Association for Information Systems

AIS Electronic Library (AISeL)

AMCIS 2000 Proceedings

Americas Conference on Information Systems (AMCIS)

2000

Examining Socio-Technical Networks in Scientific Academia/Industry Collaborations

Elizabeth Davidson
University of Hawaii, davidson@cba.hawaii.edu

Roberta Lamb
University of Hawaii, lamb@cba.hawaii.edu

Examining Socio-Technical Networks in Scientific Academia/Industry Collaborations

Elizabeth Davidson, College of Business Administration, University of Hawaii, davidson@cba.hawaii.edu
Roberta Lamb, College of Business Administration, University of Hawaii, lamb@cba.hawaii.edu

Abstract

We frequently think of university scientists as inventors of new technologies, which are transferred from the university to industry organizations for innovation and diffusion. Because such processes are communication and information intensive, there are high expectations that use of information and communication technologies (ICTs) can facilitate technology transfers and subsequent economic development. However, communication processes that foster scientific discovery and knowledge transfer are embedded in social networks; if ICT use influences technology transfer, it is likely to be through these networks. At the same time, ICTs will be shaped through their use in these social networks. We suggest a socio-technical perspective is best suited to study these reciprocal influences. In this paper, we outline a program of research to examine socio-technical networks in scientific academia/industry collaborations. We begin by reviewing key findings and projections about use of ICTs in knowledge creation and transfer processes and then outline our approach for studying socio-technical networks that span academic/industry boundaries.

Introduction and motivation

In relating academia and industry, we frequently think of university scientists as discoverers of new phenomena and inventors of new technologies. Their basic research discoveries and inventions become innovations when the new technologies are applied, or used to develop new products and processes (von Hippel, 1988; Eveland, 1986). Industry organizations historically have been a key locus of such innovations (Constant, 1987). Ideally, the linear diffusion of innovations from the university, through industry, to the wider community will result in economic and social returns to individuals, organizations, and governments.

Using this linear model of diffusion, and a simple model of communication[1], policy makers and visionaries have speculated that a massive application of information and communication technologies (ICTs) could dramatically increase the diffusion rate of scientific discovery and invention (Gilder, 1997; Negroponte, 1995; PITAC, 1999). Researchers also expect ICT use among scientists in academia and industry to play a critical role in shaping innovation processes. These expectations rest, in part, on the observation that scientists *already* rely on ubiquitous, high-speed telecommunications systems, such as email, cellular phones, and fax, and computerized data collection, storage and distribution systems.

However, the path from invention to economic returns is neither straightforward, nor determinate, nor proximate. Diffusion scholars know that inventions do not automatically become innovations, and economic and social returns from innovations accrue very slowly, if at all (Rogers, 1995). Researchers who have carefully examined the contexts of economic opportunity, in Silicon Valley for example, have stressed the need for empirically grounded challenges to linear diffusion models of innovation (Castells, 1989; Castells, 1996). Notably, studies show that *social networks* play a critical and complicated role in the transformations from invention to innovation and diffusion (Akrich, 1993; Camagni, 1991; Saxenian, 1996), particularly when social interactions sustain “communities of practice” which foster invention and innovation (Brown and Duguid, 1991; Constant, 1987; Garvey and Griffith, 1979). A massive infusion of ICTs into these social communication processes is unlikely to make the path more direct or predictable or locally controllable. In globally networked societies, there is no guarantee that local investments in scientific collaborations will yield any local returns (Amin and Robbins, 1991); it is also possible that ICT-enabled networks of scientists may instead facilitate the export of scientific knowledge to more powerful centers of economic and research activity, by-passing local economic development.

Understanding the interdependent influences of ICT use and social networks is critical to understanding how expanding ICT use may be influencing the diffusion of

[1] Based on the early technical communication models of Shannon and Weaver (1949), Johansen (1991) and others (cf. Ruhleder and King, 1991) have modeled the ways in which information and communication technologies facilitate communication, information sharing and collaboration -- fundamental aspects of processes of invention and innovation diffusion (Rogers, 1995). Their studies have raised expectations that ICTs can, to some degree, lower the barriers to invention and innovation that are directly related to communication, collaboration and information sharing processes.

scientific discovery, invention and subsequent innovations. A socio-technical perspective, which does not privilege either social or technical influences but instead recognizes that the social and the technical are largely interwoven in practice, is particularly appropriate in this context. We use the term *socio-technical network* to conceptually describe the *enactment of patterns* of interaction and relationship which occur between individuals, within and between organizations and institutions, and through the information and communications technologies which embed, and are embedded in, these interactions.

In this paper, we outline a program of research to examine socio-technical networks in scientific academia/industry collaborations. We begin by reviewing and discussing key findings and projections about scientists' use of ICTs. Interestingly, despite a heightened interest in technology transfer dynamics during the 1980's, much more is known about collaboration and ICT use *within* academia than is known about ICT use that span university/industry boundaries. However, research in social network analysis as well as studies of ICT use in commercial organizations provide interesting and relevant insights that are briefly reviewed here. We conclude by discussing our approach for studying scientific socio-technical networks and the general research questions that will guide the research program.

The emergence of socio-technical networks in science

In her study of "invisible colleges," Crane (1972) described how scientific knowledge grows through the diffusion of information within and among formal scientific communities and informal social communications networks. Social communications networks emerge, as links within a network are added or dropped, changing and adjusting to internal and external factors such as research funding, realignment of institutions, and technology innovations (Monge and Eisenberg, 1987). The diffusion and adoption of ICTs within academic communities has significantly influenced scientific communications networks--and has been the subject of much research. ICT researchers have studied, for example, the use of online databases by oceanographers (Hesse et al, 1993), remote sensing instruments by atmospheric scientists (Finholt et al, 1995), collaborative systems by geneticists (Star and Ruhleder, 1996), and electronic journals within various disciplines (Kling and Covi, 1995; Kling and McKim, 1999). They have found some support for the optimistic perspective that ICT use can lower traditional barriers to communication and collaboration, such as those posed to geographically dispersed scientists, by reducing the cost of communication and increasing its speed. Evidence suggests that online databases and e-mail, for example, have increased the incidence and extent of collaboration among scientists (Hesse et. al, 1993, Walsh et. al. 1999). ICT use can promote more equal access to scientific resources, such as expensive equipment and the time and attention of other scientists. This access may be critical for scientists who are peripheral to the scientific core due to their geographic location and/or their seniority in the field (Hesse et. al, 1993; Ross-Flanigan, 1998; Walsh et. al, 1999).

Such empirical findings are encouraging, but the degree to which ICT investments may actually provide "returns to science" remains unclear (Hesse et al., 1993; Walsh, 1998; Walsh et. al., 1999; Ross-Flanigan, 1998). It is unlikely that ICT use alone could account for reported increases in the productivity of individual scientists, extensions of the range of communications networks beyond the elite scientific core, or a narrowing of the temporal gaps between theory development, experimentation, and the publication of research results. Instead, it is likely that scientists have incorporated use of ICTs in their interactions, creating what has been termed "computer supported social networks" (Wellman et. al. 1996), and that the interdependent influences of the technology and the social network result in observed outcomes.

However, the social network analysis (SNA) approach for studying ICT use in social networks (Garton et. al. 1997) has been criticized for focusing primarily on structural features of social networks, and for ignoring the dynamic and situated nature of human interaction (Lea, O'Shea and Fung, 1995). To overcome these limitations, and to explore processes questions, such as how these socio-technical networks evolve, researchers have sought to combine social network concepts with alternative theoretical perspectives. Van Alstyne and Brynjolfsson (1996) have combined economic concepts of bounded rationality with social network theory to hypothesize that ICT use could lead to increased fragmentation and segmentation in an academic discipline, rather than broader collaboration. They argue that geographic barriers to communication actually *foster* opportunistic, cross-disciplinary collaboration among scientists who are physically close. Once geographic barriers are lowered, communications barriers may develop that reflect narrowly focused research boundaries and the limits of time and common interests. Researchers guided by institutionalist perspectives have theorized that, rather than promoting equality, ICT use might reinforce existing disparities among scientists (Walsh et. al 1998; Ross-Flanigan, 1998). That is, ICT-enabled science networks could have broader participation, but no leveling effect, because the communication network does not, by itself, alter scientists' access to non-ICT resources, such as financial support for research and institutional prestige. Other promising approaches have combined social interactionist theory with socio-technical studies to examine the simultaneous social influence of ICTs and social shaping of technology (Bijker, 1995; Fulk et. al., 1992; Kling and McKim, 1999; Orlikowski, 1992; Orlikowski et. al. 1995). This line of research suggests that ICTs will be shaped differently by existing norms and institutions within each scientific discipline, and that, although some changes in practices will undoubtedly take place, incorporation of ICTs, such as e-journals, will vary by field and will likely proceed by institutional incrementalism (Kling and McKim, 1999).

To summarize, the foregoing studies conclude that the influences most likely to shape both the use of ICTs in science and their influence on collaboration within communities of practice include:

- The nature of the scientific phenomena studied and the work organization of the discipline (Kling and McKim, 1999; Walsh et. al 1999);
- The fit of information and communication technologies to the research and communication tasks of the discipline (Walsh et. al 1999);
- Institutionalized practices for assessing the quality and value of information/knowledge, through which trust in scientific knowledge is engendered (Kling and Covi, 1995; Kling and McKim,1999);
- Institutionalized relationships with publishers and funding organizations (Kling and McKim,1999) which may entail legal restraints to dissemination of information;
- Incentive and reward structures for scientific work, knowledge discovery, and sharing of knowledge (Kling and McKim,1999; Van Alstyne and Brynjolfsson, 1996);
- The size and informality of the research community, and thus the extent of the community of practice (Hesse et. al, 1993; Walsh et. al 1999);
- The discipline's “closeness” to a commercial market and increased privatization of scientific knowledge (Walsh et. al 1999).[2]

Socio-technical networks in academic/ industry collaborations

Clearly, many phenomena influence communication and collaboration processes within communities and organizations, but much more is known about scientific/academic processes than is known about university/industry collaborations. Some insights from the studies discussed earlier, particularly the last three items listed above, suggest potential dynamics of socio-technical networks that span university/industry boundaries. Similarly, research and theorizing about innovation diffusion and technology transfer (cf. Rogers, 1995), social networks and the importance of informal communications (weak ties) (Granovetter, 1973) as well as formal associations and contractual agreements (strong ties) (Krackhardt, 1992) can inform our understanding of communication and collaboration processes in and between academia and industry.

Insights from interorganizational networks studies that have used institutionalist perspectives, population ecology theory and sociometric methods to examine the complex interconnections of strategic alliances that link commercial biotechnology companies and biotech researchers (Powell and Brantley, 1992; Powell et al., 1996; Barley et al.,1992) also highlight potentially interesting issues. Examinations of this emergent industry have traced the expansion of biotech networks from the university researchers who developed the first biologic techniques, to the investment-capital backed startups that inspired a proliferation of in-house biotech research projects within drug companies that eventually blurred the existing boundaries of pharmaceutical industry organizations. These studies do not theorize about ICT use, but they strongly suggest that the phenomena likely to be particularly critical in the context of ICT-enabled academia/industry communication and collaboration include:

- The potential of university-based discoveries and inventions to shape new industries or blur existing industry boundaries through complex strategic alliances (Barley et al.,1992);
- Interorganizational collaboration networks which serve as a locus of learning and innovation (Powell and Brantley, 1992; Powell et al., 1996).

Such research and theorizing, which focuses on interorganizational communications networks, emphasizes the role of infrastructures and the value of social constructionist and institutional perspectives (Giddens, 1984; Scott, 1987; Powell and DiMaggio, 1991). In a study of online information resources, guided by insitutionalist perspectives, Lamb (1997) found that informational environments strongly influence the shape and use of ICTs. Although no one pattern or practice neatly defines the informational environment of any industry, five interdependent phenomena characterize the technical and institutional dimensions of informational environments in the three industries studied: 1) interactions with regulatory agencies; 2) demonstrations of competence and superior service to clients; 3) opportunities to obtain information from other organizations through outsourcing, partnering or purchasing information services; 4) existence of industry-wide infrastructures to provide critical information; and 5) client expectations for timely, cost-effective information exchanges (Lamb, 1997). Two of these phenomena particularly highlight the importance of interorgani-

[2] Walsh et. al do not specify exactly what kind of “closeness” a discipline might have to an industrial/commercial market, but they imply that this is related to the immediate commercial applicability of research findings. We would note that a relevant “closeness” might also refer to the availability of commercial funding for university research.

zational networks for understanding ICT use: interactions with regulators and customer/client relationships. Lamb's (1999) study of intranet development in organizations similarly suggests that regulatory agencies and customer/client demands shape ICT development and use, but that those effects are strongly mediated by the influence of communities of practice (Lamb and Davidson, 2000). Her study, which follows socio-technical network examination methods to trace the processes and relationships that shape intranet development and use, emphasizes the need for a better articulation of socio-technical network theory and research methodologies.

A research program to examine socio-technical networks in scientific academic/ industry collaborations

The focus of our research program is the use of networked ICTs, such as multimedia communication systems, remote sensing instruments, intranets and email, among scientists and between scientists and their collaborators in industry and government. Our goals are to understand the reciprocal social and technical influences that shape patterns of interaction among these actors as they use ICTs, the social shaping of technology through development and use of ICTs, and the broader implications of ICT use in academic/industry collaborations for economic and social development. We recognize this is an ambitious research agenda. However, we expect we will be able to draw heavily from the research outlined above to develop detailed research questions, the research design, and methodological approaches for data collection and analysis. Initially, we will draw on concepts from social network analysis (cf. Garton et. al. 1997) to investigate the social aspects of socio-technical networks of academic and industry researchers in selected scientific disciplines. However, because SNA has limitations for examining the *co-evolution* of social and technical influences of ICT use (Lea, O'Shea and Fung, 1995) and its focus is more on network structure than on networking processes, we will also draw relevant concepts from social constructionist and institutional perspectives to build what we hope will be a stronger socio-technical network theory from existing theory and the empirical research basis of this program.

Our initial plans are to conduct a series of intensive case studies in selected scientific disciplines (i.e., sub-specialties within disciplines), in a form similar to the SNA ego-centered network study (Garton et. al. 1997). This approach to network tracing involves selecting a set of individuals and collecting data about whom they interact with, for what reasons, and in what ways (in this case, scientists' interactions with collaborators in academia, industry, or government). In this way, we will examine the relations enacted by actors, their goals in maintaining relations, and relevant characteristics of the ties between actors, such as their composition, multiplexity, and strength (Garton et. al. 1997). In addition to collecting data about social relationships, we will also collect information about the ICTs used in interactions and examine the ICTs directly. At some point, the ICTs may become the focal point of further study, as we explore the social shaping of technology and the influences of the technology on patterns of social interaction. Although ICTs are often developed and diffused quickly, we believe that a longitudinal study will be needed to better characterize ICT-related changes and the evolution of scientific socio-technical networks. Thus, we anticipate conducting each case study over a period of three years, and comparing data collected at different points in time.

Selecting a good initial sample of research scientists for the case studies will be critical to the success of this approach. We will focus the study initially on a subset of University of Hawaii scientists within selected disciplines (i.e. astronomy, oceanography and marine biology), and their interactions with constituent groups in other academic institutions, industry and government. Situating this study within these world-class scientific domains at University of Hawaii and exploring the links from Hawaiian researchers to the international scientific community and to local and global centers of industry offer several research advantages. Hawaii is the most geographically isolated spot on earth, suggesting that there may be fewer options to ICT use for University of Hawaii researchers who seek to contribute to and participation in scientific developments. Therefore, we expect that changes in socio-technical networks that are directly related to ICT use may be more visible through Hawaiian scientists. In addition, for the selected disciplines, Hawaii's unique location and ecology provide comparative advantages that may strengthen socio-technical networks by attracting collaborators from academia and industry both physically and virtually. Finally, the broader implications of ICT use in academic/industry collaborations for the local economy and social development will be more easily discernable in this isolated, island state.

Three broadly stated research questions will initially direct our inquiry and analysis:

1. In each discipline, how have socio-technical networks evolved as ICTs are developed and incorporated into academic/industrial collaborative processes? How have communities of practice that utilize key ICTs shaped their design and use, and alternatively, how have the technologies influenced the communities?

2. In each context studied, has ICT use influenced network characteristics[3] such as the degree of specialization and fragmentation in the academic field or the breadth of participation by actors at the periphery of the discipline? Has ICT use facilitated inclusion of periphery groups or facilitated exploitation of their local resources by core groups?

3. Has ICT use facilitated (or constrained) the diffusion of scientific knowledge from academia to industry (or vice versa) in the areas studied? What critical network relations influence the development of socio-technical networks that span academic/industry communities? How do contextual features, such as different incentives for knowledge creation and sharing in academia and in industry influence the way ICTs are designed and used in academic/industry collaboration?

Our research will begin with scientists at one university, but by following the heterogeneous links that connect them to their collaborators, our study will trace out a socio-technical network of scientific individuals, organizations, institutions and technologies. In so doing, we expect to identify the ways in which informational environments constrain and enable scientific interactions, and the ways in which ICTs may help to weaken or reinforce barriers, beyond those posed by geographic isolation. By comparing our findings across selected disciplines that have been successful in overcoming geographical and inter-organizational barriers, we expect to illuminate the ways in which dynamic communities of practice shape new ICTs, the ways in which socio-technical networks co-evolve with ICT use, and the ways in which existing socio-technical theory may be strengthened through this research approach.

Expected contributions

We anticipate the predominant contribution of our research program will be to further delineate a socio-technical model of ICT use that will challenge simple linear diffusion models. With the increasing globalization of informational environments, and the near ubiquity of network infrastructures, researchers and policy makers need a network-centric theory of ICT use to guide their development of and investment in information infrastructures that support socio-technical interactions at individual, group, organizational, and inter-organizational levels.

In Hawaii, for example, policy-makers, guided by linear diffusion models of technology transfer, expect that local resources and local scientific knowledge will facilitate local research-related industrial development. But, as Castells points out, in a network society, local resources no longer ensure local development. On the other hand, further explication of socio-technical network dynamics may reveal whether locally dense socio-technical networks can retain "returns to the community" from locally-based scientific collaborations that might otherwise accrue to global centers of industry. Our study promises to provide insights into these critical questions.

[3] By network characteristics we mean typified enactment of patterns of interaction.

References

Akrich, M. (1993). "Inscription et Coordination Socio-Techniques: Anthropologie de Quelques Dispositifs Energetiques," Paris: Ecole Nationale Superieure des Mines de Paris, These pour le doctorat Socio-Economie.

Amin, A. and K. Robbins (1991). " These are not Marshallian times," in R. Camagni (ed). *Innovation Networks: Spatial Perspectives*, London: Belhaven Press, pp. 105-120.

Barley, S., J Freeman and R. Hybels (1992). "Strategic Alliances in Commercial Biotechnology," in N. Nohria and R. G. Eccles (eds). *Networks and Organizations: Structure, Form and Action*, Boston: Harvard Business School Press.

Bijker, W. (1995). *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*, Cambridge, MA: The MIT Press.

Brown, J. and P. Duguid (1991). “Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning and Innovation,” *Organization Science*, Vol. 2, No. 1, pp. 40-57.

Camagni, R. (1991). "Local milieu, uncertainty and innovation networks: towards a new dynamic theory of economic space," in R. Campagni (ed)., *Innovation Networks: Spatial Perspectives*, London: Belhaven Press, pp. 121-144.

Castells, M. (1989). *The Informational City: Information Technology, Economic Restructuring, and the Urban-Regional Process*. Oxford: Blackwell.

Castells, M. (1996). *The Rise of the Network Society, Volume 1 of The Information Age: Economy, Society and Culture*. Oxford: Blackwell.

Constant, II, E. (1987). “The Social Locus of Technological Practice: Community, System, or Organization?” in W.E. Bijker, T.P. Hughes, and T.J. Pinch (Eds)., *The Social Construction of Technological Systems*, Cambridge: MIT Press, pp. 221-242.

Crane, D. (1972). *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: The University of Chicago Press.

Eveland, J. (1986). “Diffusion, Technology, Transfer and Implementation,” in *Knowledge Creation, Diffusion, Utilization*, 2, pp. 303-322.

Finholt, T., S. Lewis and W. Mott (1995). “Distance learning in the Upper Atmospheric Research Collaboratory (UARC).” North Central Sociological Association Annual Meeting, Pittsburgh, PA.

Fulk, J., J. Schmitz, and D. Schwarz (1992). "The Dynamics of Context-behavior interactions in computer-mediated communication," in M. Lea (eds)., *Contexts of Computer-mediated Communications*, London, UK: Harvester-Wheatsheaf.

Garvey, W. and B Griffith (1979). “Scientific communication as a social system,” In. *Communication: The essence of science*, W. D. Garver (ed), New York: Pergamon, pp. 148-164.

Giddens, A. (1984). *The Constitution of Society*, Berkeley: University of California Press.

Gilder, G. (1997). *Meaning of the Microcosm*, Progress and Freedom Foundation.

Granovetter, M. 1973. "The strength of weak ties", *American Journal of Sociology*, 78, 6 (1973), 1360-1380.

Hesse, B., L. Sproull, S. Kielser, and J. P. Walsh (1993). Returns to Science: Computer Networks in Oceanography. *Communications of the ACM*, August, Vol.36, No.8.

Johansen, R. (1991). “Teams for Tomorrow,” *Proceedings of the 24th Annual Hawaii International Conference on Systems Sciences*. Los Alamitos, CA: IEEE Computer Society Press, pp. 520-534.

Kling, R. and L. Covi (1995). “Electronic journals and legitimate media in the systems of scholarly communication,” *The Information Society*, 11(4):261-271.

Kling, R. and G. McKim (1999). “Scholarly Communication and the Continuum of Electronic Publishing,” *Journal of the American Society for Information Science*.

Krackhardt, D.(1992). "The Strength of Strong Ties: The Importance of *Philos* in Organizations", in Nohria, N. and Eccles, R.G (eds) *Networks and Organizations: Structure, Form and Action*., Boston: Harvard Business School Press, 216-239.

Lamb, R. (1997). "Interorganizational Relationships and Information Services: How Technical and Institutional Environments Influence Data Gathering Practices", Ph.D. Dissertation, University of California, Irvine.

Lamb, R. (1999). "Using Intranets: Preliminary Results from a Socio-technical Field Study", in *Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences*, IEEE Computer Society Press, 1999.

Lamb, R. and E. Davidson (2000). “The New Computing Archipelago: Intranet Islands of Practice,” (with Elizabeth Davidson), *IFIP WG 8.2 Working Group Conference IS2000*, in Aalborg, Denmark (June, 2000).

Lea, M, T. O'Shea, and P. Fung (1995) "Constructing the Networked Organization: Content and Context in the Development of Electronic Communications," *Organization Science*, 6:4, 462-478

Monge, P. and E. Eisenberg (1987). Emergent communication networks. In F. Jablin, L. Putnam, K. Roberts, & L. Porter (Eds)., *Handbook of organizational communication* (pp. 304-342). Newbury Park, CA: Sage.

Negroponte, N. (1995). *Being Digital*, Vintage Books, New York, NY.

Orlikowski, W. (1992). "The Duality of Technology: Rethinking the Concept of Technology in Organizations," *Organization Science*, Vol. 3, No. 3, pp. 398-427.

Orlikowski, W., J. Yates, K. Okamura, and M. Fujimoto (1995) "Shaping Electronic Communication: The Metastructuring of Technology in the Context of Use," *Organization Science*, 6:4, 423-444.

PITAC: President’s Information Technology Advisory Committee (1999). “Information Technology: Transforming our Society” in PITAC – Report to the President, National Coordination Office for Computing Information, and Communications. URL: http://www.ccic.gov/ac .

Powell, W. and P. Brantley (1992). "Competitive Cooperation in Biotechnology: Learning Through Networks," in N. Nohria and R. G. Eccles (eds). *Networks and Organizations: Structure, Form and Action*, Boston: Harvard Business School Press.

Powell, W. and P. DiMaggio (eds) (1991). *The New Institutionalism in Organizational Analysis*. Chicago: The University of Chicago Press.

Powell, W., K. Koput and L. Smith-Doerr (1996). "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology", *Administrative Science Quarterly*, Vol. 41, pp. 116-145.

Rogers, E. (1995). *Diffusion of Innovations*. New York: Free Press.

Ross-Flanigan, N., (1998) "The Virtues (and Vices) of Virtual Colleagues," *Technology Review,* March/April, 1998 (at www.techreview.com/articles/ma98/ross-flanigan.html).

Ruhleder K and S. Star (1996). "Steps Towards an Ecology of Infrastructure: Design and Access for Large Information Spaces," *Information Systems Research*, 7:1, pp. 111-134.

Ruhleder, K. and J. King (1991). "Computer Support for Work Across Space, Time and Social Worlds," *Organizational Computing*, Vol. 1, No. 4, pp. 341-356.

Saxenian, A. (1996). *Regional Advantage*. Cambridge, MA: Harvard University Pres.

Scott, W. (1987). *Organizations: Rational, Natural, and Open Systems, Second Edition*, Englewood Cliffs, NJ: Prentice Hall.

Shannon, C. and W. Weaver (1949). *The mathematical theory of communication*, University of Illinois Press, Urbana.

Strauss, A. and J. Corbin (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, Newbury Park, CA: Sage Publications.

Van Alstyne, M. and E. Brynjolfsson (1996). "Electronic Communities: Global Village or Cyberbalkanization?" *Proceedings of the International Conference on Information Systems*, Cleveland, Oh.

von Hippel, E. (1988). *The Sources of Innovation*, New York: Oxford University Press.

Wellman, B., J. Salaff, D. Dimitrova, L. Garton, M. Gulia, and C. Haythornthwaite (1996). "Computer Networks as Social Networks: Collaborative Work, Telework, and Virtual Community," *Annual Review of Sociology*, 1996.

Walsh, J., S. Kucker, and N. Malone (1999). "Connecting Minds: CMC and Scientific Work," working paper, online at http://www.uic.edu/~jwalsh/JASIS.jw.

Walsh, J. (1998). "Scientific Communication and Scientific Work: A Survey of Four Disciplines," *Internet Research* 8(4): 363-366.