Scholarly Networks as Learning Communities: The Case of TechNet

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WIRING SCHOLARLY NETWORKS

Rapid developments in computer mediated communication are associated with a paradigm shift in the ways in which institutions and people are connected. This is a shift from being bound up in small groups to surfing life through diffuse, variegated social networks. Although the transformation began in the pre-Internet 1960s, the proliferation of the Internet both reflects and facilitates the shift.

Much social organization no longer fits a group-centric model of society. Work, community and domesticity have moved from hierarchically arranged, densely knit, bounded groups to social networks. In networked societies: boundaries are more permeable, interactions are with diverse others, linkages switch between multiple networks, and hierarchies are flatter and more recursive. People maneuver through multiple communities, no longer bounded by locality. Organizations form complex networks of alliances and exchanges, often in transient virtual or networked organizations (Bar & Simard, 2001). Workers --especially professionals, technical workers, and managers -- report to multiple peers and superiors. Work relations spill over their nominal work group's boundaries, and may even connect them to outside organizations. In virtual and networked organizations, management by network has people reporting to shifting sets of supervisors, peers, and even nominal subordinates (Wellman, 2001).

How people learn is becoming part of this paradigm shift. There has been some move away from traditional classroom based, location-specific instruction to online, virtual classrooms. There has also been some move away from teacher-centered models of learning to student-centered models and flatter hierarchical relations. Physically dispersed learning is part of this shift. It has moved beyond traditional many-to-teacher correspondence and educational television courses to computer-supported many-to-many learning. Even before the development of the Internet, text-based computerized communication supported communication and collaborative among physically dispersed scholars (Finholt, 2001; Finholt, Sproull & Kiesler, 2002). This is now being joined by online audiovisual technologies supporting collaborative work (Ragusa & Bochenek, 2001; Barrett, 2000; Churchill, Snowdon & Munro, 2001). Distance education programs now offer a variety of courses, supplementing traditional means of instruction with computer-mediated activities and projects (Harasim, Hiltz, Teles & Turoff, 1995). In some cases, computer mediated communication has enabled the operation of entire university programs online (Acker, 1995; Noam, 1998). Instead of university faculties localized at their university departments, formalized “collaboratories” link far-flung scholars, institutions and research centers (see Kling this volume; Finholt, 2000). Even more prevalent are informal collaborations between researchers and professors located in different universities spanning the globe (Koku, Nazer, et al, 2001).

Computer mediated communication is providing a technological basis for new forms of spatially-dispersed, loosely-bounded, networks of scholars that are more connected than the fitful, amorphous relationships of the past and less physically proximate and bureaucratically structured than contemporary universities. The velocity of communication is more rapid, distant scholars stay in touch more, and email and attachments fill gaps between face-to-face meetings.

The ability of all to communicate rapidly with all, no matter where located has created hopes that peripheries would become as well-connected as centers. As distance matters little for computer mediated communication, spatial isolation should not be a problem. As all are connected to all, formerly disconnected persons, groups and branch plants should be as able as those at the center to communicate with others. This should affect the structure of scholarly networks: As email helps maintain direct ties, social density increases and the periphery – whether spatial, social or scholarly – can become better connected with the core.

Preliminary research has shown that computer mediated communication supports a range of instrumental, informational, social and emotional exchanges in work and leisure contexts (e.g., Baym, 1995, 1997; Rice, D’Ambra & More, 1998; Wellman & Gulia, 1999). Building on this work, there is a need to understand the types of interpersonal interactions, multiple exchanges of material and emotional support, intimacy, trust, and self-disclosure that characterize learning communities online and offline (Granovetter, 1973; Marsden & Campbell, 1984; Wellman & Berkowitz, 1988; Wellman, 2001). By "opening the black box of community and looking inside, [analysts] can examine the types of interactions and social linkages that connect community members" (Haythornthwaite, 2002, p. ###). Social network analysis provides an approach that can facilitate understanding of communities. Viewing community as comprising social networks of relations enables analysts to examine the types of interactions -- such as information, emotional support, material support, companionship -- that affect online communities. It facilitates the assessment of the extent to which computer mediated communication supports online learning communities with low levels of centralization and hierarchy (Ahuja & Carley, 1999).

In this chapter, we analyze social network ties and structures of “TechNet”, a scholarly network in a North American university. We address a series of questions:

- What is the size and heterogeneity of scholarly work, friendship and communication networks?
- To what extent are such work, friendship, and communication relationships associated?
- How are the size and heterogeneity of scholarly networks related to communication patterns?
- What is the role structure of this scholarly network?
- Is the role structure of the email contact network more egalitarian than that of the face-to-face contact network?
- What are the implications of the network’s role structure for communication patterns?

In the next section of this chapter, we describe social network analysis and discuss how it can aid understanding of scholarly networks, online and offline. The chapter continues with a description of TechNet as a community of practice (Wenger, 1998) engaged in peer-to-peer interaction and learning. In the last sections of the chapter, we use survey and qualitative data about TechNet's structure and relationships to address our research questions.

SOCIAL NETWORK ANALYSIS OF COMPUTER SUPPORTED NETWORKS

Much research on computer-mediated communication has focused on how the characteristics of different communication media affect what each medium can convey (Garton, et al., 1998). Such characteristics include the richness of cues a medium can convey (for example, whether a medium is text only such as email or also includes visual and auditory cues), the visibility or anonymity of the participants (video-mail versus voice mail); whether communications identify the sender by name, gender, title; and the timing of exchanges (e.g., synchronous or asynchronous communication). Until recently, social scientific research into computer mediated communication has concentrated on how individual users interface with computers, how two persons interact online, and how small groups function online. Much less attention has been paid to how computer networks fit into the broader social networks and contexts in which these individuals, duets, and groups are connected. Yet, the social relationships that people have with each other are embedded in social networks that affect their social resources, mobility, happiness, and work habits (Wellman, 1999, 2001).

Social network analysis stresses the importance and patterns of relationships among interacting units: people, organizations, states, etc. The social network approach enables analysts to go beyond viewing relationships only in terms of groups and isolated duets. It incorporates into research a set of structural variables such as the density, clustering, heterogeneity, and multiplexity of networks (Wellman, 1998, 1999; Berkowitz, 1982, Scott. 1991, Wasserman & Faust, 1994, Wellman & Berkowitz, 1988, Ahuja & Carley, 1999; Tindall & Wellman, 2001). Social network analysts have developed procedures for seeing how different types of relationships interrelate, detecting structural patterns, and analyzing the implications that structural patterns have for the behavior of network members. For example, the fact that Person A and Person B interact online may be understood better if one takes into consideration their offline reporting relationships to Person C, the company Vice President.

Thinking about relationships in terms of social networks rather than in groups can allow analysts to examine the social contexts of online relationships and focus on the potential of computer mediated communication to support less-bounded, sparsely-knit interactions (Rice, Grant, Schmitz, & Torobin, 1990; Fulk et al., 1987, 1995, Wellman & Gulia, 1999, Wellman, Salaff, Dimitrova, Garton, Gulia & Haythornthwaite, 1996). For example, analysts may enquire whether there is a core and periphery in a particular network structure, and then examine how involvement in such structural blocks helps explain the behavior and attitudes of network members. For example, do peripheral people send more email and do they communicate only with members of their own clusters or with others?

Network analysts look at both *whole networks* and *personal networks*. Whole network analyses look at patterns of relationships in a social system, be it a set of scholars or a set of states. Personal network analyses look at each person's own network, such as the differences between scholars' network (Wellman & Berkowitz, 1988).

In the past four decades, the social network approach has evolved into a set of theories, models, and substantive applications in many domains that have traditionally interested social scientists. The growth of the social network approach is partly reflected in the longevity of the International Network for Social Network Analysis, a multidisciplinary scholarly organization founded in 1977. It publishes two refereed journals, *Social Networks* and *Journal of Social Structures*; an informal journal, *Connections;* holds annual conferences; maintains a lively list serve, *SocNet;* and hosts an information-rich website. Network analysts have demonstrated the role of social networks in understanding:

- Communities (Fischer, 1982; Wellman, 1999; Newman, 2001);
- Provision of interpersonal support (Lin et al., 1986; Lin & Westcott, 1991; Wellman, 1992b; Wellman & Wortley, 1989, 1990)
- Social capital (Lin & Gao, 2000; Lin et al., 2001)
- Diffusion of innovations (Rogers, 1979; Valente, 1995)
- Sociology of science (Carley & Wendt, 1991; Carley et al, 1993; Crane, 1972, Newman, 2000);
- Computer mediated communication (Haythornthwaite, 2000; Haythornthwaite & Wellman, 1998; Rice, 1991, 1994, 1997, 2001; Teigland & Wasko 2000; Wellman & Gulia, 1999; Wellman et al., 1996).

The social network approach has developed a battery of concepts and methods that can aid analysis of communities, online and offline. Using examples from online communities in general, and learning communities in particular, the next section of this chapter examines the usefulness of social network concepts such as range (size and heterogeneity), density and boundedness, centrality, tie strength, multiplexity (multiple roles), and network blocks for understanding online communities and social relationships.

Network Range (Size, Heterogeneity)

The concept of network range pertains to the size and diversity of the population within the network's boundaries (Burt, 1983; Haines & Hurlbert, 1992). Networks with high range (large, heterogeneous) are good for seeking and obtaining new resources (Wellman, 1999; Newman 2001). On the other hand, networks with low range (small, homogeneous) are able to conserve resources and information within their boundaries.

Computerized conferences, newsgroups and listserves facilitate and increase the range of social networks (Smith, 2000). The asynchronicity and relatively inexpensive cost of online communication transcends spatial and temporal limits, enabling system users to communicate over different time zones and maintain contact with their weak ties. Therefore, online communication links can increase the range of social networks. Given that email relationships have few social cues and social presence, the only personal detail that communicators may initially know about each other are their email addresses and signatures. Such limited personal information allows development of relations based on shared interests rather than on shared social status (Hiltz & Turoff, 1993).

Centrality

Network centrality indicates the extent to which certain network members are prominent in a given network in terms of connectivity among network members. Centralization scores (measured as a percentage) measure how variable or heterogeneous the individual network member centrality scores are. It records the extent to which a single network member has high centrality scores, and the others lower scores. A high centralization score means a network's activity centers on a particular member.

Two important types of centrality are pertinent to this study: degree centrality and betweenness centrality. Scholars who have high degree centrality are those who have many connections with other network members. Such scholars are involved in relations with many others and could be recognized by other scholars as a major channel of scholarly information and activity. Well-connected network members usually play a key role in shaping the behavior and perceptions of others in the network, particularly in the diffusion of innovations (Rogers, 1983; Valente, 1995) and the use of available media. Central network members tend to use a variety of media (Haythornthwaite & Wellman, 1998), have the most positive experiences with media use (Papa & Tracy, 1988), and are early adopters of a new information system and facilitated the development of critical mass of users for the system (Rice, Grant, Schmitz & Torobin, 1990, Rice, 1997).

When directionality is taken into account, there are two kinds of degree centrality: *In-degree centrality* measures how many other network members report having a relationship with a specified person. For example, others mention scholars with high in-degree centrality as people they approach for advice or discussions. Thus, in-degree centrality is one measure of the prestige of a network member. By contrast, *out-degree centrality* measures how many other network members a person reports being connected to. Thus it is an indicator of the extent to which a scholar reports reaching out to others.

Betweenness centrality measures the extent to which a network member occupies a location between others in the network. Someone with high betweenness is positioned in the collaborative and communication network between people who are not directly connected. Network members with high betweenness facilitate communication and information flows. They broker information, linking otherwise disconnected scholars. They transmit information across disciplinary and organizational boundaries (Burt, 1992; Tushman & Scanlan, 1981; Ahuja & Carley, 1999; Orlikowski & Barley, 2001). Thus, scholars with high betweenness are in powerful collaborative and communication brokerage positions between otherwise disconnected scholars.

Studies of invisible colleges have drawn attention to the importance of centrality in the control and diffusion of information (Crane, 1972). Central scholars are able to sustain a more central communication role than peripheral ones in part because of prestige, popularity, and grant funding. This has positive feedback effects, leading to increased conference attendance, speaking engagements and interaction with disparate others (Perry & Rice, 1996). All of these interactions expose scholars to more ideas, make them better known within professional and policy circles, and popularize their research. This sustains the cycle of centrality and prestige because central scholars are better able to respond to promising ideas, influence the direction of policy, and retain funding.

Central scholars tend to have a sophisticated level of knowledge of the things worth knowing: the debates and lore that are crucial for leading-edge scholarship. They may play an essential role in introducing peripheral ideas into the mainstream, which otherwise might lack the attention or awareness within the scientific community (Perry & Rice, 1996). As Erickson (1996) suggests, one of the useful consequences of being in the center is that central people know what they can afford not to know.

Density

The density of a social network is the extent to which its members are in direct contact with each other. Hence, the rate of information flow in networks partly depends on whether networks are densely or sparsely knit. Densely-knit, bounded networks (i.e., “groups”) are characterized by frequent contact among members. In such networks, most relationships remain within the population, with the exception of a few boundary spanners and gatekeepers who maintain links outside. Frequent contact within these groups and the wide range of group activities often fostered by members create close relationships among members.

By contrast, members of sparsely-knit networks have many ties with others who are not members of any given network. Ties in sparsely-knit networks tend to be more variable than those in densely-knit networks (Danowski, 1986; Wellman, 1997) in terms of what network members do together, how supportive they are, and how frequently they interact.

Computer mediated communication supports both densely-knit and sparsely-knit networks. Focused task and work groups, MUDs and some moderated newsgroups and listserves are densely-knit communities, as they evolve rules and leadership structures and require attention and commitment from their members (Kollock & Smith, 1998). Message management features of email systems can increase network density and enable friends and colleagues to keep informed. Third parties spread the word about who has help, who needs help, who has been helpful in the past, and who has been a free rider. Forwarding communications to third parties also provides indirect connections between previously unconnected people. Ease of direct reply can then transform a transitive, indirect tie to a direct tie.

Computer networks also support sparsely-knit networks. Participants can send email to anyone whose address they know, and they can belong to multiple discussion lists and chat groups simultaneously. They can engage in different kinds of discussions about different subjects on different lists, varying their involvement and commitment in different work groups, maintaining connections with distant acquaintances and forming new ties with strangers. Information may come unsolicited through distribution lists, chat groups, forwarded messages from friends, and direct e-mail from strangers connected through mutual ties. Sparsely-knit networks are usually connected through weak ties to a variety of social circles. Hence, they are more apt to be sources of new information and potential alliances (Granovetter, 1973, 1983).

Tie Strength

The strength of a tie is a multidimensional construct comprising social closeness, voluntariness, and multiplexity, and (Granovetter, 1973, 1983; Wellman & Wortley, 1990). Strong ties often provide more support and information, and a sense of belonging. However, Granovetter shows that weak ties are useful for specific purposes. He argues that people live in a cluster of others with whom they have strong relations. Information circulates at high velocity within these clusters, and each person tends to know what other cluster members know. The spread of new information, ideas and opportunities must therefore come through the weak ties that connect people in separate clusters.

Some studies have focused on the effect of tie strength on resource and information flows among scholars. Friedkin's (1980, 1982) study of university faculty contrasts the importance of strong versus weak ties for information flows. He shows that in the aggregate, the large number of weak scholarly ties contribute significantly to information flows. Although strong ties provide much information about activities within an organization, weak ties provide useful information about activities outside of a work group or organization (Levin, Cross, & Abrams, 2002).

Marshall McLuhan (1962) claimed that the medium is the message. Does computer mediated communication determine the content of messages and the pattern of their communication? In particular, does computer mediated communication support only weak, narrow and instrumental messages as analysts once feared (Fulk, et al., 1987)?

Despite e-mail's limited social presence and absence of social cues, its ease and ubiquity supports strong, frequent, supportive, and companionable contact (Nie, 2001, Wellman & Gulia, 1999; Garton & Wellman, 1995, Kling, 1996, Rheingold, 2000, Sproull & Kiesler, 1991b). So strong and supportive are some online relationships that some participants in an online group came to feel that fellow members were their closest friends (Hiltz & Turoff, 1993). Concerns about how computer mediated communication supports strong ties ignore the many relationships that combine online and offline communication. Computer mediated communication is often used to maintain contact between face-to-face meetings and phone calls. Indeed, computer mediated communication often coincides with in-person meetings, fills in gaps between, and helps arranges future meetings. Conversations began in one medium and drift to another. For example, most computer scientists working in the same physical space communicated by email as well as face-to-face (Haythornthwaite & Wellman, 1998). Learning communities are no different, with friendship and informal relationships -- online and offline -- being the fluid that lubricates the formality of collegial and academic collaborations (Carley & Wendt, 1991; Grimshaw, 1989; Gresham, 1994; Toren, 1994; Glanz, 1999).

Blockmodels

Traditional tests of social influence explain the similarity of attitudes shared among a set of individuals according to attributes such as age, occupation or degree of innovation (Rice & Aydin, 1991). However, network analysts argue that people's attitudes are, in part, a function of their patterns of relations with others (Wellman, Carrington & Hall, 1988; Erickson, 1988). The structural context of their relationships provides the mechanisms by which individuals are influenced by the information, influence and behavior of others. Specifically, such structural contexts are important in explaining perceptions of communication media and media use. One indicator of such a structural context is “structural equivalence” and “blockmodeling”.

Unlike many network analytic techniques, blockmodel analysis does not examine the direct connectivity of members of a network. The notion of equivalence underlies blockmodeling, a quantitative technique that assigns members of a network to blocks. Two scholars are equivalent if they have similar relationships to and from all other scholars in the network (Wasserman and Faust, 1994). Blockmodel analysis starts by partitioning (subdividing) and permuting (reordering) the rows and columns of the socio-matrices of relationships under study to discover patterns of links among the actors in the network. Specifically, the goal of this reordering is to arrange network members into sets (termed blocks) so that network members who are assigned to the same block occupy adjacent rows and columns in the permuted matrix.

Equivalent persons may share similar attitudes -- not necessarily because they are directly related to each other but because they occupy similar positions and are exposed to similar sets of influences, obligations and expectations (Rice & Aydin, 1991; Burt, 1980). For example, equivalent organizational members often perceive and use information systems in similar ways (Robertson, 1988; Contractor & Eisenberg, 1990).

The above discussion shows that network analysis concepts such as size, heterogeneity, centrality, density, tie strength and blockmodeling can facilitate our understanding of the underlying structures of online and offline communities, and can also help us understand use of communication media in such communities. Network density, for example, gives us an understanding of the extent of direct connectivity among network members and how this affects communication patterns and access to resources; tie strength shows the extent to which communities are differentiated by different degrees of closeness and how this affects their choice of communication media and work relations. The next section describes TechNet as a scholarly community, and analyzes the network structure and communication behavior of the scholars.

TECHNET: A SCHOLARLY COMMUNITY

TechNet is a network of scholars and professionals in a North American university interested in a coherent set of issues at the intersection of the social sciences, humanities, sciences and engineering. It began informally in the early 1990s and formally became a university research institute in the mid-1990s. Its goals are to:

- Facilitate an intellectual community of scholars, researchers and students from a number of disciplines.
- Facilitate appropriate partnerships with other universities, the private sector, non-profit organizations and government.
- Afford the intersection of the relevant disciplines a more prominent place and role within the university.
- Create and support colloquia and lecture series.
- Facilitate visits to the university of distinguished scholars and research working in these areas and to increase support for graduate students.
- Establish one or more appropriate funded chairs and professorships.
- Create additional relevant courses, and increase awareness of existing course that cross disciplinary boundaries.

- Create a new collaborative degree program
- Develop and offer short professional development courses for industry and society.

TechNet's activities have been guided by a multi-disciplinary steering committee that meets monthly. Membership in TechNet is voluntary and open to all faculties with an interest in TechNet’s domain. At the time of our data gathering at an early stage of TechNet’s development, administration was informal, with only one part-time paid adminstrative assistant. There were 24 members of TechNet -- from the social sciences, physical sciences, medical sciences, humanities, and engineering. Members of TechNet organize and meet in a variety of online and offline forums to exchange ideas, discuss emerging research and to socialize. Some of these are weekly multi-disciplinary seminars, annual conferences and symposia, retreats, end-of-semester/year parties.

TechNet is a scholarly network or more broadly, a community of practice with a shared history and cosmology (Barab & Duffy, 2000). Many founding members and some other members were initially linked through participation in joint research, conference attendance, reading the same journals, membership in university committees, and advising on graduate student projects. TechNet is also linked with other communities interested in the intersection of the humanities, social sciences and technology. As one member explains in an interview:

> The ways that an entire citizenry can be much more actively and successfully involved in knowledge development and knowledge society is the core interest of mine and that of a number of TechNet members. I just think that this interest is grossly under-represented in the kind of work that is done in the university and underrepresented in formal structures. There are lots of faculty who are doing exciting things, but there are no formal structures to network together.

Scholarly networks, such as TechNet, have existed since at least the Middle Ages. Fragmented archival records attest to the correspondence among scholars show that scholarly networks communicated actively during the Enlightenment. In England and elsewhere, some were recognized as royal societies (Marshall, 1970). Studies of scholarly networks have increased since the early 1960s when Price (1961) coined the term "invisible colleges" to describe the patterns and structure of scholarly networks (see also Crane, 1972).

Scholarly networks contain:

- A core group of elite scholars;
- A high degree of communication through formal (conferences, papers) and informal channels among members;
- Frequent communication between prominent core scholars and subsets of less prominent, non-core scholars;
- Interactions among core members and their adherents hold the invisible college together;
- Contacts between members of invisible colleges and outsiders enable mutual exchange of information.

Within the last three decades, developments in transportation, telecommunication and computer-mediated communication have transformed some invisible colleges into "visible colleges" (Nazer, 2000; Walsh & Bayama, 1996). With the advent of the Internet, there are fewer constraints of time and place on communication. Scholars can stay in their locale to connect, interact, and collaborate with each other over great distances (Finholt, 2001; Assimakopoulos & Macdonald, 2001; Koku, Nazer, et al., 2001; Matzat, 2001; Mutschke & Quan, 2001). To facilitate the design of communication tools to aid scholarly communication and online learning behavior, it is useful to understand the social structure of scholarly networks, the types of media used by these networks, and the conditions under which different media are used.

METHODS

We interviewed all 24 TechNet members in 1997-1998 about their work, friendship and media use inside and outside of TechNet, asking members to describe their scholarly and social relations with each other TechNet member. This elicited reports about 405 pairs of scholars: their work relationship, social closeness, friendship, frequency of scholarly communication, and type of communication media used. Although much of these interviews are analyzed statistically in this chapter, we also rely on notes of conversations held during the interviews and our own active participation in TechNet since its inception.

Relationships

Collaborating Relations: TechNet members' reports about the presence or absence of a collaborative tie with other members. As there are non-academic members of TechNet (those holding administrative or quasi-research blocks), and there are academics that engage in collaborative work with the non-academics, we define collaborative work as all professional work that has scholarly related outcomes. Hence, joint participation in grants applications, university review committees, research projects, and collaborative teaching are all considered as collaborative work.

Discussing Research: TechNet members' reports about which other members they discuss research questions or seek advice about research issues. These relationships are important in their own right and are often corollaries to collaborative relationships.

Reading Work: Members' reports about whether they read the work of each other member.

Social Closeness: Members' reports about the type of social relationship they have with each other member. Respondents were asked if they are a "friend", "colleague", "acquaintance", or just "aware of" each other member. This variable was recoded into four matrices indicating the presence or absence of a friendship, collegial, acquaintanceship and awareness relationship between pairs of scholars.

Frequency of Communication: Members' reports of their frequency of contact with each other member within the past month. This is recoded into yearly estimates by multiplying the monthly counts by 12.

Perceived Effectiveness of Media for Scholarly Work: Members' rating of the effectiveness of email and face-to-face media for accomplishing scholarly activities. The ratings are: "not effective," "moderately effective," "effective," and "very effective".

Network Structure (calculated with UCINet software; see Borgatti, Everett, et al. 1999):

Network Density: Measures the proportion of relationships that are actually present in a network. Density ranges between 0 for a network with no relations among members, to 1, for a network with all members directly connected to each other.

Network Heterogeneity: Standard deviations indicate the extent of variation in the composition of a scholar's collaborative, discussion, reading, interpersonal, and communication relationships.

Network Size: The total number of other TechNet scholars with whom each scholar maintains relations of a specified tie (e.g., discussing work).

Centrality of Network Members: Each scholar's prominence in scholarly relations. We use the following measures:

- *Out-Degree Centrality:* Scholars with high out-degree make many choices, reaching out towards others
- *In-Degree Centrality:* Scholars with high in-degree are the object of many choices and hence, the members of many others' networks.
- *Degree Centrality*: Degree centrality counts the number of specified relationships that a person has, without regard to directionality. The degree centrality measure is applicable to relationships where one cannot clearly distinguish choices made (out-degree) and choices received (in-degree).
- *Betweenness Centrality:* A scholar with high betweenness centrality straddles the communication or interaction paths between two non-adjacent scholars. Such a scholar mediates the communication or relationship between other scholars. Scholars with high betweenness centrality are more likely to control interactions between pairs of other scholars in the network.

We computed these indices for each scholar's collaborative, discussion/advice seeking, and reading work networks. To enable comparisons across these different relational networks, we standardize indices by dividing the individual degree values by the maximum possible degree expressed as a percentage (Borgatti, 1999).

RELATIONSHIPS AND NETWORKS IN TECHNET

Range

TechNet scholars report having an average of 5 friends within TechNet (22 percent of the total membership), 10 colleagues (43 percent), 9 acquaintances (39 percent), and are "just aware" of 4 others (17 percent; Table 1, see also Table 3 below; Koku, et al., 2001). They are in email contact with 19 (82 percent) other members and in face-to-face contact with 14 (61 percent). Most use email where necessary for work relationships such as discussion of research, and supplement this with face-to-face communication when they meet in person in workshops, seminars, and other collegial gatherings. Sheer statistics underestimate the significance of face-to-face contact, as it is usually of longer duration and provides more communication bandwidth than email contact. Those pairs of TechNet scholars who are in touch are in relatively frequent contact: a mean of 20 times per year and a median of 10 times per year. As all TechNet members are comfortable with computers, they use email often: 56% of all Technet pairs have some email contact.

<<< Table 1 about here >>>

Email supplements face-to-face contact rather than supplants it, with members using it to arrange face-to-face meetings, disseminate news, and exchange documents. Those TechNet members using email send messages to each other at a mean rate of 24 times per year, an average of twice per month. To Technet members, non-face-to-face communication means computer mediated communication. Only a minority use telephones, faxes and couriers, and those who do use these media, use them infrequently. The most widely used of these are local telephone calls, used by only 25 percent of the members. Those who telephone do so on the average of once per month (mean=11 calls per year). Most TechNet pairs use a combination of communication media to keep connected. 32 percent use two media while 23 percent use three or more..

Discussing and seeking research advice are not uniformly distributed in collegial communities (see for example, Lazega and Duijin's study of law firms, 1997). The more intense the work relationship, the smaller the scholar's network. The average TechNet member discusses work with 17 other TechNet members (74 percent), but reads the work of only five (22 percent) and also collaborates with five (22 percent; not necessarily the same five) in research and proposal writing. These may be overlapping networks, with some scholars discussing each other's work, reading these works, and collaborating in research.

Larger scholarly networks vary more in the intensity of their communications (e.g., email) and scholarly (e.g., discussion) networks. Thus, email contact networks are large and heterogeneous as face-to-face contact networks. Similarly, research discussion networks are larger and more heterogeneous than reading or collaborative networks. The size and heterogeneity of email networks stems in part from the from the ease of making contact without regard to spatial and temporal separation, and the ease of including several scholars in the same message. Moreover, forwarding email messages fosters the development of more extensive and intensive relationships among scholars. The development of such heterogeneous linkages is facilitated by TechNet's weekly seminars, workshops and other social events that provide an in-person focus (Feld, 1981) where scholars make and sustain collegial and sociable contact with people from different disciplines (for a similar pattern in another scholarly network, see Koku, Nazer & Wellman, 2001; Nazer, 2001). Such networks are important avenues for the provision of social, instrumental, and emotional support, and the mobilization and coordination of collective activity.

Network Density

TechNet's email contact network is quite densely knit (.64; Table 1). That nearly two-thirds of all possible TechNet pairs are connected by email reflects the ease by which people can communicate one-to-one or one-to-many. The lower density of face-to-face contact networks (.40) reflects the greater effort needed to journey across a large campus in what often is below-freezing weather. Nevertheless, two-fifths of all TechNet pairs do have face-to-face contact, testifying to the success of this visible college in fostering ties across dispersed disciplines and buildings.

The high density of the discussing work network (0.74) also shows TechNet's success in fostering contact and awareness of the members' work. Within TechNet, small sets of members work together, reflected in the lower collaboration network density of .21 and reading work density of .12. There are no projects involving a majority of members.

These are essentially awareness and contact based networks of colleagues (density=0.41) and acquaintances (0.29). The low friendship network density of 0.19 shows that TechNet does not have a dominant friendship cluster, although as blockmodeling will show later, there are coherent sets of planners and researchers within it.

The Intertwining of Scholarly Relationships

There is a moderately strong correlation between scholars interpersonal and work relationships. "Friends" and "colleagues" are likely to collaborate (Table 2).[1] Collaborators also communicate more

[1]UCINet's QAP correlation function examines this by permuting the rows and columns (together) of one of the input matrices, and then correlating the permuted matrix with the other data matrix. This process is repeated hundreds of

frequently by both face-to-face and by email contact. By contrast, acquaintances and colleagues are more likely to have the weaker relationship of discussing research. Reading each other's work is widely diffused through TechNet. It is not significantly associated with either TechNet members' frequency of contact or the intensity of their relationships (friendship, colleagueship, etc.).

<<< Table 2 about here >>>

There is a social aspect to scholarly relationships (Hert, 1997). Having a collegial tie is usually not enough for having collaborative ties: Friendship is usually involved. Strong scholarly and friendship relations develop in positive feedback loops. Friends collaborate and discuss each other's work, and collaborating scholars develop stronger friendship ties As cosmologist James Hartle (University of California, Santa Barbara) says of his collaboration with Nobel Prize winner Stephen Hawking (Cambridge University): "Generally, it is the science that drives it, while friendship naturally follows" (Glanz, 1999, p. ###). Frequent email and face-to-face contact are significantly related to having both collaborative and friendship relations. All media are used in such collaborative/friendship relationships. These scholar-friends use whatever means is necessary and handy (Haythornthwaite & Wellman, 1998; Koku et al, 2001).

Each medium plays a different role in supporting scholarly activities. For instance, the positive and moderately strong correlation (r=. 24) between collaborative work and the frequency of email contact suggests that the velocity and timelessness of email supports collaboration. Although the scholars perceive face-to-face contact as effective for accomplishing scholarly activities, computer mediated communication means that TechNet collaborators can work effectively despite being dispersed throughout a large university (Kraut, 1990).

Centrality and Communication

TechNet's email contact network is less centralized (centralization score=34) than its face-to-face network (score=56). Most Technet members send and receive emails, but face-to-face contact between them is more variable.

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times to build up a distribution of correlations under the null hypothesis of no relationship between the matrices. A low p-value (< .05) suggests a strong relationship between the matrices that is unlikely to have occurred by chance.

TechNet scholars with large personal networks of collaborators and high (degree) centrality communicate more face-to-face and by email (Table 3).[2] Scholars with high betweenness centrality have a similar pattern, except that they have appreciably more face-to-face contact with their collaborators. Scholars with large collaborative and reading networks use more media to communicate, and are more likely to perceive email and face-to-face contact as effective for scholarly communication (see also Ahuja & Carley, 1999).

<<< Table 3 about here >>>

The centrality of scholars in a network is significantly related to their communication behavior in four ways:

1. Scholars who reach out (have high out-degree) to other scholars for advice and discussing research tend to use several media (QAP r=0.19) in their communications and to value email as an effective means of fostering discussions (0.26). Scholars who need advice and want to discuss their research increase their opportunities by using multiple communication media. However, the frequency of email contact itself is not related to scholarly centrality because much TechNet email traffic is administrative or public service broadcasts, such as notices of forthcoming lectures.

2. High-prestige (high-in-degree scholars), those who report being asked by many others for advice, perceive face-to-face contact as effective in scholarly work (0.28). Such central TechNet members tend to be frequent seminar goers, making them accessible for such spontaneous encounters. Face-to-face contact enhances the status of prestigious scholars by giving them more information and visibility in TechNet. When such face-to-face contact is scheduled, it indicates the seriousness by which the advice-seeker regards the knowledge given. When face-to-face contact results from spontaneous encounters (such as encounters at seminars), it is a less intrusive medium than email for acquiring advice.

[2] We analyze associations between the size, density, heterogeneity, and centrality of the networks by importing personal network and centrality indices from UCINET into SPSS. Given that these indices are on individual level, we treat them as personal attribute information and merge them with respondent-level data (Wellman & Frank, 1991; Wellman, 1992). This enables us enable us analyze the implications of individual attributes for communication behavior of scholars.

3. The high betweenness centrality scores of frequently-collaborating scholars are related to their frequency of email contact (0.19), use of multiple communication media (0.12), and especially, perception of the effectiveness of face-to-face communication for scholarly work (0.37). High betweenness implies greater capacity for brokerage, with email and face-to-face communication combining to facilitate such brokerage. The forwarding features of email facilitate the development of collaborative relations between two scholars through the intervention of a third party. However, scholars perceive face-to-face contact as effective in scholarly work as face-to-face meetings, conferences and other meatspace contexts can both initiate and solidify collaborative relations.

4. The strength of TechNet members' ties is related to the frequency of face-to-face and email contact as well as to the perceived effectiveness of email and face-to-face communication. Friends are much more likely than acquaintances to use email (0.50) and face-to-face (0.22) contact and to use multiple media for contact (0.36). Colleagues are also more likely than acquaintances to be in face-to-face contact (0.13), use multiple media (0.21), and perceive email as an effective medium for scholarly activities (0.16). Scholars who are only aware of each other have less face-to-face and email contact (-0.56 and -0.31). There are differences in the relative strengths of the association, with the frequency of email contact between a pair of scholars related to the strength of their tie. Friends communicate more frequently than those who are work colleagues only. Yet, colleagues communicate more than acquaintances, with those who are just aware of each other communicating the least.

The foregoing analysis has drawn attention to the salience of email and the use of multiple media for supporting scholarly relations. Connectivity is associated with communication: Those central within TechNet -- whether through out-degree, in-degree or betweenness -- are the most active communicators. Tie strength is associated with communication: Those with stronger ties of collaborative work and friendship communicate more. The demands for maintenance of scholarly relationships across time and space, and the increasing importance of friendship and other social aspects of the scholarly life, calls for flexibility and adaptability in choice of media. Email, supported by face-to-face communication, is instrumental in fulfilling these tasks.

ROLE STRUCTURE

Blockmodeling TechNet

What would the structure of TechNet look like if all the relationships of its scholars were aggregated to reveal patterns *across* the multiple networks they comprise? An answer to this question lies in *blockmodel analysis* (White, 1976), which examines similarities in relational patterns, such as collaborative, friendship, and email networks in TechNet.

Blockmodeling is important for our analysis for two reasons: First, TechNet is an interdisciplinary network, and the scholarly activities of its scholars span disciplines. Given that boundary-spanning and inter-network communication is a possible characteristic of scholarly networks such as TechNet, blockmodeling can usefully describe which subsets of scholars are jointly engaged in working relationships with similar others. Second, focusing on the blocks of scholars can aid in understanding the informal and underlying structure of TechNet and the roles of individual scholars within it.

We use the CONCOR blockmodeling procedure of UCINet to analyze TechNet's collaborating, discussing, and reading networks (Breiger, 1975). CONCOR works from the top down, starting by partitioning all network members into two non-overlapping mutually exclusive subgroups. Partitioning is based on the similarity of choices made and choices received by all scholars across all relationships under study. In other words, two scholars are grouped in the same block if their overall patterns of choices made and received are similar and not necessarily because they are directly or indirectly connected to each other.

CONCOR produced a four-block partition of TechNet members. Our knowledge of scholars' attributes and involvement in TechNet helps us to interpret these blocks in terms of scholar's roles in the establishment, continuing operation and visibility of TechNet. Given the interdisciplinary aspirations of TechNet, it is noteworthy that the blocks are based on varying roles in TechNet and not entirely on disciplinary affiliation.

Block 1 (six persons) contains many of the founding core planners of TechNet, who are also on its executive committee. The monthly face-to-face meeting of the executive committee, frequent meetings of other committees, and much emailing keeps this block in active and coordinated contact. Its members mostly come from one scientific and one social scientific discipline.

Block 2 (twelve persons) comprises members from who are less managerially central but who often have scholarly visibility. They come from many disciplines.

The two members of the small Block 3 work within one well-defined area at the intersection of a scientific and a social scientific discipline. They are not frequent interactors with most other TechNet members

Block 4 contains four faculty members who are less active in TechNet.

Relationship between Blocks

Each block comprises equivalent scholars. Analyzing scholarly relationships between blocks can aid understandionng of how scholarly networks operate. Figures 1a-1c represent *block matrix* structures of the collaborative, discussion of research and reading work relationships. To facilitate detection of relational patterns between the blocks, we suppress the “0s” in the matrices that signify the absence of relations. Concentrations of 1s in the matrices indicate the relative presence of relationships among the scholars in the various blocks. For example, the matrices in Figure 1a (collaborating) and 1c (reading work) are relatively sparse compared to Figure 1b (discussing research), implying denser connections among scholarly blocks when discussing research. The larger size of the research discussion networks (Table 1) clearly aids communication between blocks.

<<< Figure 1a – 1c about here >>>

To aid detection of relationships between the blocks, we converted the block matrices in Figure 1 to *reduced block matrices* and *reduced graphs*. We show links between the blocks in Figure 2, rows 2 and 3. The reduced block matrices and graphs enable us to describe the structural patterns of the blocks with respect to the scholarly relationships under study.

<<< Figure 2 about here>>>

Collaborating: Members of Blocks 1 (the planners) and 3 (technology, science, and social science interests) collaborate within their own blocks and with the other block. There is a similar pattern for Blocks 2 (researchers) and 4 (periphery). This suggests a pattern of two alliances. The first is based on the planning and technological interests, as evidenced by the ties between Blocks 1 and 3. The second is based on the researchers in Block 2, with some links to the two scholars in Block 4. At the same time, the reduced graphs show that members of Blocks 1 and 2 discuss research with each other, but not with the members of the smaller Blocks 3 and 4. [3]

There is more to the structure than two separate alliances. The data provide some evidence of a cross-cutting core-periphery pattern, with the planners (Block 1) and the researchers (Block 2) collaborating only with each other and not with the members of the other two blocks. There are no links between the peripheral Blocks 3 and 4. Scholars in these blocks are peripheral either because they have not actively represented their interests in TechNet or because they are inactive participants in TechNet. One Block 3 scholar says, "I don't recognize myself as an academic in terms of connections to other academics," while another reports, "I am a technical administrator. [Hence, I] concern [myself] only with technical details of or interests within TechNet."

Reading Each Other's Work: There is more interconnectivity between blocks in terms of reading each other's work than there is for collaboration. Members of the large, planners Block 1 read the work of the members of Blocks 3 and 4. In other words, core and peripheral scholars want to learn about each other's work. Thus, some members of Block 1 read the work of the two Block 3 scholars whom they regard as eminent even though these Block 3 scholars keep to themselves and rarely reciprocate by reading Block 1's work. In addition, the two Block 4 members read the work of some leading researchers in Block 2. Members of the peripheral Blocks 3 and 4 also read each other's work, possibly to remain intellectually and socially connected with TechNet members. Note that some of the scholars peripheral to TechNet are important to their own disciplinary specializations, and core TechNet members can learn what is happening outside of their network through their relationships with the TechNet periphery.

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[3] All terms are oversimplifications; as the "planners" are also scholars, the "researchers" sometimes help plan TechNet activities, and "peripheral people" sometimes get involved in core projects. The difference is principally in the extent of involvement in planning.

The block models suggest that TechNet members read widely. In this way, the TechNet's ideal of inter-disciplinary cross-fertilization is being realized. However, when it comes to the actual practice of research, TechNet scholars stay more narrowly within their own disciplines and blocks.

Blocks and Communication

How do the blocks differ in email and face-to-face contact, as well as in the perceived effectiveness of email and face-to-face communications for scholarly activities? In this section, we analyze the implications of the blocks for email and face-to-face contact, the use of multiple communication media, and varying perceptions about the effectiveness of face-to-face and email contact for accomplishing scholarly tasks. >

Face-to-Face Contact: Nearly three-quarters (73 percent) of TechNet pairs (405/552) have at least one type of relationship with each other: collaborating, discussing, or reading. The block location of scholars is associated with their face-to-face contact (Table 4). In general, 38 percent of TechNet members have face-to-face contact somewhat frequently (5-12 times/year), while 19 percent have frequent (more than 12x/year) face-to-face contact with their scholarly ties. Almost a third (29 percent) have infrequent face-to-face contact (< 5x/year, while only a few (12 percent) have no face-to-face contact. For example, one of the 405 pairs could be a frequent discussion tie and another could be an infrequent reading tie between the same two TechNet members. That slightly more than half (57 percent) of TechNet pairs maintain frequent or somewhat frequent face-to-face contact, while almost 43 percent have contact suggests that face-to-face contact is an important means of communication. It brings strong ties together or meetings and tête-à-têtes, and both strong and weaker ties for larger scheduled events.

<<< Table 4 about here >>

Different roles in TechNet affect variations in face-to-face contact within and between blocks. Block 1 planners stand out with 71 percent of their face-to-face relationships in TechNet being frequent or somewhat frequent. By contrast, only 43 percent of the two peripheral Block 3 members' face-to-face relationships are frequent or somewhat frequent. Block 1 planners and Block 2 researchers have frequent or somewhat frequent face-to-face relationships through informal chats and joint participation in TechNet's meetings, workshops and seminars (Figure 2).

Email Contact: Email contact relationships for collaborating, discussing, and reading research have different characteristics than face-to-face relationships. Nearly half (47 percent) of all TechNet pairs do not use email to communicate. In keeping with this, most pairs (60 to 69 percent) of each block never or infrequently communicate by email. However, those TechNet pairs who are in email contact tend to use it more frequently than face-to-face contact. For example, although only one-fifth (20 percent) of all TechNet pairs are in frequent email contact (82/405), 38 percent (82/216) of those pairs that use email, use it frequently (more than 12x/year). Thirteen percent of all TechNet pairs are in somewhat frequent email contact (5-12x/year), while 20 percent are in less frequent contact.

In general, there are differences in email and face-to-face contact and in the perceived effectiveness of each medium in scholarly activities. These relate to the roles and research interests of various scholars in TechNet. Face-to-face contact brings together both active TechNet members and otherwise-disconnected TechNet members. Face-to-face contact is the predominant medium of contact for the planning Block 1 and the researchers in Block 2, because it suits the context of their reciprocal discussion of research and other interactions. By contrast, email connects active TechNet members in a focused, selective way and allows core planners to broadcast to and communicate with peripheral members. Different patterns of email use among blocks fit the scholarly roles of TechNet members. The planning Block 1 uses email to communicate with the peripheral, Internet-habituated, members of Block 3. The planning Block 1 and research Block 2 communicate less by email because their TechNet activities brings them into frequent face-to-face juxtaposition at seminars, conferences, grant preparation, and administration. Email is the natural medium of choice for the peripheral members of Blocks 3 and 4 as it gives them remote access to the rest of TechNet while removing the burden of journeying to face-to-face meetings.

A SCHOLARLY NETWORK IN A COMPUTER MEDIATED WORLD

Our analysis shows that TechNet is a learning community focused on peer-to-peer learning. Most TechNet members discuss and seek advice about their work with each other, but only read the work of a few and collaborate with few others in research and proposal writing. Social network analysis provided us with an approach to understand the structure of relations underlying this scholarly community. It reveals overlapping networks, with some scholars discussing each other's work, reading these works, and collaborating in research. Two kinds of networks affect the scholars' communication behavior: formal work relations and informal friendships. The centrality of TechNet members varies markedly, both in internal prominence (choices by others) and in how they are in brokerage positions that link different parts of the TechNet networks. TechNet members use both email and face-to-face contact to get advice from prominent members. Email is extensively used among friends and collaborators, as well as for communication within the core, and between the core and the periphery.

The nature of the tie predicts media use more than the nature of the communication task does. Friendship as well as collaboration drives frequent communication, face-to-face as well as by email Strongly-tied collaborators and friends use whatever communication means are necessary to interact, exchange information, and coordinate. The more types of relationships they have, the more frequently they communicate by email and face-to-face. Those scholars with larger (personal) networks have varied communication patterns, and mostly use email as a medium of communication. Even when working nearby, they often find email communication handier for spontaneous communication than walking a few hundred, often-cold meters to talk face-to-face. These ties are strong enough that they can be maintained extensively through the narrower bandwidth of email and refreshed through occasional face-to-face get-togethers.

Blockmodeling provides a view of internal differentiation within TechNet. This is not a densely-knit network where all are connected to all. Neither is it a disconnected aggregate. There is much communication within and between the blocks, and TechNet members are scarcely aware that the blocks exist. This is not a set of mutually exclusive cliques. Indeed, all TechNet members are probably connected to all others by only one or two steps. TechNet has sizeable core blocks of planners and researchers plus two peripheral blocks. The block configurations are related to communication patterns of scholars. Face-to-face contact continues to play a strong role in inter and intra-block communications. The core planning block of TechNet uses face-to-face contact, both as a means of reaching out to peripheral members, but also because they are active in all of TechNet's public and private activities. TechNet members with higher administrative or research prestige are frequently sought out for advice when they are in public, face-to-face gatherings. Email is extensively used among friends and colleagues working together, for contacts to and from peripheral blocks, and for broadcasting announcements from the core planners.

Email and face-to-face contact play complementary roles and reinforce each other. The impact of email is not so much in what is communicated, but in who communicates with whom, how frequently, and over what distances. Despite TechNet's frequent public gatherings, face-to-face contact is more centralized than email contact. Core planners and researchers combine face-to-face, email and occasional phone contacts. Peripheral members are more apt to use one of these media to keep in touch with TechNet activities. Some rely on scheduled face-to-face get togethers to find out what is happening administratively and intellectually. Others, who do not want to go across campus to meetings, rely on email broadcasts and occasional focused exchanges. These blocks have fluid and permeable boundaries for the structure of relationships in TechNet varies according to the activity being performed (for similar findings, see Ahuja and Carley, 1999). These networked scholars use email for a wide range of things: exchanging drafts among coauthors, setting up meetings, asking for information, or gossiping about colleagues. Although pundits worried a decade ago about whether merely textual email could sustain a wide range of interactions -- from information seeking to emotional stroking -- it is the social context, more than the nature of the medium that affects whether email will be used. Expectations only a decade ago that email would only be used for purely instrumental communication appear to have been a product of early fascination with the novelty of email and an overemphasis on McLuhan's (1962) speculation that the medium is the message.

In short, TechNet has been a success in building a scholarly network and turning it into a semi-visible college. At the time of our data collection in 1997-1998, in TechNet's brief period of operation, it had already:

1. Linked scholars across a variety of disciplines in the humanities, social sciences and sciences.
2. Provided a milieu where most members are aware of each other's work.
3. Fostered a large amount of innovative collaborative work and discussions across disciplines.
4. Integrated the use of email and face-to-face contact into useful means of communication.

TechNet has continued to build from these early strengths. The scholarly network has become more visible and somewhat institutionalized. As of writing in early 2002, collaborative research has become more extensive, and well-attended lecture series solidify internal communication and reach out to other scholars, policymakers, technology companies, and the public. A new graduate program offers a set of core interdisciplinary courses and an extensive list of affiliated courses with collaborating scholarly departments in the social sciences, physical sciences and engineering. Although most arrangements are still informal, there is a full-time paid administrator and additional paid part-time staff.

Our findings suggest that scholarly communities of practice are not homogeneous entities, whether they are in virtual space, meatspace, or both. Online mutual-learning communities consist of scholars with varying roles, levels of involvement, positions, and varying levels of connectivity with other community members (Hiltz and Wellman, 1997). Further, the structure of these relationships is related to the types and variety of communication media used. Rather than seeing the Internet as a separate interaction system, they use it opportunistically to fit into their everyday lives. For designers of online educational communities, our study suggests the need to take a broad look at the social networks of community members, and how their internal structure and media use facilitate and constrain mutual peer-to-peer learning.

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Table 1: Selected Characteristics of Work, Interpersonal and Media Use Personal Networks

Variable:	Mean Size of Personal Network	Heterogeneity (Standard Deviation)	Density
Work Relation			
Collaboration	5.0	0.34	0.21
Discuss	17.4	0.50	0.76
Read Work	5.2	0.32	0.12
Interpersonal Relationship			
Friend	3.1	0.34	0.19
Colleague	6.7	0.46	0.41
Acquaintance	5.1	0.42	0.29
Aware	2.0	0.28	0.11
Media Use			
Email	18.9	0.47	0.64
Face-to-Face	13.4	0.49	0.40

Note: If all 24 network members are in contact with each other, we would have a maximum of 552 asymmetric (one-way) ties (24 x 23). In practice, we have only 405 active ties. The summary characteristics are based only on these 405 ties.

Table 2: QAP Correlation between Work, Interpersonal and Media Use Relations

	Collab-orative	Discuss Research	Read Work	Friend	Coll-eague	Acquain-tance	Aware	Email Contact	Face-to-Face Contact
Work Relationships									
Collaborative	-								
Discuss Research	-0.30	-							
Read Work	0.03	-0.12	-						
Interpersonal Relationships									
Friend	0.45*	-0.00	0.04	n/a	-				
Colleague	0.15*	0.35*	-0.07	n/a	n/a				
Acquaintance	-0.18	0.48*	-0.06	n/a	n/a	-			
Aware	-0.12	-0.29	-0.01	n/a	n/a	n/a	-		
Media Use									
Email	0.32*	0.03	-0.02	0.25*	0.02	0.02	-0.08	-	
Face-to-Face	0.44*	0.04	-0.03	0.48*	0.03	-0.11	-0.11	0.49*	-

* $p < .05$: A low p-value (< 0.05) suggests a strong relationship between the matrices that is unlikely to have occurred by chance.
n/a =Not Applicable

Table 3: Pearson Correlation between Network and Tie Characteristics with Frequency and Perceived Effectiveness of Email and Face-To-Face Contact

	Frequency of Face-to-Face Contact	Frequency of Email Contact	Multiple Media Use	Perceived Effectiveness of Face-to-Face Contact for Scholarly Communication	Perceived Effectiveness of Email Contact for Scholarly Communication
Size:					
Collaboration	.13**	.24**	.19**	.25**	.05
Discussing Research	-.04	-.04	-.03	.06	-.03
Reading Work	.11*	.11*	.08*	.25**	.33**
Density					
Collaboration	.13**	.06	.14**	-.42**	-.01
Discussing Research	.04	-.11*	-.11*	-.24**	-.07
Reading Work	.12*	.03	.03	-.18**	.03
Degree Centrality					
Collaboration	.13**	.24**	.19**	.26**	.05
Discussion *(Out Degree)*	-.02	-.01	.13**	-.14**	.16**
Discussion *(In Degree)*	.00	.02	-.05	.28**	-.06
Reading Work *(Out Degree)*	.10*	.10*	.10*	.21**	.22**
Reading Work *(In Degree)*	.00	.03	-.04	.04	.24**
Betweenness Centrality					
Collaboration	.01	.19**	.12*	.37**	.01
Discussing Research	-.02	.06	.07	.15**	.05
Reading Work	-.08	-.06	-.22	.12	.12
Tie Strength					
Friend	.22**	.50**	.36**	.10*	.01
Colleague	.13*	.06	.21*	-.19**	.16**
Acquaintance	.05	-.28**	-.12*	.05	-.02
Aware	-.56**	-.31**	-.61**	.11*	-.23**

* $p < 0.05$ ** $p < 0.01$

Table 4: Relationship between Scholarly Blocks and Overall Monthly Face-to- Face and Email Contact with Perception of Effectiveness of Media

Block and Number of Ties:	Block 1 (N=105)	Block 2 (N=219)	Block 3 (N=23)	Block 4 (N=58)	*N*	*Total %*	*Contact %*
			Percent Within Blocks				
Monthly Face-to-Face Contact							
None *(0)*	3	18	13	10	*51*	*12*	--
Infrequent *(0.1-4.9)*	26	30	44	31	*121*	*29*	*34*
Somewhat Frequently *(5.0-12.9)*	50	37	17	31	*156*	*38*	*44*
Frequent *(13-441)*	21	15	26	28	*77*	*19*	*21*
Total	*100*	*100*	*100*	*100*	*405*	*100*	*100*
			$\times^2$*=27.3 DF=9 P <0.01*				
Monthly Email Contact							
None *(0)*	55	47	35	36	*189*	*46*	--
Infrequent *(0.1-4.9)*	11	22	26	24	*81*	*20*	*37*
Somewhat Frequent *(5.0-12.9)*	9	14	22	16	*53*	*13*	*24*
Frequent *(13-441)*	25	17	17	24	*82*	*20*	*38*
Total	*100*	*100*	*100*	*100*	*405*	*100*	*100*
			$\times^2$*=14.9 DF=9 P<0.09*				
Multiple Media Use							
No Media	2	17	13	7	*47*	*11*	--
One Media	46	28	22	26	*129*	*31*	*36*
Two Media	28	32	57	41	*135*	*33*	*37*
Three Media	25	24	9	24	*94*	*23*	*26*
Total	*100*	*100*	*100*	*100*	*405*	*100*	*100*
			$\times^2$*=31.4 DF=9 P<0.001*				
Perceived Effectiveness of Face-to-Face Contact							
Not Effective	9	9	0	0	*29*	*7.2*	--
Slightly Effective	0	23	52	32	*81*	*20*	*21*
Effective	51	25	0	17	*117*	*28.9*	*31*
Very Effective	41	43	48	50	*178*	*44.0*	*47*
Total	*100*	*100*	*100*	*100*	*405*	*100*	*100*
			$\times^2$*=74.2 DF=9 P<0.001*				
Perceived Effectiveness of Email Contact							
Not Effective	0	10	0	0	*22*	*5.4*	--
Slightly Effective	35	19	0	17	*89*	*22*	*23*
Effective	34	33	100	33	*150*	*37*	*39*
Very Effective	31	38	0	50	*144*	*35*	*37*
Total	*100*	*100*	*100*	*100*	*405*	*100*	*100*
			$\times^2$*=72.3 DF=9 P<0.001*				

Figure 1: Block Matrix Structures for Work Relations

Figure 1a: Collaborative Work

```
                 1 1           1 2 1 1 1 2 1   2     1   1 2 2 1
           1 2 3 7 8 9   4 7 8 0 3 2 3 4 1 6 6 4   5 1   9 2 0 5
          -------------------------------------------------------
  1      |   1 1 1 1 1 | 1 1       1   1         |     |       1 |
  2      | 1     1 1 1 |                         | 1 1 |         |
  3      | 1           | 1         1   1     1   |     |         |
 17      | 1 1     1 1 |     1               1   | 1 1 |         |
 18      | 1 1   1   1 |       1       1         |     |   1     |
  9      | 1 1   1 1   |                         | 1 1 |         |
         ---------------------------------------------------------
  4      | 1   1       |       1   1             |   1 |         |
  7      | 1           |                         |     |         |
  8      |       1     |                     1 1 |     |       1 |
 10      |         1   | 1           1 1 1     1 |   1 |         |
 23      |             |             1           |     |   1 1   |
 12      | 1   1       | 1                       |     |         |
 13      |             |       1 1               |     |     1   |
 14      | 1   1   1   |       1               1 |     |     1 1 |
 21      |             |       1           1   1 |     |       1 |
 16      |             |                 1       |     |         |
  6      |     1 1     |     1                   |     | 1   1 1 |
 24      |             |     1 1       1 1       |     |       1 |
         ---------------------------------------------------------
  5      |   1   1   1 |                         |   1 |     1   |
 11      |   1   1   1 | 1     1                 | 1   |         |
         ---------------------------------------------------------
 19      |             |                     1   |     |         |
 22      |         1   |         1               |     |     1   |
 20      |             |         1   1 1     1   | 1   |   1     |
 15    | 1           |     1         1 1   1 1 |     |         |
          --------------------------------------------------------
```

Overall Network Density = .21
Standard Deviation within Blocks = .41

Figure 1b: Discussing Research

	1	2	3	17	18	9	4	7	8	10	23	12	13	14	21	16	6	24	5	11	19	22	20	15
1			1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2				1	1		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	
3	1			1	1		1	1	1		1	1	1	1	1		1	1				1	1	
17	1	1	1		1		1	1	1	1	1	1	1	1		1	1	1	1		1	1	1	
18	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
9	1						1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	
4		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
7	1	1	1	1	1	1	1		1		1	1	1	1	1	1		1			1	1	1	1
8	1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1		1		1	1	1
10	1	1		1	1	1	1		1		1		1		1	1	1	1			1	1	1	1
23	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	
12	1	1	1	1	1	1	1	1			1			1	1	1	1	1				1		
13	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1		1	1		1
14	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1
21	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1
16	1	1		1	1	1	1	1	1	1	1	1	1	1	1			1			1	1	1	
6	1	1	1	1	1	1	1		1	1	1	1	1	1	1			1	1		1	1		1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							
5	1	1		1	1	1	1				1		1	1			1						1	
11	1				1	1	1		1		1			1	1						1	1	1	1
19	1	1		1	1			1		1	1		1	1	1	1	1			1				
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1				
20	1	1	1	1		1	1	1	1	1	1			1	1	1			1	1				
15	1						1	1	1	1			1	1	1		1			1				

Overall Network Density = .76
Standard Deviation Within Blocks = .43

Figure 1c: Reading Work

	1	2	3	17	18	9	4	7	8	10	23	12	13	14	21	16	6	24	5	11	19	22	20	15
1			1					1	1				1											
2			1						1											1				
3						1																		
17																								
18						1					1			1				1			1		1	
9	1									1									1	1				1
4																								
7																								
8				1						1				1							1			
10																								
23																		1						
12							1									1			1		1			
13																								
14																				1			1	1
21						1																		
16		1					1																	
6																								
24				1																				
5								1						1		1				1		1		
11								1				1						1					1	
19			1				1								1					1			1	
22			1					1			1						1		1	1				
20	1														1	1						1		
15		1									1				1						1	1		

Overall Network Density = .12
Standard Deviation Within Blocks = .32

Figure 2: Representation of Block Densities, Reduced Block Matrices, Reduced Graphs and Frequency of Ties Within and Between Positions

	Collaboration	Discussing Research	Reading Work
Block Densities	**1 2 3 4** **1** .73 .17 .50 .08 **2** .17 .18 .08 .23 **3** .50 .08 1.0.13 **4** .08 .23 .13 .17	**1 2 3 4** **1** .60 .94 .67 .67 **2** .94 .89 .42 .73 **3** .67 .42 .00 .63 **4** .67 .73 .63 .00	**1 2 3 4** **1** .17 .11 .25 .13 **2** .06 .05 .08 .08 **3** .00 .25 .50 .25 **4** .17 .19 .36 .33
Reduced Block Matrices	1 2 3 4 - - - - 1 1 0 1 0 2 0 0 0 1 3 1 0 1 0 4 0 1 0 0 Rule: y(i,j) = 1 if x(i,j) > 0.21, and 0 otherwise.	1 2 3 4 - - - - 1 1 1 0 0 2 1 1 0 0 3 0 0 0 0 4 0 0 0 0 Rule: y(i,j) = 1 if x(i,j) > 0.76, and 0 otherwise.	1 2 3 4 - - - - 1 0 0 1 1 2 0 0 0 0 3 0 1 1 1 4 1 1 1 0 Rule: y(i,j) = 1 if x(i,j) > 0.12, and 0 otherwise.
Reduced Graphs