Libri, 2006, vol. 56, pp. 239–251
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Libri
ISSN 0024-2667

Scholarly Communication in Scientific Research Practice – A Study of Computer Sciences Faculty

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This study explores computer scientists' modes of communication within scientific inquiry. Situated in a socially constructed research practice, the findings provide a focused view of the collective use of two sets of communication mechanisms – electronic information mechanisms and interpersonal communication channels – within a technology-intensive field. These results are theoretically and pragmatically interesting for both scholarly communication research and library and information professionals. They suggest that to understand scholarly communication, exploring social cues embedded in the real world practice will yield valuable information, while the detailed examination of research practice may provide a resource for the general design of systems to support collaborative scientific work.

Introduction

Knowledge-based assets are now widely recognized by scholars as valuable resources, and scientific knowledge especially receives a great deal of attention. The Internet and World Wide Web have grown rapidly in the past decade and have come to play a major role in supporting knowledge sharing in scientific communities. In an ever-changing and progressing information environment, the growth of emerging technologies and the availability of multiple information channels offer more and more opportunities for scholars to enhance their scholarly communication and scientific techniques. Given the growing importance of information technology and the resulting major shifts in scientific practice (Kling & McKim 2000), there is a need for empirical study of scientists' modes of communication in scientific inquiry.

Computer science as a discipline is unique for the current research topic because it involves both the research on information technology and the use of such technology for supporting research. In the field, researchers are more interested and involved in technology that spills over into their professional endeavors. Computer scientists' knowl edge-sharing skills are expected to be highly sensitive to technological advances. The study of scholarly communication in this high-resource discipline could offer suggestions for other disciplines about how to best take advantage of new electronic communication technologies to ease or improve research techniques, and to gain rich information resources.

Information technology and scholarly communication

Nentwich (2003) broadly defines scholarly communication as all communication involving at lease one scholar at one end, in whatever form or with the help of whatever medium. It could take place among researchers, between researchers and the object of research, as well as between researchers and the outside world. Current research on the influence of electronic communication technologies, such as electronic mail, World Wide Web, electronic journals, bibliographic databases, on-line

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This paper has received *honourable mention* in the *2006 Libri Best Student Award Competition.*

card catalogs, groupware, and other community computing and support systems, suggests that they broaden academic research communities and change the ways researchers work (Covi 2000). By providing a means for communicating and collaborating over time and distance, electronic media have created new opportunities for researchers to share scarce resources such as data sets, expensive scientific instruments, ideas, and human attention to intellectual pursuits (Covi 2000; Kling & McKim 2000). The growing availability and use of such services has even given rise to a new type of scientific enterprise: "the collaboratory" (National Research Council 1993), which refers to research centers where scientists can work together across geographic distance and share resources via computer networks.

But differences exist in scholarly communities' application of technology. Kling and McKim (2000) state that the shifts towards the use of electronic media in scholarly communication are uneven, both with respect to field and with respect to the form of communication. Walsh and Bayma (1996) argue that these scholarly differences are likely due to differences among the fields in terms of work organization (i.e. how interdependent the members of a collaboration are), technical imperatives of the field (e.g., whether data are digital or not), size of research communities (and, therefore, greater or lesser reliance on informal communication), closeness to the commercial market (with its emphasis on privatizing information), and technological fit (that each field relies on data or communications that are more or less easily transmitted via information technology). Kling and McKim (2000) make the argument that scientific forums play different communicative roles within different fields. Using the Social Shaping of Technology (SST) perspective, they identify the important social forces of trust and of legitimate communication as shaping the use of technology within a field.

Scholarly communication forums (SCF), either through digital mechanism or physical devices or both, include a broad family of communication forms such as face-to-face meetings, paper journals, linked websites, central server-based repositories and so on. The role of SCF in computer science is the current topic of interest. Previous studies examined the disciplinary features and found that computer scientists usually express a sense of urgency in terms of creating, finding and utilizing materials in a timely manner (Covi 1999). Computer science scholarly communication involves efficient and dense information transformation and consumption. The use of different information channels in this field constitutes the current research topic.

Social network and knowledge sharing

Some prior studies have focused on how knowledge is stored, distributed and used, and especially, on the major role of information technology and physical information resources supporting scientific work. Other studies have focused on the informal network in organizational information processing. These studies centered on people as information sources and studied the natural social interaction aspects of communication activity within an organizational context. Informal network stresses the "qualitative, intangible, human, and value-laden aspects of communication" (Grosser 1991). Deal & Kennedy (1982) perceive the informal network as the primary means of communication within an organization's formal structure. Not only is this network largely independent of formal information systems, but it also overcomes many of the problems of such systems, such as transmitting information with lightning speed, being highly selective, differentiating the significant from the less significant, and overcoming problems of information overload (Deal & Kennedy 1982; Grosser 1991). The informal network "adds value" to the raw data of formal communications, assigning meaning, interpreting significance, and embellishing events to make them exciting and more palatable for human digestion (Deal & Kennedy 1982; Grosser 1991).

Extant research, however, has not examined how these technical and social factors collectively shape the scientific practice of knowledge sharing among computer scientists within the context of a single empirical study. The primary purpose of this study, therefore, is to explore how electronic and interpersonal communications impact knowledge sharing of computer scientists. The current questions of interest include:

1. What communication channels have been developed and are used in computer science?

2. What roles do these communication channels play within the field?

Two theories can be applied in understanding media use by computer scientists and its impact on computer science research. One is media richness theory, which explains why people choose certain communication media for certain communication tasks based on the media capabilities. It has been widely applied in communication studies. The other is communities of practice approach, which provides a new theoretical framework in studying scholarly communication within the social norms of actual research practice, and will be applied in this study. Both theories have utility and limitations; their comparison will be discussed later in this paper.

This paper first describes communities of practice, the theoretical framework for the study, and develops the research expectations. It then describes the methodology for data collection and data analysis. The third section summarizes the finding results. The final section discusses the utility of the communities of practice theory, comparing it to media richness theory – another theory commonly used to explain why people choose certain media for certain communication tasks. It also considers the practical implications that ensue, and notes the limitations imposed by the study design.

Theoretical framework

The theoretical frame for this study is the idea of communities of practice, which essentially suggests that knowledge work is inseparable from its own historical and social location of practice, and should be studied in the actual practice of work (Brown 1998; Brown & Duguid 1991; Blackler 1995; Lave & Wenger 1991; Hayes & Walsham 2001).

A practice organizes knowledge in a way that is especially useful to practitioners whose shared learning brings value to a community (Wenger *et al.* 2002). Pragmatically, such examination is warranted because it draws "attention away from abstract knowledge and cranial processes and situates it in the practice and communities in which knowledge takes on significance" (Brown & Duguid 1991). The communities of practice approach suggests that what is learned is highly dependent on the context that the learning takes place in, and the context is central to the transfer and consumption of information. This requires "looking at the actual practice of work, which consists of a myriad of fine-grained improvisations that are unnoticed in any formal mapping of work tasks." (Hayes & Walsham 2001) Such beliefs are utilized in this study to approach and explain the usage of communication mechanisms among the computer scientists.

Furthermore, communication contributes to the work of "negotiating" a shared domain and the building of a shared practice (Cagna 2001; Wenger *et al.* 2002). Thus, examining the communication mechanisms constitutes the major construct of the current research. As multiple communication channels exist in the actual practice of scientific work, and because there is considerable support in the literature for the importance of both electronic and interpersonal communications, the current study focuses on both computer-mediated participation and face-to-face interpersonal communication.

Based on the studies cited above, coupled with the predominant findings from previous theoretical and empirical research, the researcher expects that the use of electronic and face-to-face interpersonal communications are complementary in computer science scientific inquiry. These different ways of keeping track of academic information are not mutually exclusive and are utilized synthetically. Computer scientists' mode of consumption and contribution to scholarly communication is dynamic and comprehensive. The empirical test of the expectations is described next.

Methodology

The expectations described in the preceding section were tested in the context of the use of different information channels for research inquiry by faculty in the Department of Computer Sciences at The University of Wisconsin-Madison during October 2002. Five semi-structured interviews were conducted, lasting from 1 to 2 hours each. All participants were interviewed in their campus offices to allow for easy access to supporting materials as examples to describe work practice. After explaining her identity, the purpose of the research, and assuring the confidentiality of the interview, the researcher asked initial questions in a relatively

Table 1: Key Themes and Conveyances

Electronic Reference Sources	Conferences	Computer Mediated Communications	Interpersonal Networks
World Wide Web and public access catalogs are used for online literature research to capture existing scientific work: • identify and locate materials; • track citations; • obtain materials electronically.	Physical gathering and interpersonal communication in conferences have three major functions: • facilitate socialization, friendship formation, and the creation of group identity; • provide the opportunities for getting involved in the current research discourse, learning latest research issues and practice, getting immediate feedback, and generating new ideas; • enrich learning experience among scholars through meeting people within and across field boundaries.	E-mail as a major tool for computer mediated communications facilitates and extends: • scientific conversation; • scientific collaboration. But easy and spontaneous e-mail communication reduces the sense and appearance of control, thus: • increase the ambiguity of received information; • produce information overflow; • lower the quality of information content.	The physical and interpersonal communication and interaction are the major practice during scholarly collaboration: • By providing social and physical background, they facilitate coordination behaviors situated in social context; • By permitting interactive exchanges between researchers, they facilitate active knowledge sharing process, in which scholars can solicit input for decisions, ask advice on research, provide ideas, and share knowledge and skills.

structured way to get the basic understanding of the general research practice and resources used (see Appendix 1). Extended questions were then pursued according to any emerging themes and issues during the interview in an unstructured way. This flexibility allowed for the modification of the research design in the light of emergent or unanticipated analytical problems presented by the context or the data (Layder 1993).

The researcher took field notes, and tape-recorded all interviews. During the data collection, the respondents were sometimes asked to comment on disciplinary work practice discovered in other interviews as a consistency check. On a few occasions, there were contacts through e-mail with respondents after the interview, to follow up on unanswered questions. The selection of 5 interviews reflects the constraints of collecting data with limited time and resources.

In keeping with established methods of qualitative research (Bogdan & Biklen 1992; Glaser & Strauss 1967; Lincoln & Guba 1985; Miles & Huberman 1994; Strauss 1987), the data analysis was done in the field as data were collected and organized. The emerging findings were tested and reexamined in the remaining data. At this level, the analysis helped to generate and focus additional questions in subsequent interviews. In addition, the researcher's own emerging interpretations were shared with the respondents during the interview process for clarification. Questions were asked to make certain that the researcher understood the meaning the respondents intended both explicitly and implicitly. Finally, the data analysis occurred during the writing process so that the researcher could write what was seen and heard in a way that translated as clearly as possible to the reader.

Since this is a qualitative exploratory study with a small number of cases, open coding analysis was performed to discern general pattern and key themes in all or most of the cases by assigning short names, letters, or other symbols to typical and frequent elements in the data. To find the relationships between the separate cases, the researcher conducted comparison and classification among the data. After conceptually labeling all the events, the researcher compared the derived concepts against each other and categorized them based on their similarity. Table 1 illustrates the key themes and their conveyances developed during the coding process.

Findings

Research practice in computer science

An interview with a senior faculty and the e-mail communication with the department manager reveal some contextual information about the life

of computer science faculty at the University of Wisconsin-Madison, a large research university. At this site, the faculty is judged on three major contributions: research, teaching and service, with research being the most important consideration and the other two being equally weighted. Research has three components: publications, grants and the letters of recommendation from outside senior scholars in similar areas, with the latter given more weight as to understand what the outside perception is on the faculty's research contributions to their areas. Because they go through a peer-reviewed process, conference publications are generally considered more prestigious than journal publications in computer sciences. Faculty members need to have several publications, and especially have papers accepted at the top conferences in their areas by the time for tenure consideration. In terms of scholarly collaboration, collaborating with the same person, especially with a particular senior colleague, is discouraged by tenure committees, but collaboration is viewed positively if the scholar has done a number of collaborations. The National Science Foundation (NSF) is one major source of funding, which includes costs of travel. The Graduate School at the university also provides a $500 grant for the faculty every other year to attend conferences within the U.S. Faculty members can reasonably request travel funds to visit their research collaborators from their funding agencies.

Based on the understanding of general research practice in computer science, the following sections elaborate the identified themes and major findings in this study.

Electronic reference sources

Electronic networking, as a mechanism for harnessing and integrating distributed information and knowledge across a scientific field, provides opportunities for widespread online literature research. The use of online information sources increases the scope and relative efficiency in capturing existing scientific work. All the respondents reported that electronic sources helped identify and locate materials, as well as obtain materials. The respondents reported using the World Wide Web as a reference source of first resort, for example, Google, personal websites or JSTOR. On-line public access catalogs, such as *MathSciNet* and *Citeseer,* are used a great deal and are highly valued. The major aim of a literature search is to obtain and browse abstracts in the hope of finding relevant papers, which then are used as a basis for obtaining references and downloading full-text documents. Table 2 illustrates the evidence from the responses. Tracking citations is another essential factor in the acquisition of information for existing research work. For example, one respondent stated,

Table 2: Online information search

Respondent	Comment
1	*"If I look for papers, the first thing I do is to get on the Web."*
2	*"Often, if I know specific people who work in the area, I'll go to their websites because most people in computer science post their publications on personal websites."*
3	*"To access stuff, I find the two most useful things are the online Mathematical Reviews called MathSciNet, and the online citation index."*
4	*"I think one advantage of electronic (resources) is in these indexes and abstracts. You can do phrase searching on abstracts. I do it a lot."*
5	*"One thing I find useful is these online archives, like JSTOR, which stands for Journal Storage. It has articles from the back issues of various journals. I use it if I know about a specific article and want to make a copy of it."*

> "Usually, my research involves initially doing a literature survey to see who has done the related work. So, often, what I do is using a search engine, like Google, and typing in some key phases. That usually leads to a website called 'Citeseer'. It tells you a certain publication, the abstract of the publication, and who cited it in other publications. It also tells you the related publications, and usually you can get the text of the paper itself."

Conferences

Interpersonal communication, as the means to develop and maintain in-depth relationships with other scholars, presents opportunities for socialization and "in-depth participation" in research practice to take place. It provides a deeper appreciation as to what is involved in being a member of the scientific community. For example, all the respondents reported attending conferences as ways to learn about the latest research issues and practice, get immediate feedback and generate new ideas. They viewed conferences as the op-

Table 3: Conference Participation

Respondent	Comment
1	*"I usually attend two or three conferences each year. I tend to publish much more in conferences than in journals. In the computer sciences, I think that's normal. The turnout time is much faster. You have an opportunity to go and present the paper in front of people and get feedback. The whole process is intellectually stimulating."*
2	*"In conferences, you can get ideas for new projects as well as get feedback on old project. I do both. If I give a talk, people will come in on it. If I don't, I'll sit down in lunch with someone and say, here is what I am doing, then I get responses. Or they tell me what they are working on, so I can generate some ideas."*
3	*"One source to know the latest results is going to conferences, seeing the titles of published papers and finding interesting ones. Sometimes, I contact the author asking for the paper."*
4	*"The important part of it is you see people from other institutions and learn about what they are doing. (To get this information through websites) is harder. You have to spend forever to look through each person's website. Probably, it won't be so much fun."*
5	*"A conference is a very important source for getting some variety. Going to conference is an opportunity to interact with people in the same area but all over the world, which I couldn't interact with very easily otherwise."*

portunities to know what other people did and are doing, as well as to introduce themselves and outline what they are participating in and what they require. They saw such interaction as a way to generate familiarity and understanding between scholars and to socialize formally and informally with other scholars. Moreover, the respondents felt that the increasing complexity of scientific research requires an approach that focuses on detailed and cross-functional perspectives. Gathering to meet people within and across field boundaries and expose oneself to various ideas allows for an enriched learning experience and active participation in current research discourse. Table 3 illustrates the relevant evidence from the responses.

Edney (1976) points out that physical propinquity and interpersonal interaction promote friendship formation and bonding processes. He indicates that bonding is facilitated by the contacts likely to occur between people occupying the same place, and it is aided by the cognitive sense of unity and sharing a group identity. The primary positive effect indicated among the respondents appears to relate to "being in the loop and being connected to a network of scientists and scientific activities" (Walsh *et al.* 2000). For example, one respondent commented on the importance of attending conferences, "the important part of it is you actually see people from other institutions and talk to them face-to-face about what they are doing and what they know about. It would be so much fun." He continued, "We social creatures seem like that. Most of the time, people enjoy belonging to union. I think going to these conferences is one way that you sort of feel belonging to these communities." In this process, communication skills in oral presentation were highly valued, and were looked upon as important to get into the current scientific discourse. This is evident from one respondent's comment: "oral presentation is very important. In 20 minutes, you have to tell people what you did, [you should be good at using] body language, feel comfortable taking questions and answering questions, and be able to sense if the audience is with you or not. These are important to get involved in the current research discourse." The socializing and bonding process through physical gathering and interpersonal communication initiates friendship formation and exploits the potential for research collaboration.

Computer mediated communications

The next theme in the scholarly community of practice is computer-mediated communication that, by bridging the temporal, spatial, and functional divides among scholars, facilitates scientific conversation and coordination. Electronic mail is one such technique that extends the established practice of face-to-face discussion and private correspondence in academic communication. The respondents perceived e-mail use as efficient, spontaneous, and having led to increased contact with other scholars. Such responses are illustrated in Table 4. One major result inherent from e-mail use is much more various scientific collaborations. "I think e-mail has made it possible to collaborate over longer distance." One respondent remarked, "In my area, I would say the majority of papers have at least two authors. I think this has something to do with e-mail. There are many more collaborations facilitated by e-mail now."

However, easy and spontaneous electronic communication poses problems too. In the virtual world, there are still no clear and common

Table 4: E-mail Use

Respondent	Comment
1	*"It seems to me that the main advantage of technology is e-mail, fast communication."*
2	*"I use e-mail all the time, in terms of research, to communicate with my student assistants."*
3	*"With the advent of e-mail, the messages are usually much more spontaneous. The means really change the end. The media change the way things are written. Because it's so easy, you just type and say, I have the following ideas… and five minutes later, you send another e-mail for a new idea. You can send three e-mails in a day to the same person with the same topic. That just wouldn't happen with the post, with which you think through what you want to say and maybe finally make a decision not to say at all."*
4	*"I have a colleague in Japan. We have been extremely efficient in communicating by e-mail. As he works at night and I work at daytime, we just type on the computer for nearly real-time conversation.*

rules for the organization, structure and continuity of information and communication behavior. Electronic communication reduces the sense and appearance of control in the surrounding environment, and thus increases the ambiguity of received information. According to the respondents, it produced mail overflow and the amount of unwanted incoming e-mails rose so much that it became an annoyance. It also lowered the quality of information content, and thus increased distractions from research. As a result, the randomness of e-mail communication actually increased the amount and complexity of information an individual scholar processed. For example,

> "There are a couple of newsgroups I read regularly, but I don't contribute much. I tend not to post my own stuff because the problem is, if you post something to a newsgroup, you immediately attract a lot of junk e-mails. I am not sure how to handle them. I think it's really a distraction. Maybe you can participate without giving your e-mail address. Besides, there is always an automatic program that will generate tons of e-mail that you really don't want. We do need some sort of filtering mechanism."

> "Most of the e-mail I get is junk. It's kind of unfortunate."

Interpersonal networks

Getting into the stage of actual scholarly collaboration, physical and interpersonal communication and interaction again become the major themes of practice. Electronic networks present opportunities for widespread participation; interpersonal networks present opportunities for comprehensive and in-depth participation to take place. Part of this relates to the human needs for social interaction and to the high premium placed on developing meaningful relationships with others, to working in a conducive and mutually supportive environment (Grosser 1991).

The respondents all showed their appreciation for the informational role of interpersonal networks that involve more interactive exchanges between researchers.

> "Maybe you can pick up subtleties that you can't do otherwise, like, whether somebody is enthusiastic about an idea? You can be more direct, so if you want to ask somebody something, you can ask it right away. Based on their answers, you can presume another question, just like in an interview."

Interpersonal communication is an active knowledge sharing process. All the respondents reported that they had frequent face-to-face communications with other scholars. Through such interaction, they solicited input for decisions, asked advice on research, provided ideas and shared knowledge and skills. For example, one respondent described, "The ideas originate from other researchers who come by and say 'hi, I am trying to solve this problem, do you know anything about this?'" He continued, "actually, the last thing I worked on, I learned about it in a dinner when some speaker said, 'well, here is the thing I am trying to do, this is the paper I am dealing with, do you have any ideas?'"

Interpersonal conversations and group meetings also secure immediate information exchange. They provide people feedback quickly without the distraction of other events and the space for delay, as otherwise in e-mail transactions. Comparing e-mail, one respondent mentioned the constraints of e-mail in that "typing is a little slower than saying," there is no timeline for responses, and it is incapable of "getting the facial feedback right away." He explained, "If I send an e-mail message, I don't expect instantaneous reply. It might take at least a few minutes, or maybe a few hours…" The idea is echoed by another respondent, "I think in the office, there is always something else to do that is more pressing. If someone sends you e-mail, you don't have to answer right away, sort of figuring

Table 5: Interpersonal Communication

Respondent	Comment
1	*"I think it's important to know people, talk to people, and get to know their ideas."*
2	*"I probably have personal conversations with local colleagues everyday. I talk to people next door, hi, here is an idea I have, here are some problems I work on, and here is something I just did… That's useful for getting feedback immediately. Sometimes, You can encourage people to cooperate in your project."*
3	*"Sometimes, people do a project with a pretty big scope. It needs a lot of hands to accomplish… I consult someone who knows about certain pieces of information. I think no one person has enough knowledge to solve any problem. So, sometimes you want to work together with other people."*
4	*"…Person-to-person conversation is really something not to be replaced. I don't think that is a point."*

that you can do it later. While, if in a coffee break with people, you set aside time to talk to them."

The other part of the interpersonal networking relates to coordination behavior situated in social context. Research is a social activity. "More papers are co-authored than single authored." One respondent explained, "The big reason is that people like to work with other people, and generally, people are more productive working as a group. The whole academic system is actually set up that way." The higher coordination requirements of reciprocity in scientific research require the collaboration of researchers. The physical context for interpersonal collaboration provides common ground and social cues to the human interaction. Researchers interact regularly with each other; spend time coordinating and consulting on different parts of the endeavor. The interpersonal communication and interaction situated in certain surrounding environments facilitates knowledge sharing and coordination practice by providing organization, structure and reliable social and physical background for advanced behaviors and adaptive efforts by scholars. For example,

> "You get to see people, talk to people, and they know about what you have done. They associate your face with the (research) results. Then, the next time, when thinking of some results, they think of you. For example, I am thinking of this problem, I can think of what you did; I have this problem, and you have another contribution; I have a set of ideas, and you have something to add. I mean the entire social context that matches is informative."

Furthermore, most respondents reported traveling as a means to collaborate with outside scholars. This further highlights the interpersonal coordination for knowledge sharing over long distances, and that could not be replaced by computer-mediated communication. Other comments are illustrated in Table 5.

Discussion

The contribution of this current study is closely examining one particular discipline, computer science— a field with intensive engagement with information technology and extensive connections between research and technology— to study the use of different communication mechanisms within the field. It provides a focused view of the dynamic relationship between information channels and scientific research practice within a technology-intensive field. Two research questions are initiated and answered in this study.

1. What communication channels have been developed and are used in computer science?

Drawing upon the findings, the conclusion is that the computer scientists in the current study developed their communication practice by getting to know other scholars in the research community through four major sources of information. Firstly, conferences and workshops provide the best opportunities for people to meet the others working in similar areas and keep up with the most recent development. Secondly, journals and conference proceedings contain the recent works that have been published and their authors. This would give the clue of whom to contact. Thirdly, a peer-reviewed conference has program committee composed of 8–20 people. Those committee members read all the submissions and usually meet together in one place for several days to discuss the works. Serving on those committees would help the scholars find out who is doing what, and meet and discuss with colleagues in their interested fields. Lastly, on the Web, the scholars can easily search on keywords relevant to their research and find out who else are working in the same areas. All these information channels foster the social networking among the scholars in their communities of practice. The computer scientists in the current study developed their

research practice by synthesizing information and knowledge from a variety of channels, including electronic media and interpersonal channels. The empirical results support the research expectation that the usage of electronic and face-to-face interpersonal communications are complementary in computer science scientific inquiry. It furthers the understanding of the underlying relationships among the different information channels and actual research practice.

2. What roles do these communication channels play within the field?

According to the findings, electronic communication channels speed up and widen access to scholarly communications and facilitate collaborations among the computer scientists. These channels are used to satisfy the research needs to identify and locate existing scientific work and to extend the established relationship in face-to-face communication by continuing scientific conversation and coordination online.

Interpersonal communication channels facilitate social interaction, strengthen community bonds and enable idea generation among the computer scientists. These channels are used to satisfy the scholars' needs for social, emotional, and contextual information as well as intellectual interaction. These communication mechanisms collectively and dynamically shape the scholars' information exchange. The empirical results support the research expectation that these different ways of keeping track of academic information are not mutually exclusive and are utilized synthetically.

Limitations of the two existing theories and the findings of this study

Based on these findings, this section of the paper considers the utility and limitations of two theories in understanding media use by the computer science researchers and its impact on computer science research. First, it considers the communities of practice approach, and then it considers the media richness theory.

The communities of practice theory first suggests that what is learned is highly dependent on the context that the learning takes place in, as it is central to the transfer and consumption of information. This idea explains the importance of social cues and physical background in interpersonal communication for scientific knowledge sharing, for example, the subtlety of facial expression in interactive conversation and the physical order of interpersonal collaboration. Second, this theory emphasizes social norms of media use by looking at actual practice of work that organizes knowledge in a way meaningful to practitioners whose shared learning brings value to a community. Furthermore, communication contributes to the work of "negotiating" a shared domain and the building of a shared practice. These ideas express the reflexive relationship between communication and social norms of practice. They explain that social relations play a role in the choice and use of communication media among the computer scientists. For example, belonging to the community of computer researchers and engaging in the current scientific discourses require the scholars to search for information online for current awareness of scientific works in the field; the higher coordination nature of scientific research requires interpersonal interactions among scientists for idea generation, feedback, and collaboration. In another example, interpersonal communications initiate and enrich social relationships by providing social cues and interactive exchange among the scholars. Conference interactions help form friendships, and informal conversations with next-door colleagues support research networking. Electronic communications maintain and extend social relationships by transmitting interactive communication around the world at a rate close to the speed of thought; for example, searching online public access catalogs for sharing pooled knowledge and e-mail communication for long distance conversation and coordination. The communities of practice approach helps identify these social relations embedded in the research practice. However, this approach is limited, as it doesn't fully explain specifically why, given equal social acceptability or use, scholars may choose certain media for certain research tasks.

Media richness theory offers an alternative perspective on computer scientists' use of different communication channels. It is one of the most widely applied theories of media use and essentially suggests a "task-media fit", in which me-dia choice is dependent on matching the media capabilities to the needs of communication tasks. Daft and Lengel (1984) define media richness as the

"potential information-carrying capacity of data". They present a hierarchy of media richness based on four criteria: (1) speed of feedback; (2) medium's capability to transmit multiple cues, including body language, facial expression, and tone of voice; (3) medium's ability to personalize message; and (4) language variety carried in the medium.

Face-to-face is the richest form of communication medium as it provides immediate feedback, conveys multiple cues, is personal in nature, and utilizes rich natural language. Media richness theory originated from organizational information processing and managerial information behavior studies (e.g. Daft & Lengel 1986; Daft, Lengel & Trevino 1987; Lengel & Daft 1988; Trevino, Lengel & Daft 1987). Media richness theory can be applied in an academic setting to explain scholars' media use and communication behavior. For example, it explains the computer scientists' preference for personal contact and informal sources of information in socialization, intellectual exchange, and coordination processes in terms of the information richness of face-to-face communication. It also explains the scientists' search of online information databases for existing scientific works in terms of the impersonal nature of the task that is routine and unequivocal and can be best performed via electronic media. The use of computer-mediated communications as moderately rich media is suitable for facilitation and clearly defined information tasks, such as the extension of communication and coordination among the researchers with established relationships.

However, it is quite limited to rank media in absolute terms without consideration of context, which the communities of practice approach argues is central to the transfer and consumption of information. The social context is employed to assist people in creating, using and seeking information. Situating the scholarly communication behavior in the socially constructed research practice, this study shows that both the computer mediated communications and interpersonal communications possess different levels of communication capability that are important in given situations. In addition to the benefit of interpersonal communications, electronic communications provide opportunities for widespread literature research, extend scholars' contacts, and facilitate collaboration over longer distances. Together they form the richest communication media for computer science research activities.

Communities of practice and media richness theory could approach the same phenomenon from different perspectives: a group level view of social norms as how they influence media use and an individual level view of media affordances and how they influence media use. The integration of both theories could offer a more comprehensive understanding of scholarly communication by explaining the mutual shaping of media affordances and social practice in academic settings.

The study results suggest that the computer scientists utilize different communication media for different information needs. The study also suggests several working hypotheses that require further investigation. First, results suggest that scholars may use different media during different stages of research and therefore, different communication media might play unique roles in certain stages of research practice. Results also suggest that scholars with different needs of scientific inquiry due to disciplinary differences might employ media differently. It comports with the research of Kling, McKim and King (2000, 2003) by confirming the "social shaping of technology" perspective, in which people's use of technology is built in the socially constructed research practice and information needs. Finally, it could be that doctoral students utilize communication media differently from faculty. It doesn't agree with Covi's research (2000) that doctoral students reinforce their advisor's patterns of work and resource use in terms of their general communication practice, but suggests a new research agenda in terms of their information needs, social relations and media affordances. These working hypotheses should be explored in future research.

Drawing comparisons with previous research, this study supports the general expectation that information and communication technology can substantially improve communications and collaboration among scientists (e.g. Hiltz & Turoff 1978; Hiltz & Turoff 1981; McClure, Bishop, Doty & Rosenbaum 1991), for example, accessing the cumulative knowledge base of research works, collaborating research and co-authored work over long distances, and exchanging ideas and academic thinking interactively and efficiently. It also supports previous findings that scientists use different media for different information purposes

(e.g. Covi 1999). For example, the scholars utilize electronic networking for capturing existing but widespread scientific works; they make use of interpersonal networks to initiate social interaction and generate familiarity between those in the field; and they use electronic networking to extend the scientific conversation and coordination. It confirms the importance of informal networks in scientific research practice (e.g. Crane 1972; Price 1963). For example, conferences are important for orienting, socializing and community bonding among the people, and informal face-to-face communications are important ingredients for a conducive and mutually supportive working environment. The difference of this study is that it synthesizes the arguments from previous studies and examines how electronic and interpersonal communications collectively shape and impact the scholarly communication among computer scientists within the context of scientific research. It reveals that both sets of communication mechanisms are integral part of the academic working environment.

Certain limitations inherent in the study need to be acknowledged. Due to the time and resource constraints, the study sample includes only five scholars. Given this small sample, the results cannot be generalized. Furthermore, the study employs only a single method, the interview, and a single set of respondents to explore the scientific research practice of scholars. Dependence on a single method has the disadvantages of the restriction of views and potential biases due to interviewer characteristics, expectations, and verbal idiosyncrasies and interviewees' social desirable responses (Podsakoff *et al.* 2003). In addition, this is an exploratory research with a small number of cases. As an initial research, it is conducted without a clearly defined problem and determined real scope immediately in advance. Being of an exploratory character, the research does not intend to provide definitive answers or give conclusive results. Further judgment and justification need to be in place for decision-making or application.

However, the exploratory approach allows the researcher to familiarize herself with the problem and concept to be studied. It can provide significant insight into the given situation and give some indication as to "why", "how" and "when" the scholarly use of different communication channels occurs. It would be reasonable to investigate the possibilities to generalize and extend the results to wider populations in other studies.

As alluded to earlier, several areas remain for future research. Researchers could explore a more inclusive picture of the scientific community by studying the whole network of computer scientists. Research could be done on the scholarly communication in other disciplines and in different participant groups, such as doctoral students. Research could develop electronic systems and information services based on disciplinary or community research practice. More intensive and extensive study could be done on the complexity of the situational and social context within which communication channels contribute to scientific knowledge sharing. Further research could explore scholars' use of different media during different stages of academic research by looking at the "Task/Media Fit" aspect of dynamic communication using media richness theory (Daft & Lengel 1984; Daft & Lengel 1986; Daft, Lengel & Trevino 1987; Suh 1999). To this end, researchers could rely on a mix of ethnographic method and research techniques. The purposes could be set to observe the key process of research practice that people engage in; to understand what is important to scholars, what they do and do not value, and how research is done; and to explore the ways in which their research practice are influenced by social and institutional issues. In addition, we could combine these with methods that allow us to record and quantify patterns of scholarly communication across different activities in scientific work. Incorporating quantitative data may help further develop our understandings of the relationships suggested by qualitative data, giving us a more concrete and complete picture of the scholarly communication in scientific work.

Conclusion

Based on the argument that knowledge working is inseparable from its own historical and social locations of practice and should be studied in the actual practice of work, the researcher sought to offer a holistic perspective on the information mechanisms employed in scholarly communication in computer science. To this end, the study examined the collective effects of two sets of communication channels: electronic information mechanisms and interpersonal communication

channels. The theoretical rationale drew upon the communities of practice theory.

The study has two primary contributions. First, it provides a rich description of computer science researchers' perspectives on different media and types of knowledge they share via the media. Second, it applies the communities of practice approach to study scholarly communication within social context and identify reflexive relationships between media use and social relations embedded in actual research practice. These results will help refine the understanding of dynamic relationships between different information channels and scientific research practice.

Several theoretical and practical implications follow. From a theoretical perspective, the research findings suggest that to understand scholarly communication, exploring social cues embedded in the real world practice will yield valuable information. The analysis of the scholars' perception of scientific communication and interaction suggests that interpersonal closeness and socially organized setting provide important cues about the research identity and state of relationship among scholars, and thus shape and are shaped by the media choice, which facilitates the social-dynamic processes of knowledge sharing.

From a pragmatic perspective, the practice of a scholarly community has a range of important implications. The detailed examination of research practice provides a resource for the general design of systems to support collaborative scientific work. Understanding the scientific knowledge sharing in a social context, and gaining insights into how to adapt the services and systems better to accommodate the realities of human information handling in scientific work, library and information professionals will be better grounded in the planning and provision of information services. Thus, scientific workers would gain optimal effectiveness from the information resources.

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Appendix 1: Initial interview questions

My research topic is CS Faculty's scholarly communication in academic research. I am interested in the resources and information channels you refer to in your research practice.

- So first, could you please describe the general research activities in the field?
- Could you please describe how you get to know the most current research issues and practice in your field?
- Could you describe, in the process of your research practice, what resources or tools do you usually use, and how you use them?
- How do you participate in personal communications with other scholars? And how do you think these personal interactions are helpful in your research practice?
- How do you use information and communication technologies for your scientific inquiry? And how are these technologies helpful in your research?

Editorial history:
paper received 3 March 2006;
accepted 14 August 2006.