days, with major impact on tool use for tools that they use (Grudin, 2004a). Within the support staff, IT professionals show yet another pattern of tool use. The technostructure role is less fully reported upon, but difficulties incorporating work processes in software in an effective way, notably in workflow systems, could be felt disproportionately there because they are often expected to deliver automated process systems.

A recent CSCW taxonomy of the capabilities of collaboration tools builds explicitly on the work of these social scientists. Weiseth, Munkvold, Tvedte, and Larsen's (2006) *wheel* is centered on models of content, content lifecycle, and process integration, with thirteen distinct activities in support of coordination, decision-making, or production. Each is a potential focus of technology support. They identify physical workspace, digital devices, and portals as technological components that bear consideration.

Conclusions: Taxonomy Use and Evolution

It is noteworthy that the taxonomies proposed by social scientists made no reference to the temporal and spatial dimensions that were central in the taxonomies produced and used by the CSCW community. Digital technology greatly amplified the ability to interact across space, but created new challenges by filtering out contextual information. Asynchronous communication and exchange provided far finer granularity than travel and post had, and also created new temporal challenges. These challenges captured the attention of researchers and developers, but as problems were addressed, patterns emerged that confirm the relevance of some prior social science.

The new challenges were initially tackled one at a time. Rooms to support meetings were built as stand-alone systems, not networked to the outside world. Johansen et al. (1991) used such stand-alone systems, but noted that eventually we would need *anytime, anyplace* solutions. Today, software would not be taken seriously if it supported real-time face-to-face activity but did not allow easy importation of documents prepared earlier, participation by remote participants, and exporting the fruit of the activity digitally for subsequent use.

Spatial and temporal distinctions retain technical and behavioral implications, but as conventions for handling digital capabilities come into place, those distinctions are less central. The social behaviors that have governed groups and organizations for thousands of years again rise to prominence.

Theory in CSCW

We have noted that cognitive psychologists who focused on human-computer interaction initially had a mission of constructing a theoretical foundation for design. By the late 1980s, the pace of technology change had stilled these ambitions. CSCW also began with efforts to construct an encompassing conceptual base. These too lasted for only a few years. Beyond that, most invocation of social science theory is to broaden theories developed elsewhere, with little building or testing of conceptual constructs. The choices of theories are often governed by the phases of the development and technology use cycle in Figure 2.

We identify four distinct roles of theory in CSCW: (a) There is some traditional theory development through hypothesis-testing; (b) A theory’s use as a referent can support efficient communication among people familiar with its terminology and constructs; (c) A theory can motivate or justify system architectures or development approaches; and (d) Theory can serve as a guideline or checklist for researchers or systems developers.

Traditional Theory Construction

The engineering orientation of North American CSCW, defined by Greif (1988) as a research field focused on the role of the computer in group work, was immediately countered by European participants who attended in large numbers in 1988. These included Scandinavians influenced by the trade union movement and others who desired to develop a conceptual and theoretical framework.

The Scandinavian’s political stance focused on worker empowerment. They cited philosophical approaches (e.g., Heidegger’s) and especially the psychologically and culturally focused Activity Theory.

Liam Bannon, Kjeld Schmidt, and Mike Robinson led efforts to forge a unifying conceptual framework for CSCW. Bannon & Schmidt (1989) was a manifesto in the first European CSCW conference that cited the work of Robinson *inter alia*. The three formed the journal *CSCW*, with a revision of the 1989 paper as the first article (Schmidt & Bannon, 1992). The papers are worth reading 20 years later. They identify core issues that have developed yet not disappeared, and include a vision of CSCW that did not materialize in illuminating ways.

Bannon and Schmidt (1989) took issue with Greif's (1988) notion that CSCW should focus on the group as a unit of analysis. They took even stronger issue with the notion that technology or groupware should be the focus. They argued for adopting an organizational focus, writing "we need to develop a theoretical framework that will help us understand the complex interactions between the technical subsystem, the work organization, and the requirements of the task environments. To design CSCW systems designers must analyze the target organizations," and they identified a range of sensible issues for analysis.

Both articles focus on two core issues: (a) the under-appreciated role in organizational work of secondary tasks (often invisible to management and system specification writers) that mediate, mesh, and adjust the work of individuals and groups in accordance with shifting circumstances; and (b) the tension between providing people with some control over self-disclosure and creating a common information space that includes details about individuals and their work often needed for interaction but stripped away by the digital systems of the era. This boundary between disclosure and privacy is notoriously difficult for people to place and continues to be a problem in CSCW systems. The earlier article added a third core issue, nicely outlining the complex issues involved in the unplanned co-evolution of technologies and organizations. The authors concluded by decrying the absence of attention within CSCW to topics including computer-integrated manufacturing, computer-assisted design, and organizational information systems. They argued for including everything that fit a careful unpacking of *computer supported cooperative work*.

No serious effort to address their agenda materialized. Few if any continued to call for broad theory development. The reasons seem clear. Bannon and Schmidt's (1989) analysis showed that the task would be daunting, and CSCW was indeed primarily an engineering discipline. The North Americans remained focused on supporting groups and hoped to find solutions that were independent of organizational context, as they had with word processors, spreadsheets, and email.

Finally, technology changed too rapidly to draw a theoretical bead on its development and use. The articles were written when large organizations developed software internally, the context in which the British sociotechnical systems and Scandinavian design approaches appeared. As those days ended, technology acquisition and adaptation took on a different cast.

A few CSCW researchers worked to extend theory, most notably Activity Theory. Originally a theory of the development of intellectual, social and cultural understanding in children, it was extended to include CSCW. Yuri Engestrom was a major theorist who made minor contributions to CSCW (Engestrom, Engestrom, & Saarelma, 1988). Kari Kuutti wrote of the potential of Activity Theory and explored case studies as tests of its elements, although in truth the elegant theory has a limited degree of falsifiability (e.g., Kuutti, 1991; Kuutti & Arvonen, 1992). Arne Raiethel's (1991) chapter was an ambitious effort by a theoretician who was active in the CSCW milieu. Jacob Bardram (1998) explicitly expanded the individual focus of Activity Theory to encompass collaboration. He wrote, "theory within a design discipline, such as CSCW… is to be judged upon its contribution to a systematic expansion of possible actions within a particular practice." Not everyone sees CSCW as solely a design discipline subject to this utilitarian view, but arguably no adequate body of organized and stable observations exists on which to build useful high-level theory.

As the 1990s progressed, the drawbacks of a technology-centric focus were countered not by an influx of theory but by its opposite, an influx of ethnography much of which eschewed efforts at generalization. Some used *Grounded Theory* to justify hypothesis-free exploration to theory-obsessed colleagues, but few of the Grounded Theory proponents in CSCW pursued theory-building beyond the identification of patterns.

In 2008, an explicit effort to define what might constitute theory in CSCW and then build one was published (Ackerman et al., 2008). This edited collection of analyses, some dating from studies conducted in the early 1990s, undertook to build a small-scale theory of artifacts or resources "that would allow CSCW and adjacent fields to move forward in a more systematic and less hit-or-miss way." With contributions from leading CSCW researchers, they claimed progress on developing statements with "descriptive power" and "rhetorical power," but concluded that "years of research work and many dissertations" would be needed to achieve "inferential power" or "application."

Nevertheless, despite rarely being created, extended, tested, or discussed in a deep way in CSCW, a wide range of theories are invoked with no explication and little explanation, to the possible consternation of students and other readers. The rest of this section explores rationales for the invocations of theory.

Theory as Communicative Expedient

Invoking the common ground of a familiar theory is particularly useful in a conference-oriented field with short papers and a bias for empirical results. It is a shorthand way of communicating with those already familiar with the theory, and perhaps of impressing those who are not. For example, frequent allusions to media richness theory in the literature rarely explain it and never discuss prior results that appear to support or refute it. Activity Theory is invoked with perhaps a paragraph of explanation, wholly inadequate as an explanation of this extensive, complex theory. Communication via theory can be a double-edged sword, as when a CSCW researcher confided to us that she was reframing her results around Goffman because she felt it would be more acceptable to reviewers than her original and preferred construction around the concepts of Durkheim.

Theory as Motivation or Justification for System Design or Experimental Methodology

When an existing theory is unfamiliar to the CSCW community, its explication can motivate the acceptance of a paper. For example, Fitzpatrick, Kaplan, and Tolone (1995) is divided evenly between a presentation of Strauss's (1993) Theory of Action and the description of a system comprising relatively familiar features assembled in a manner inspired by the theory. At CSCW'88, Bødker, Ehn, Knudsen, Kyng, and Madsen and Engestrom et al. described Activity Theory as an inspiration for their designs and analyses, but did not explain it to an audience that was almost entirely unacquainted with it.

Theory as Guideline or Checklist

The use of theoretical constructs and associated frameworks as a prompt to look for patterns in observations or data is often implicit in the justifications of theory use in design or in placing results in a theoretical structure. Researchers and system designers can draw on theoretical constructs to insure that they consider potentially relevant aspects of a situation. Actor-Network Theory and Activity Theory often appear to be used to direct attention and expand views of a particular sociotechnical setting, uncovering significant aspects that are at risk of being overlooked.

Discussion

We are now ready to reexamine the models and theoretical approaches with the phases of our model of collaboration and technology introduced in Figure 2. An example could give this abstract discussion some concreteness, so we first describe the CSCW literature citations of one theory.

Case Study: Citations of Media Richness Theory in CSCW

Media Richness Theory originated outside CSCW but is often invoked. We conducted an informal study by identifying all citations within the CSCW literature to a seminal work, Daft and Lengel (1986). Media Richness Theory states that richer communication media should be employed to support tasks that are more ambiguous and uncertain, and that task performance will suffer if the medium is insufficiently rich. This theory is unquestionably relevant to technological support for collaboration. Daft and Lengel's (1986) paper describing the theory has been referenced by 12 papers presented at CSCW conferences, three papers presented at ECSCW conferences, and three papers published in the CSCW journal. Only two of the 18 papers explicitly tested Media Richness Theory; both were coauthored by Robert Kraut, who also wrote the survey of social psychology discussed in the introduction. Kraut, Cool, Rice, and Fish (1994) found results consistent with the theory and Galegher & Kraut (1992) disconfirmed it, finding that users adapted their work practices to available media with no impact on performance.

Half of the papers (Bietz, 2008; Dabbish & Kraut, 2006; DiMicco, Pandolfo, & Bender, 2004; Grinter & Palen, 2002; Karsten, 2003; Nardi, Whittaker, & Bradner, 2000; Setlock, Fussell, & Neuwirth, 2004; Weiseth et al., 2006; Yamauchi, Yokozawa, Shinohara, & Ishida, 2000) explore factors that influence preferences for media or the performance effects of using different media. These papers do not test media richness theory or even attempt to manipulate richness. They establish common ground by citing Daft and Lengel (1986) when noting that collaboration via media can be challenging. Another paper (Fish, Kraut, & Chalfonte, 1990) described differences between formal and informal communication and noted that these differences paralleled, to some extent, differences between impoverished and rich communication channels as described by Daft and Lengel (1986). These are examples of using a theory as a communicative expedient.

One paper (Hauber, Regenbrecht, Billinghurst, & Cockburn, 2006) cited Media Richness Theory as the motivation for choosing a task that has a high level of uncertainty. We noted that researchers at times use theory to justify a system design choice; in this case it justified a choice of experimental methodology.

The explicit use of theory or frameworks as guideline or checklist is more likely in a development project than in a research paper. The closest we saw to this was Huysman et al. (2003) who referenced Daft and Lengel (1986) without citing the paper or mentioning Media Richness Theory at all, alerting the reader to the authors' familiarity with the theory.

Revisiting the Model

Each step depicted in Figure 2 constitutes a domain of human activity of potential relevance, but the principal CSCW focus is on four of them. For example, of 62 papers presented at the closely-analyzed twentieth-anniversary CSCW 2006 conference, 24% aimed at understanding collaboration in a context, generally concluding with implications for technologies that might support this collaboration. Defining technology requirements was the primary focus of 11%. Innovative new technologies and comparisons of technological approaches were the principal focus of 29% of the papers. Nearly a third of the papers (32%) investigated adoption of technologies and how it influenced collaboration.

At the top of Figure 2 is collaboration, with or without technology, a major focus of social science research. CSCW research rarely proceeds far without foregrounding technology. A partial exception is Malone's development of Coordination Theory (Malone & Crowston, 1990). Coordination Theory reflects the interdisciplinary origins and ambitions of CSCW, building on the observation that similar fundamental questions about the coordination of activities are asked in eight disciplines, ranging from linguistics to computer science. Coordination Theory considers the goals, activities, and actors in group or organizational contexts, and their interdependencies. It then works out the effects of technologies on the management of different kinds of interdependencies.

Malone and Crowston (1990) sought to define a general theory of coordination, but most CSCW research into collaboration employs ethnographic fieldwork in specific settings. CSCW 2006 included studies of collaboration in playing the online game World of Warcraft (Nardi & Harris, 2006), how pastors use technology to communicate with church attendees (Wyche, Hayes, Harvel, & Grinter, 2006), how elderly people manage their medications (Palen & Aaløkke, 2006), and how users of high performance computing systems collaborate (Danis, 2006). Extracting general principals from ethnographies performed in such diverse settings is an unsolved challenge.

Some of this work had a long-term goal of informing technology requirements; requirements are often a principal research focus. For potentially novel technologies, this may take the form of ethnographic or ethnographically inspired research. For example, Nomura, Hutchins, and Holder (2006) employed ethnography to study the uses of paper in commercial airline flight operations as a foundation for future technology requirements, their methods shaped by a distributed cognition theoretical framework (Hollan, Hutchins, & Kirsh, 2000). Also within the air travel industry, Lucy Suchman (1993) employed ethnography to study complex collaborative airport ground operations and make the findings accessible to system designers (Suchman, 1995). With more mature technologies, a requirements analysis may comprise a comparison of alternatives, such as an experimental study exploring the efficacy of alternative video camera views of remote tutors guiding a worker performing a complex physical task (Ranjan, Birnholtz, & Balakrishnan, 2006).

System developers engage in technology investigations when creating new capabilities. For example, Xia, Sun, Sun, Chen, & Shen (2004) and (Li & Lu, 2006) developed technology that allows people to collaborate using applications designed for individual use. Such investigations are rarely guided overtly by social science frameworks or theory.

Technology development itself can become the focus of research studies. It is a costly and collaborative activity, and CSCW researchers have sought to understand it and define requirements for tools to support it. For example, Gutwin, Penner, and Schneider (2004) studied how people maintain group awareness while contributing to an open source development project. They cited no theories but conducted qualitative field research.

CSCW research often spans multiple steps in the model, but the page limits of conference proceedings compel most researchers to focus on one at a time. Ackerman (1994) and McDonald (2001) are careful studies of organizational behavior that led directly to building systems for locating information or expertise. Thus, they took the work through the first three steps of the cycle.

At the bottom of the Figure 2 cycle is technology development. CSCW is a showcase for prototype systems. A subset of the HCI field, which emphasizes constant user testing and iterative design, CSCW accounts of prototype system-building almost always include limited user tests to gather feedback. A team that has invested heavily in building a system invariably also conducts the test, which can inhibit candid feedback and imbue the report with an optimistic bias. Typical reports show some successes, some areas for improvement, and generally positive users. However, remarkably few of the prototype systems see extended use, even when such was the plan. This does not mean that nothing of value was learned, but it does mean that readers must reflect carefully and consider whether or not follow-ups have appeared.

Marketing often coexists uneasily with Engineering. Despite its potential relevance, it is not studied or discussed in the CSCW community. Adoption, in contrast, is frequently studied, both to understand responses to new technologies and to identify direct and indirect influences on social interactions and work performance. Studies of technology adoption often serve as requirements analysis for the next version of a maturing application.

Two influential CSCW papers examined obstacles to adoption. Grudin (1988) surveyed a range of technologies and identified three factors affecting small-group collaboration support that were not present in individual productivity tools or organizational systems: (a) Use of relatively inexpensive groupware tools was rarely mandated, so those that required more work from some group members who perceived no benefit often were not used even where a collective benefit might exist; (b) Decision-makers with good intuition for individual applications often did not anticipate these problems; and (c) Evaluation was much more difficult than for individual productivity tools.

Orlikowski (1992) examined a consulting company's adoption of Lotus Notes and reported that it was influenced by cognitive and structural elements of the organization itself, not just by features of the technology. In particular, the benefits of the system were most apparent to senior partners; the incentives for consultants did not support its intended collaborative use. Orlikowski's (1992) description of the co-evolution of technology and the organization is widely seen as an extension of Giddens's (1979) structuration theory, although the latter's work is not directly cited. The interplay of technology, organizational structure, and collaborative practices has been the focus of many studies of technology adoption. Grinter and Palen (2002) employed the concepts of structuration theory to describe how teenage children use instant messaging and how it affects other elements of their lives. Munkvold, Ellingsen, and Koksvik (2006) and Bossen (2006) described adoption of electronic patient records in hospitals leading to unanticipated collaboration changes with negative consequences.

A major thread of research on technology deployment in enterprise settings explores variants of the Technology Acceptance Model (TAM) proposed by Davis (1989), which is rarely cited in CSCW but heavily in the Management Information Systems literature. CSCW focuses on discretionary use of tools, and thus refers to technology *adoption*, whereas for much of the past quarter century MIS has focused more on mandated enterprise use, hence *acceptance*.

Conclusion and Future Research

CSCW is the principal locus within Computer Science for dialogue and collaboration among social scientists and technologists. It quickly became a major ACM conference series and spawned a European series and a journal. Submissions and publications have risen steadily over a quarter century. The conferences are very selective, comprising highly polished papers.

CSCW was conceived as a forum, and although not all of the early vendors and shoppers continue to visit, the marketplace attracts technologists, psychologists, sociologists, and ethnographers. There are CSCW courses but no CSCW departments, programs, degrees, handbooks, or professionals. HCI is a core component of the Computer Science curriculum, and CSCW is a component of HCI, but it is relative distant from mainstream Computer Science. Being somewhat marginal there, CSCW is susceptible to flight, notably to Information Schools.

The high selectivity of the conferences redirects much of the submitted work to a host of closely-related conferences and conference tracks. These include CollabTech, predominantly a showcase for Asian work, CollaborateCom, which emphasizes technology, Collaborative Technologies and Systems, a broad conference focused on government systems, WikiSym, International Conference on Weblogs and Social Media (ICWSM), and GROUP, the latter comparable to CSCW with perhaps more of an organizational focus. Tracks and minitracks of the Hawaii International Conference on Systems Sciences (HICSS) series have emphasized relevant MIS work, computer-medicated communication, and social computing. This proliferation yields high-energy specialized small conferences. The cost is that related work is scattered, at least until sophisticated search tools appear that can re-aggregate it.

CSCW has produced a significant repository of grounded qualitative research on technology use and impact. Technical explorations of architectures for synchronized activity, backtracking ("group undo") in collaborative use, and other topics have formed a foundation on which systems are built. Studies of technology prototypes virtually always include a report on usage, albeit not often in neutral contexts. Some of the technical work has been rendered obsolete by advances in capabilities and the platforms and tools that are available. To progress from a research prototype to a commercial system now involves a major effort to engage with a complex federation of services and assumed capabilities.

At a 1988 panel discussion, CSCW founder Irene Greif predicted that what was then a niche interest in a world of individual productivity tools would come to embrace all of digital technology use—support for group activity would be part of all software. That has largely come to pass. Nevertheless, opportunities for social scientists expand. Technology is drawn upon to support our activities in finer-grained detail. Applications are shifting from general-purpose to domain-specific, extending attention from group behavior to organizational dynamics. And the allure of new technology requires that researchers understand the present context, the significant effects on organizations and society that unfold around the inventions that have succeeded.

Research Trajectories and Opportunities

Twenty-five years ago, there were no courses, a handful of researchers and scattered product developers working on collaboration support. Few of the latter had any exposure to social science. Everyone knew one another and research proceeded at a leisurely pace. Today, there are thousands of researchers and tens of thousands of fiercely competitive developers, many of them trained at universities and familiar with the literature. It once took many years to get any software into use, today a Facebook application can be launched within minutes of completion. The gap between research involving system construction and development shrank.

Although much has changed, research from industrial and organizational psychology has only made a small impact, and there is a considerable opportunity here, both for CSCW researchers to learn from past work in the social science and for more social scientists to contribute to the understanding of emerging phenomena, working together with or independently of today's CSCW researchers.

CSCW research has only recently come to appreciate some of the simple frameworks developed by Mintzberg and McGrath in the 1980s, and has not done so in any depth. For example, the work of Van de Ven et al. (1976) and Mintzberg (1983) on modes of coordinating work activity has not been applied. One technology trajectory is to support work in ever finer detail, requiring an understanding of workflow at a finer granularity, as well as an understanding of how work differs across organizations and industries, to which this and work that has followed can contribute. Similarly, much has been done since McGrath on the nature of tasks engaged by work groups (e.g. Kozlowski & Ilgen, 2006), which will certainly be of use in guiding CSCW research and understanding study results, and at the same time may itself need to be extended to account for emerging phenomena.

The hardware curve points to another opening frontier: embedded systems, networks of sensors and effectors that will be used to pick up, filter, and report huge amounts of contextual information. To date, research into computational analysis of contextual information has focused on supporting personal information management, but determining how to route, organize, and present contextual information to facilitate collaboration is a pressing challenge. Information visualization is a rapidly-growing research area, and we are still in the infancy of the information explosion.

The reader will not be surprised to hear us endorse qualitative field research as an area with unlimited potential. As technology extends its reach in all directions, we have never looked closely at its deployment without finding phenomena of interest. In reporting our results, we have found that qualitative researchers often dismiss quantitative data and some quantitative researchers consider it cheating to ask people to explain what they've done. This creates great opportunities for a new generation of researchers and research teams that combine quantitative and qualitative expertise—that can follow the analysis of the vast flow of quantitative information available over networks to find patterns with qualitative research to discover what the patterns mean, and then formulate the next round of quantitative analysis.

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Note: The many cited papers from CSCW and related ACM conferences are in the ACM Digital Library at http://portal.acm.org/dl.cfm. Abstracts are freely accessible, full papers require a membership, but most research universities have a site license. ECSCW papers are accessible at http://www.ecscw.uni-siegen.de/2009.htm.

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