Discussion Tool Effects on Collaborative Learning and Social Network Structure

Astrid Tomsic and Daniel D. Suthers

Department of Information and Computer Sciences, University of Hawai`i at Manoa, Honolulu, HI 96822, USA
Tel: 1-808-383-0411
atomsic@hawaii.edu
suthers@hawaii.edu

ABSTRACT

This study investigated the social network structure of booking officers at the Honolulu Police Department and how the introduction of an online discussion tool affected knowledge about operation of a booking module. Baseline data provided evidence for collaboration among officers in the same district using e-mail, telephone and face-to-face media but showed minimal collaboration between officers in different districts. On average, knowledge of the booking module was low. After introduction of the online discussion tool the social network structure changed, showing an increase in collaboration between different districts and an increase in knowledge of the booking module, even though frequency of collaboration did not increase significantly. The study suggests that the formation of new collaborative ties is more significant for learning through information sharing in social networks than raw frequency of interaction. This work is framed by theories of knowledge building, social architecture, and communities of practice.

Keywords

Collaborative learning, Knowledge building, Social network analysis, Online discussion

Introduction

This paper reports on a study that investigated how the introduction of a web-based discussion board changed the social network of an organization, with concomitant changes in distribution of knowledge concerning the use of a new tool that had been recently introduced into the organization. The study was situated in the Honolulu Police Department (HPD), a multi-district and hence distributed organization. At the outset of our study, the Department had recently introduced a client-server Records Management System (RMS), replacing a centralized system requiring that paper-based forms be submitted from district sites. The first phase of the study documented the social network structure between six different physical locations and distribution of officers' knowledge of the RMS. The second phase of the study introduced an online discussion tool into a subset of the districts that allowed officers to collaborate with their colleagues in the participating districts. Social Network Analysis (SNA) indicated that the introduction of the new software led to a change in the social network between districts. The results of a second knowledge assessment showed that there was also an increase in knowledge among booking officers using the online discussion tool. Social network structure, specifically information sharing across distributed locations, appeared to be more important than frequency of interaction. The study contributes to our understanding of the value of computer-mediated communication in distributed organizational contexts where other forms of communication are available and continue to be used.

The paper begins with an introduction to relevant aspects of the organization and practice of the Honolulu Police Department and the tool that mandated a change in practice. The next section provides theoretical background, focusing on social architecture, knowledge building and communities of practice perspectives on learning in organizations, and discusses the potential benefits of computer mediated communication for encouraging collaboration among participants and supporting communities of practice. The remainder of the paper reports on the methodology, results and implications of the study itself.

A Change of Practice in the Honolulu Police Department

The Honolulu Police Department (HPD) is responsible for police operations in the City and County of Honolulu, which consists of the entire island of O`ahu. Units included four districts and two support units. This study focused on *booking officers*, police officers who have the primary duty of processing arrestees as they are brought into a district police station. Depending on the severity of the crime or availability of holding cells, the booking officer may decide to transfer the arrestee to the main booking station, known as the Central Receiving Division (CRD).

A new computerized Records Management System (RMS) was introduced by the Information Technology Division (ITD) in August 2003. Prior to the implementation of the RMS, a standalone DOS-based booking program was used to process and track arrestees. This booking program was only available in CRD. Officers at other districts filled out paper-based forms and sent them to CRD for processing. The new RMS was client-server based and contained an integrated booking module that made entering and processing of bookings possible from any district on the island of O`ahu. With the new RMS came the need to train officers on how to use the RMS to enter and search for information. Entering accurate data and being capable of searching criminal history records is a mandatory and vital part of a police officers' daily duty and essential to effective police work. The degree of knowledge that an officer has about how to use the RMS system to locate pertinent information has a direct bearing on the outcome of criminal cases.

At the time that the RMS was introduced, officers used a combination of e-mail, telephone, face-to-face discussions and other means to collaborate with each other in order to locate information, raise issues and propose more efficient ways to use the RMS. The relevant expertise was distributed throughout the organization: the ITD staff had a good understanding of how to use the RMS in more general terms (e.g., search for a name), while police officers had a better understanding of what information they needed to find and how it related to business processes, but not necessarily the best way to find it. The existing collaboration process between police officers and the ITD staff was inefficient because knowledge was spread over many types of media, and due to the nature of these media needed to be repeated frequently to different parties at different times, was often lost and could not be easily located and improved upon. Coupled with this, officers did not have a clear understanding of who knew what and tended to address all information requests to a single ITD staff member.

This situation presented us with an opportunity to investigate how computer mediated collaboration (CMC), specifically an asynchronous discussion tool, might improve knowledge sharing and knowledge building within this distributed community of practice. Our intervention will be described in a subsequent section, but first we consider theoretical motivations.

Learning in Organizations

An intervention intended to influence learning in an organization must consider how such learning might take place. Although various social learning theories are available, the most relevant theories for the present study are those that emphasize the community aspects of learning. We draw particularly upon knowledge building theory (Scardamalia & Bereiter, 1996), Bogenrieder's (2002) sociocognitive theory, and communities of practice theory (Wenger, 1998; Wenger, McDermott & Snyder, 2002).

Knowledge Building

Knowledge building (Scardamalia & Bereiter, 1996) refers to the intentional pursuit of advances in collective understanding undertaken by a community. According to Scardamalia & Bereiter (1996), it is "work on the creation and improvement of ideas. The dynamic is social, resulting in the creation of public knowledge … public knowledge can itself become an object of inquiry and the basis for further knowledge building." At the time of our study, departmental officers and staff were engaged in negotiating practices for use of the new booking management system. The CMC technology that we introduced made statements of knowledge needs and proposed solutions public in a persistent medium available to many other community members, and hence offered the conditions for treating knowledge as an object of inquiry in this community.

Extensive research motivated by knowledge building theory has been conducted in settings for formal education (schools and colleges). For example, Sha & Van Aalst (2003) conducted a study using server log data to explore knowledge building in the classroom. The techniques of Social Network Analysis (SNA, Wasserman & Faust, 1995) were used to analyze student participation and interactivity in an online discussion database called Knowledge Forum. SNA was used to map the structure of relationships, the major lines of communication and patterns of interaction within the social network. It provided valuable insight into the effectiveness of the class's ongoing efforts to improve their knowledge building and the conditions under which knowledge building occurred. The Sha & Van Aalst study sought to extend the framework for knowledge assessment. Despite a widespread emphasis on social constructivism, assessment is still based on the individual student's final knowledge. Their study explored how server log data could be used to inform continued knowledge building. It suggested that improving connectivity within a community might provide better support for knowledge building.

Similarly, our study used server log data to map the social network and examine the content of the posts for different behaviors. It also explored how changes in the social network affected learning.

Social Architecture

Bogenrieder (2002) argues that organizational learning is a combination of both social-relational and cognitive activity. According to Bogenrieder, the social-relational aspect consists of the social networks fostered by the organization while socio-cognitive conflict (Doise & Mugny, 1984) is the vehicle for nurturing cognitive activity. Socio-cognitive conflict has two conditions that must be met for learning to take place. The first condition is that a social relationship exists between the participants and the second condition is cognitive diversity. When participants contribute different ideas, these differences trigger learning through socio-cognitive conflict (and, we would argue, other mechanisms of intersubjective meaning making: see Suthers, 2006). For example, in a police department officers have different educational backgrounds and levels of experience in police work, and varied expertise in certain types of crimes. If sharing of ideas between officers is encouraged, these differences can be leveraged to produce more effective practices for crime reduction.

Bogenrieder (2002) suggests that *social architecture* can be used as an instrument to build relationships for learning. As previously discussed, both cognitive diversity and contact between diverse people are necessary for organizational learning. The specific design for this contact—the social network—depends on the goal uncertainty and technical uncertainty that characterize the problem situation. *Goal uncertainty* is "ambiguity about the preferences or goals the decision-maker aims to satisfy" and *technical uncertainty* is "uncertainty in parameters, input data and initial states (resulting from 'inexactness' and 'conflicting evidence')" (Weber, 2000). Where conditions of high goal and technical certainty exist, instrumental network structures are satisfying. However, where goal certainty coexists with technical *uncertainty*, an effective network structure is sought based on the distribution of knowledge. In the case of officers learning the new RMS, there is high goal certainty (officers know what they want to do), but high technical uncertainty (officers don't necessarily know how to do it). In these types of networks, the network paths are not pre-determined: the structure of the network forms based on participants' seeking of the knowledge needed to resolve the technical uncertainty.

Laboratory studies have indicated that some types of network structures are more effective than others for diffusing information throughout a group (Cummings & Cross, 2003). However, the task is usually pre-defined by the researcher who establishes paths for the diffusion of information. In organizations, information flow depends on the expertise of the group, as discussed above. Therefore, while certain network structures may be more efficient for information diffusion in an experiment, these structures may not be effective for leveraging group expertise in an organization. The literature suggests that from a cognitive perspective, network structures with greater integration (connectivity) may be more effective for leveraging group expertise. Studies of transactive memory suggest that groups benefit from knowledge of who knows what in the group (Liang et. al., 1995, Moreland & Myaskovsky, 2000). Work in diffusion of innovations suggests that hierarchical network structures are both inefficient and result in the degradation of information quality (Rogers, 1995; Valente, 1995).

Communities of Practice

The theory of Communities of Practice (CoP; Wenger, 1998; Wenger et al., 2002) provides further conceptual tools for understanding how the collective knowledge of a community is sustained and adopted to new situations. According to this theory, a CoP consists of people mutually engaged in ongoing participation, oriented towards a common domain that is addressed through a shared repertoire: a "group of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger, et al. 2002). When members of a CoP are distributed throughout an organization in different teams, the interaction between them required to sustain knowledge is at risk. Information technology can be valuable for bringing community members together to share and resolve problems, as discussed in the next section.

According to CoP theory (Wenger, 1998), the knowledge of an organization—the repertoire of its communities of practice, such as the police officers—is sustained through the dynamic interplay of the *duality of participation and reification*. A duality is not a pair of polar opposites, but rather a dynamic productive pair: increasing one may well require increasing rather than decreasing the other. When discussing communities of practice, *participation* refers to how we engage together in an activity, and through that engagement generate, affirm and replicate patterns of engagement: our practices. *Reification* refers to ways in which these practices become

reflected in artifacts and other structures that help replicate the practices. For example, the practices of a police department are reflected in the structure of its booking forms. This structure supports replication of those practices in the moment by reminding participants of what they need to do, and in the long term by serving as a guide through which new members of a CoP can be brought into its practice. Reifications of practice are not restricted to physical artifacts and information technologies. Terminologies, ways of talking, conventions of social greeting, etc. can also serve as reifications of practice. Importantly, participation that engages a reification is not just controlled and constrained by that reification, but also reaffirms and sustains the meaning of the reification, and can change the meaning of (reinterpret) the reification. Participation in an online discussion results in reifications in the form of messages that can guide future participation or be reinterpreted through that participation.

Computer Supported Social Networks as Socio-Technical Capital

Wellman (1996) claims that *Computer Supported Social Networks* (CSSN's) support a focus on information exchanges. "People can easily post a question or comment and receive information in return. Broadcasting queries through CSSN's increases the chances of finding information quickly and alters the distribution patterns of information. It gives those working in small or distant sites better access to experienced, skilled people." Additionally, "online information flows spill over unexpectedly through message forwarding, providing access to more people and new social circles, thus increasing the probability of finding those who can solve problems" (Kraut & Attewell, 1993). For example, officers don't know who to ask for information, but a discussion board works to their advantage because it doesn't require that officers know whom to ask: they need only post a message for all to read. Computer mediated communication "turns communication into substance", a reification that can be accessed and elaborated on by others at different times and places in a manner not possible with volatile media such as speech. Furthermore, the value of CSSNs is not limited to sharing information. The social relationships supported by CSSN technology in conjunction with the affordances of that technology for continuing those relationships in certain ways collective constitute *socio-technical capital*: "a resource that can be accumulated and whose availability allows people to create value for themselves or others" (Resnick, 2002). As soon as an officer receives a reply, not only has new information become available, but also his or her social network has expanded. If the reply is helpful, the officer now knows who to ask for further information on that particular topic, as do others who are observing the interaction, and obligations to be helpful in a reciprocal manner are created. For these reasons, we expected that it would be beneficial for police officers and CRD and ITD staff to collaborate in an online environment. This expectation was assessed by (1) studying the changes in the network structure, (2) investigating the frequency and degree of collaboration, and (3) analyzing the content of the posted messages.

Synthesis

Organizational learning is required when practices must change to reflect changing conditions, for example, the introduction of a new tool such as the new booking system. Ideally the members of the organization engage in knowledge building, which in CoP terms can be understood as the deliberate pursuit of extensions to the collective repertoire to adapt to the new conditions. The role of a CSSN in this process is twofold, as suggested by the participation/reification duality. From the perspective of *participation*, a CSSN extends mutual engagement to a larger collection of people, in this case distributed across multiple sites. In an expanded network, cognitive diversity increases and innovations are shared more widely, as the reifications resulting from participation are shared more widely. From the perspective of *reification*, the persistent reifications generated by participation in a CSSN can influence practice at other times and places, even the practice of those not involved in the production of those reifications, and can also be reinterpreted by others. Thus, for reasons influencing both participation and reification, we expected the introduction of an online discussion tool to improve the scope and extent of mutual engagement in the knowledge building process of developing new practice around the new booking system.

Study Design and Methods

The foregoing theoretical discussion concluded that a CSSN can increase knowledge building in an organization by enabling and expanding interaction between a greater diversity of community members across space and time, through networking and persistent representations, respectively. One way to determine whether this happens in practice is to introduce a CSSN into an organization, observe whether that introduction expands the

social network of the organization (whether there is more interaction between more people), and observe whether this change is responsible for advances in knowledge (those who interact increase their knowledge concerning the topic about which they interact). Our study design applies this strategy to address the following research questions.

Research Questions and Hypotheses

Research Question I. How will the introduction of an online discussion tool affect the existing social network structure at the Honolulu Police Department for officers learning the booking module for a new Records Management System (RMS)?

Hypothesis 1 (H1). There will be an increase in collaboration about the booking module of the RMS between participants in different districts using the online discussion tool compared to participants who do not, using pre and post interview instruments and social network analysis (SNA). Rationale: CMC expands the potential social network over space and time, and officers will take advantage of this expanded network to seek the knowledge needed to reduce technical uncertainty.

Hypothesis 2 (H2). There will be an increase in frequency of collaboration about the booking module of the RMS between participants using the online discussion tool compared to participants who do not, using pre and post interview instruments and SNA. Rationale: CMC, being asynchronous and persistent, makes collaboration easier, and the need for knowledge building makes collaboration desirable.

Research Question II. How will use of the online discussion tool influence knowledge of the RMS booking module?

Hypothesis 3 (H3). There will be an increase in knowledge of the booking module of the RMS for participants using the online discussion tool compared to participants who do not, using pre and post survey instruments. Rationale: A CSSN enables sharing of information and encourages knowledge building by increasing cognitive diversity and supporting reifications that make knowledge claims open to inspection and interpretation.

Participants

Booking officers were randomly selected from a pool of officers of different ages with different cultural and academic backgrounds from four (4) different locations (districts) on O`ahu. Twenty (20) officers were selected from districts 5 and 8; of these, fifteen (15) chose to participate. We call these officers *Group A*. Another twenty (20) officers were selected from districts 2 and 3; of these, sixteen (16) chose to participate. We call these officers *Group B*. Along with these thirty-one (31) police officers, four (4) CRD civilian booking staff and seven (7) ITD staff participated in the study. Each district collaborated with the ITD staff and CRD staff. The districts were at different physical locations than each other and the ITD and CRD staff. This physical separation enabled us to minimize cross-collaboration between the two districts that were provided with access to an online discussion tool (Group A) and those that were not (Group B).

Intervention

Our intervention consisted of the introduction of an online discussion board dedicated to discussion of the use of the RMS. This discussion board was made available to Group A and the CRD and ITD staff, but not to Group B, enabling the foregoing hypotheses to be tested in a quasi-experimental design.

An online discussion board is a viable tool to support knowledge building in a distributed community of practice because it can support spatially and temporally distributed interaction and it offers persistent representations through which public knowledge becomes an object of inquiry. The HPD officers are distributed across physical HPD districts, yet are faced with a similar set of issues that non-booking officers may not be familiar with. They use the same software module in the RMS and are required to be familiar with specific procedures for booking. They must also be familiar with basic troubleshooting procedures because the software support staff (ITD) are separated from the officers who must put the knowledge to use. An online discussion board offers a shared and persistent forum for booking officers to increase their awareness of system-wide issues and booking practices. Other media such as face-to-face, e-mail and telephone lack persistence and are limiting for officers working in different districts or different shifts. However, a discussion board is not without its limitations: the challenges for

any distributed community include building trust and maintaining online participation (Preece 2000; Wenger et al., 2002).

The particular online discussion tool used in this study was Discus, available at www.discusware.org. The authors are not associated with the Discus project. The research reported in this paper is concerned with the potential impact of the *genre* of web tools represented by Discus, not with evaluation of Discus' specific design features. The first author chose this tool based on the following features. It used a standard and familiar threaded format (see Figure 1). Being web-based, Discus was accessible from every computer that ran the booking module for the Records Management System. Questions could be posted as soon as an issue occurred, and an officer could access information anytime, not only when the ITD staff or CRD staff were available. Discus also offered the ability for officers to see who posted a message. This is important in community building because if an officer finds a particular post helpful, they can continue asking the author of that post for further information. It also allows officers to become familiar with who knows what about the RMS and thus who to ask for clarification or further explanation.

Topic	Posts	Pages	Last Post	Last Poster
Board Information				
📁 Posting Guidelines	1	1	02-29-00 03:26 pm	Admin
Installation Problems				
📁 Setup help - unix servers	1462	253	06-11-04 07:52 am	Kevin W. Paulisse
📁 Setup help - Windows servers	838	153	06-14-04 10:07 am	Kevin W. Paulisse
Running Discus				
📁 Post-installation questions	10772	2060	06-14-04 10:07 am	Kevin W. Paulisse
📁 Customizing your site	3559	674	06-04-04 12:50 pm	CP Ssrebba
Product Development				

Figure 1. Layout of the threaded discussion format in the Discus tool

Procedure and Task

The study was conducted over a six-week period in March/April 2004. (At the end of this period, a department-wide reassignment of officers changed the composition of the districts.) Participants were asked to complete two (2) surveys (pre and post) and two (2) interviews (pre and post). The interview layout and content was adapted from surveys created by Krackhardt & Haythornthwaite (1998). Both the surveys and interviews were piloted with two (2) officers who did not participate in the final study and was revised according to the officers' feedback and suggestions for improvement.

The pre-survey was used to determine prior knowledge of the booking module of the RMS system. It consisted of five (5) questions with an estimated duration of ten (10) minutes. Each question consisted of typical search tasks related to the booking module in the RMS that an officer is required to perform on a daily basis. For example, "What is the report number for the FRAUD incident that occurred in sector 1 beat 150 on 10/19/2003?"

A pre-interview was conducted to determine the current social structure. It consisted of questions to determine with whom the participant collaborated about the booking module of the RMS during the prior three (3) weeks. It asked how well they knew this person, the frequency of these collaborations, and the media they used to collaborate. In order to benchmark the initial social network structure, data on each of the different types of communication media used was collected. This was necessary to determine what connections for knowledge building existed beforehand and whether new connections developed as a result of the introduction of the online discussion tool.

Participants in Group A (districts 5 and 8), the ITD staff and CRD staff were asked to contribute to an online discussion tool. They were given introductory training on the online discussion tool and provided with a login and password to record questions, comments, ideas and suggestions about the booking module. Posting activity on the online discussion tool was initially slow, so the ITD staff posted what it thought to be useful tips on how to use the booking module in order to generate activity. The ITD staff checked the board on a regular basis to ensure that questions were answered in a timely manner. This was done to encourage participants from other

districts to post questions. Group B (districts 2 and 3) continued to collaborate with the ITD staff, CRD staff and each other using the traditional face-to-face, e-mail and telephone methods of collaboration.

A post-survey consisting of five (5) questions with an estimated duration of ten (10) minutes was given to Group A and Group B to determine whether any changes in knowledge had occurred. Similar to the pre-survey, the post-survey contained search questions on the booking module in the RMS but did not have the same questions as the pre-survey to avoid participants learning from the pre-survey. For example, "Who was the arresting officer for the arrest with report number XXXXXX?"

A post-interview was conducted with the same questions as the pre-interview to determine whether any changes had occurred in the social structure between the districts.

Measures and Analysis

Scardamalia (2000) developed twelve descriptors that represent the "best practices" of knowledge building. Chan, Lee & Van Aalst (2001) used a modified subset to organize course evaluation and to scaffold knowledge-building advances. These four principles are: 1. Working at the cutting edge, 2. Progressive problem solving, 3. Collaborative effort, and 4. Identifying high points in the discourse. Sha & Van Aalst (2003) conducted a study where they focused on the pedagogical knowledge principal of collaborative effort. They analyzed the characteristics of student's social interaction by measuring participation (posts), reciprocity (replies), connectivity (linked notes), social position (activity in the social network) and social interaction (reads).

Like Sha & Van Aalst (2003), the present study measures characteristics of individual social interaction relating to collaborative effort, but groups these measurements into broader factors that investigate social interaction between districts. These factors correspond to the three hypotheses:

> *Collaboration* – defined as any new social ties between participants who had not previously communicated. This study is particularly interested in collaboration *between* districts. It is measured by the messages contributed to the online discussion tool and the interactions in other media reported in the pre and post interviews. This includes messages posted, replied to and read.

> *Collaboration Frequency* – defined as the number of interactions between participants in the social network. It is measured by the number of messages contributed to the online discussion tool and the number of interactions in other media reported in the pre and post interviews. This includes the number of messages posted, replied to and read.

> *Knowledge* – defined as the understanding, familiarity and proficiency of a participant with the booking module of the RMS. It is measured by the results of the search tasks in the post-survey and the pre-survey. Knowledge is rated on a scale of 0 for the lowest score with no tasks correct to 5 for the highest score for all tasks correct.

SAS statistical software was used to tabulate and analyze the results of the knowledge scores. The UCINet suite of programs (Borgatti, Everitt & Freedman, 1996) was used to create the data sets for SNA and a visual depiction of the socio-centric social network in the form of social network analysis diagrams. Each participant is represented as a circle or node in the network with their interactions displayed as lines. These lines have arrowheads to show the direction of each collaborative interaction. The thickness of each line represents the number of interactions or tie-strength between each node. The minimum tie-strength is zero (0) and the maximum is ten (10). However, for the combined medium diagrams, the minimum tie-strength is zero (0) and the maximum is forty (40). The district that each node belongs to is shown by the color of the node. The score that each participant receives for the collaborative learning tasks is shown by the size of each node. The minimum score for no tasks correct is four (4) and the maximum score for all correct is nine (9). The minimum of four (4) was chosen instead of zero (0) so that each node is visible on the diagram. Three SNA diagrams will be presented in the next section.

A content analysis was conducted to gain a more in-depth understanding of what types of interactions were occurring on the online discussion tool. Each message posted on the discussion board was identified and categorized using a list of behaviors suggested by Rubin & Goldberg (1992). They include basic communication relations such as *information seeking* (IS) and *information providing* (IP). Other behaviors that Rubin & Goldberg (1992) term "contractual relations" are used to indicate messages where one participant posts a

message in order to obtain a response. These are coded as *confirming action* (CA), *seeking consensus* (SC), *statement of problem* (SP), and *statement of solution* (SS). Other behaviors that showed an outcome from the discussion were coded as *making a decision* (MD), *notifying* the occurrence of an *event* (NE) and *volunteering assistance* (VA).

Results

Table 1 shows the knowledge scores for each district for the pre and post surveys. The two districts (2 and 3) that did not use the online discussion tool received a lower score and the same score respectively on the post survey. Three out of the four districts (8, ITD and CRD) that used the online discussion tool received higher scores on the post-survey. There was a significant effect for knowledge, $t(40) = 5.41$, $p < .05$, with discus users receiving higher scores than non-discus users. (In this and subsequent t-tests, we verified that variance probability for equal variance applies; Kerlinger & Lee, 2000).

Table 1. Knowledge scores by district (percent correct)

	Control group		Discus users				
	Officer Group B		Officer Group A		Staff		
	2	**3**	**5**	**8**	**ITD**	**CRD**	**Aggregate**
	n = 10	*n = 6*	*n = 10*	*n = 5*	*n = 7*	*n = 4*	*n = 42*
Pre-survey	60%	30%	64%	53%	42.8%	60%	51.6%
Post-survey	38%	30%	55%	88%	48.5%	100%	59.9%
% change	**-22%**	**0%**	**-9%**	**35%**	**5.7%**	**40%**	**8.3%**

Table 2 shows the types of behaviors examined for content analysis. Table 3 shows the results for the content analysis of the messages posted in the discussion tool. The most common behaviors were those of IS (Information Seeking) and IP (Information Providing). The next most common actions were RA (Requesting Action) and CA (Confirming Action). During content analysis, it was observed that different districts sometimes disagreed on and discussed their booking procedures. Various formatting issues were negotiated, such as whether to include the dashes in the social security number, how to format the state adult booking number, and what additional fields to include in the booking. Officers were used to the prior booking procedure where booking reports were typed onto pre-printed paper reports. Previously formatting was not an issue because a limited number of people entered the data from the paper reports into the booking system.

Table 2. Types of content analysis behaviors

Types of behavior			
Key to codes		Key to codes	
IP	Information providing	MD	Making a decision
IS	Information seeking	VA	Volunteering assistance
RA	Requesting action	RF	Raising funds
CA	Confirming action	SF	Seeking funds
SC	Seeking consensus	PF	Providing funds
SP	Statement of problem	OP	Other people
SS	Statement of solution	H	Humor
NE	Notifying occurrence of event		

Table 3. Breakdown of behaviors by district

Behavior	2	3	5	8	ITD	CRD	Total per behavior
IP			5	2	10	2	19
IS			8	3	7	1	19
RA			2	2	2	4	10
CA			6	2	6		14
RF							0
SF							0
PF							0
SP					5		5
SS					4	1	5

SC				1	3		4
MD			1	1	1		3
VA							0
OP							0
NE				1	5		6
H							0
Total per district	**0**	**0**	**22**	**12**	**43**	**8**	**85**

Table 4 shows the number of posts, replies and reads in the discussion tool by district from the server logs. ITD was the most active in posting and replying to posts. All of the districts that used the discussion tool (5, 8, ITD and CRD) were more active in reading messages posted by others compared to posting. The ratio of reads to posts was almost 41:1 in the case of ITD, 50:1 for district 5 and 22:1 for district 8.

Table 4. Number of posts, replies and reads by district in the online discussion tool

	2	3	5	8	ITD	CRD	Total
Posts	0	0	10	4	19	5	38
Replies	0	0	13	7	23	4	47
Reads	0	0	502	156	791	62	1511

Figure 2 shows the initial social network with all media combined, and Figure 3 shows the social network after the introduction of the online discussion tool with all media combined. These two diagrams allow comparison of differences in the social network. The initial social network shows collaboration within each district but a lack of collaboration between districts. The post social network shows new collaboration between the districts (5 and 8) using the discussion tool. There was a significant effect for inter-district collaboration, $t(40) = 2.57$, $p < .05$, with increased collaboration across districts following the introduction of the tool. However, there was no significant effect for collaboration frequency, $t(40) = -0.02$, $p > .05$, with discus users receiving similar scores to non-discus users. Therefore the null hypothesis for H2 cannot be rejected.
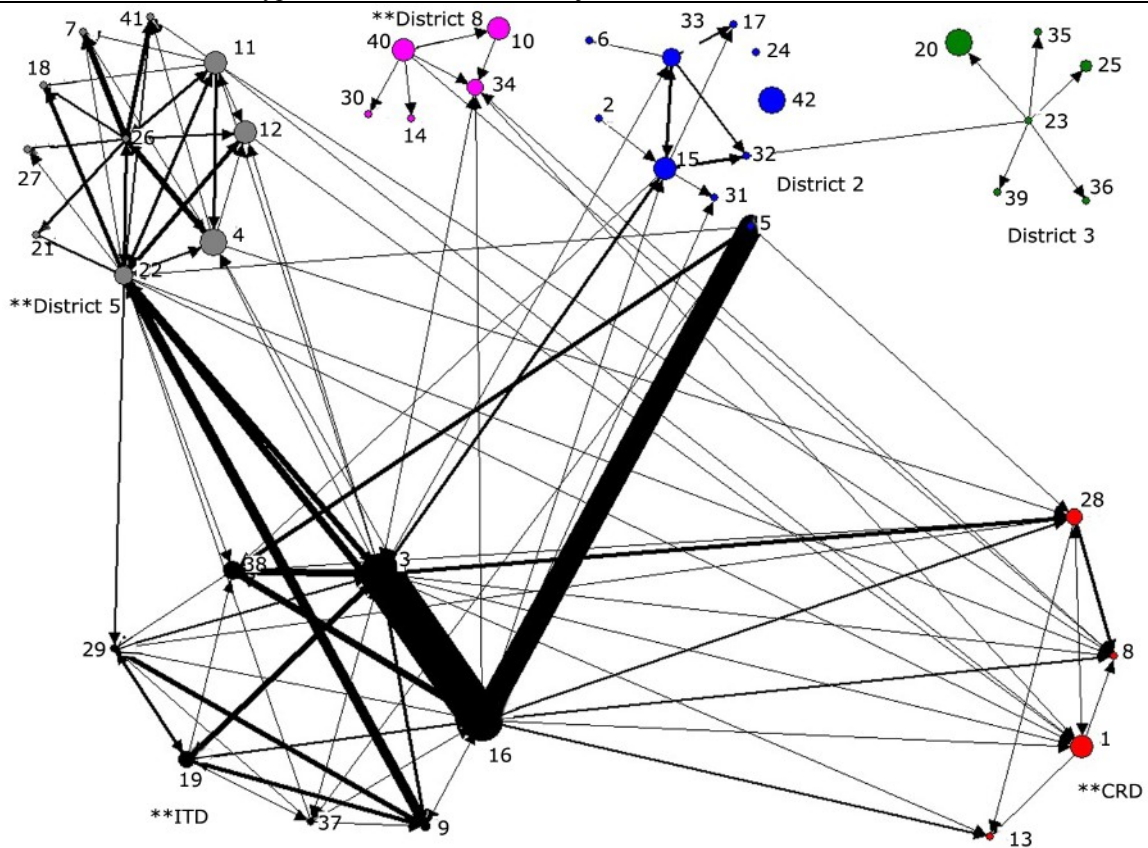

Figure 2. Social network before introduction of the online discussion tool. In this and subsequent figures, ** indicates districts that used discus
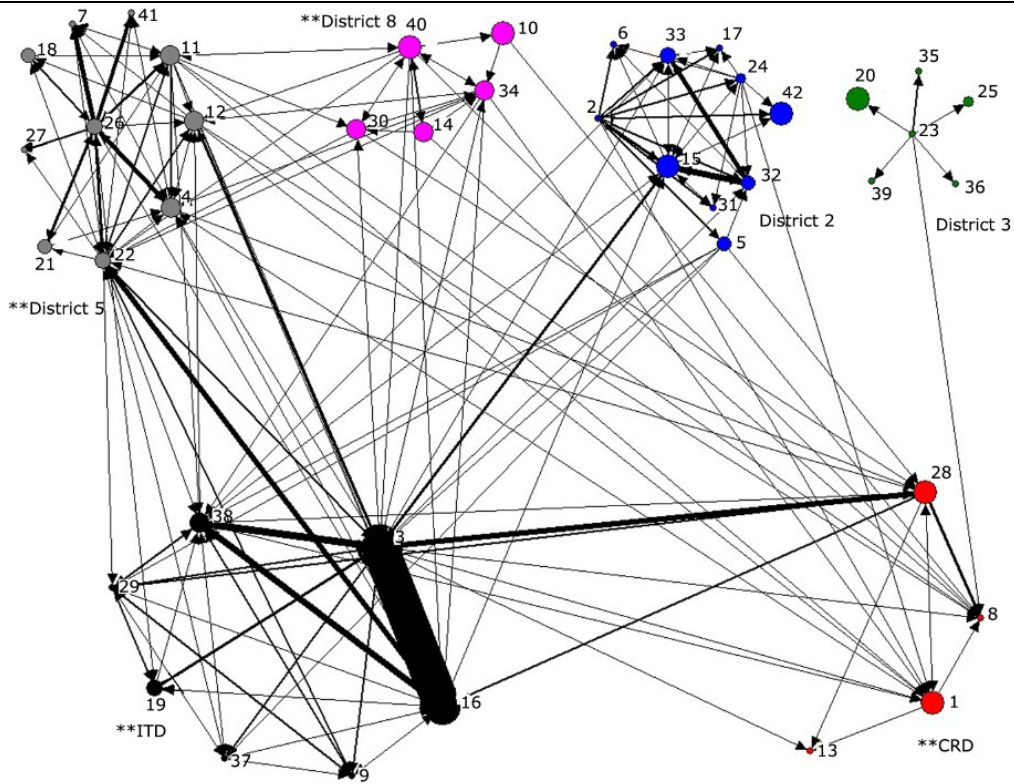
Figure 3. Social network after introduction of the online discussion tool
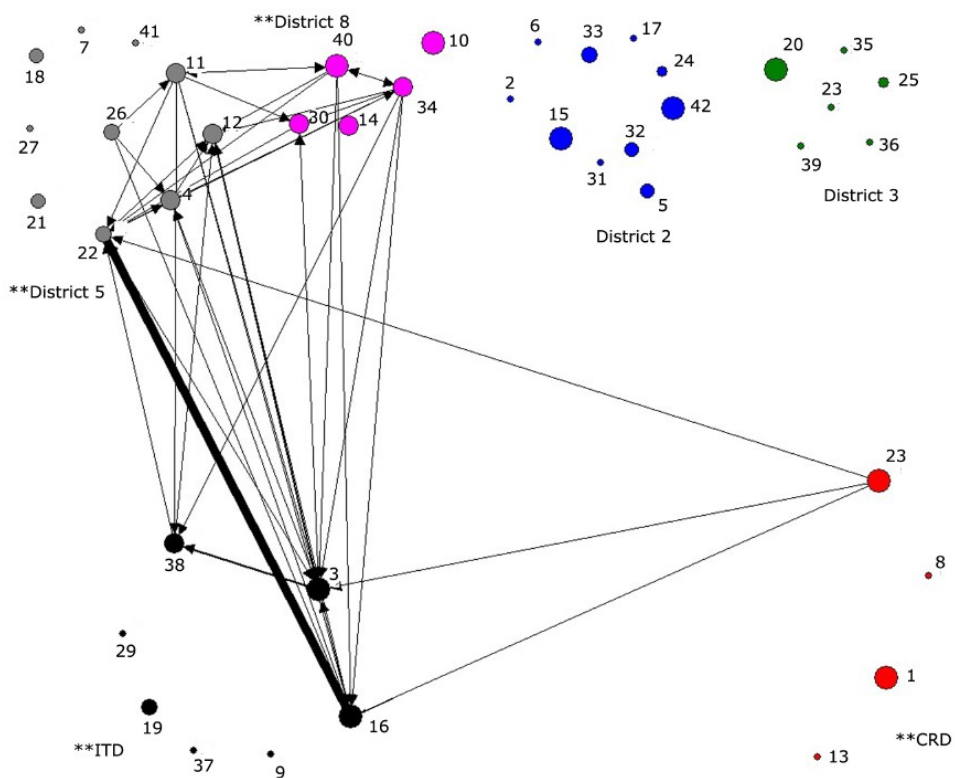

Figure 4. Social network of interactions using the online discussion tool

Figure 4 shows the collaborative interactions between the districts using the online discussion tool (connections via other media are omitted from this diagram). Figure 4 shows that there was new collaboration using the online

discussion tool between district 5 and district 8 and that the overall knowledge scores (represented as size of the nodes in the graph) had increased.

Officer Comments

Comments from officers indicated that Discus was particularly useful because it was available no matter what booking computer they were assigned to. One user commented that the ability to post attachments such as screenshots saved time by allowing other officers to refer to the screenshot, thereby reducing the amount of textual description needed to explain a point.

Discussion

The results of changes to the social network, including collaboration patterns between individual participants and different districts and collaboration frequency will be discussed.

Initial Social Network and Knowledge

The results of the initial social network analysis (Figure 2) indicate that officers tended to collaborate within their own districts for information and rarely collaborated between districts. Furthermore, Figure 2 shows that there appeared to be significant collaboration between the individuals in the Information Technology Division (ITD), and especially between two of the central individuals (3 and 16). There was significant collaboration between individuals in the ITD and individuals in the Central Receiving Division (CRD). Each of the districts appeared to have a unique network structure, with the one commonality being a central or liaison individual who collaborated with others outside the district. This central individual was not necessarily the individual who has the highest knowledge score (34, 15, 23). Similarly, some of the individuals (10, 42, 20) who are isolated received the highest knowledge scores, indicating that these individuals are underutilized for their expertise. The initial survey showed that the average knowledge score across all districts was 51.6% (Table 1). In addition, each of the districts had a different social network structure (Figure 2). The districts with the highest scores were district 5 with 64%, district 2 at 60% and CRD at 60% (Table 1). The similarity between the network structures of these three districts is that each of the individuals collaborated with others in the same district and also with individuals in other districts. The collaboration was two-way. The network structure of the districts that received the lowest pretest scores, district 8 at 53%, ITD at 42.8% and district 3 at 30% (Table 1) tended to have one or two officers collaborate outside the district and then share the information within the district. The collaboration appeared to be mostly one-way. Interestingly, ITD staff had one of the lowest overall knowledge scores. Relating this to Figure 2, it appears that two ITD staff members (3, 16) are over-utilized, creating a bottleneck in the network between other ITD staff and other districts collaborating via these two individuals.

Collaboration Between Districts (H1)

The results from the social network analysis support H1, which states that there would be an increase in collaboration between participants in different districts using the online discussion tool compared to participants who did not. The results indicated that the online discussion tool encouraged new ties to be formed between participants who had not previously collaborated. There was a significant increase in collaboration between districts 5 and 8 (Figure 3) after the online discussion tool was introduced compared to the initial social network (Figure 2). The two districts that did not have access to the online discussion tool (2 and 3) showed collaboration within their own district but there was a lack of collaboration with any of the other districts (Figure 3).

Collaboration Frequency (H2)

H2 states that there would be an increase in collaboration frequency between participants using the online discussion tool compared to participants who did not. The results from the social network analysis did not show a significant difference in collaboration frequency between the group that used Discus and the group that did not: the null hypothesis for H2 cannot be rejected. The only significant increase in tie-strength was between participants 3 and 12. There was increased collaboration between officers in district 2 but this was mainly due to

increased face-to-face collaboration. The level of participation in the online discussion database may explain why the frequency of collaboration between participants was low. To overcome this limitation, these results can be analyzed again once the online discussion tool has been used over a longer time period.

Knowledge (H3)

The results from the second survey showed an increase in average knowledge scores across all districts from 51.6% to 59.9% (Table 1). Knowledge scores across districts showed that three of the four districts (district 8, CRD and ITD) that participated in the online discussion tool showed increased knowledge scores, while the two districts that were not given access to the online discussion tool showed either constant (district 3) or decreased (district 2) overall knowledge scores. The statistical test of results from the second survey supports H3: there was an increase in knowledge for participants using the online discussion tool compared to participants who did not. This difference suggests that the changes in the social network structure (Figure 3), in addition to practice over time, improved learning.

Relationship Between Social Network and Knowledge

The districts with the highest post-scores were CRD with the highest score at 100%, followed by district 8 at 88% and district 5 at 55%. It appears that *CRD* received the highest score due to the increase in knowledge by two key individuals (28, 1). Staff member 28 was the only individual in CRD to contribute in the online discussion tool. The social network of *district 8* changed noticeably, with increased two-way collaboration between officers 30, 14, 40 and 34 (Figure 3). These individuals were active participants in the online discussion tool, communicating with ITD (Figure 4). The social network within *district 5* remained essentially the same. Officers 18, 21 and 26 increased their collaborative learning scores; however, of these only officer 26 participated in the online discussion tool. It appears that officers 18 and 21 had increased two-way collaboration to other individuals (21 to 4, 11 and 18 to 12) who did participate in the online discussion tool (Figure 4). *ITD* marginally increased knowledge scores. This can be explained by the lack of participation by ITD staff in the online discussion tool. Only staff members 38, 3 and 16 chose to participate (Figure 4), with individual 38 being the only one with an increase in knowledge score. As part of the study design, district 2 and district 3 did not have access to the online discussion tool. *District 2*'s social network structure changed as a result of increased face-to-face collaboration. Officers 5, 32, 15 and 24 marginally increased their knowledge scores. This may be explained by the social connections that these officers have outside of their own district. *District 3*'s social network structure remained the same, as did their overall knowledge score at 30%.

The results showed that there was an increase in knowledge scores for 10 out of the 14 individuals in the online discussion tool, with two of these (3 and 16) receiving the maximum scores in both pre and post surveys (Figures 2 and 3). There was an increase in knowledge scores for 4 out of the 16 individuals who did not participate in the online discussion tool. These four officers (all from district 2) have social connections outside of their own district. This overall distribution of scores suggests that the gains may be attributed to the use of the online discussion tool. Even though there was some variation in the social network structure of each district over time (pre versus post social network), the overall knowledge scores indicate that those districts that used the discussion tool improved their knowledge. An appropriate example is the change in the social network structure in District 2. They did not use the online discussion tool, but despite the network changes using other media (Figure 2), their overall knowledge score did not increase.

Content Analysis

Results from the *content analysis* of the messages posted using the online discussion tool indicated that all of the districts that had access to the online discussion tool used the board mainly to seek and provide information (IS = 19, IP = 19 in Table 3). District 5 displayed the most information seeking (IS) behavior. They have the most integrated network structure (Figure 3). It is interesting that all districts participated in information providing (IP), not just ITD and CRD as expected. To a lesser extent, the districts used the board to request actions (RA = 10) and confirm completed actions (CA = 14). An example of this is where a participant would ask participants in other districts to type data into the booking module in a certain way (see informal observations concerning the negotiation of formatting, previous section).

Participation by Reading

The logs indicate that many of the participants chose not to post messages but were active in their reading of messages posted by others. The ratio of reads to posts was almost 41:1 in the case of ITD, 50:1 for district 5 and 22:1 for district 8. This indicates that the frequency of collaboration by posting and replying to messages was low, with most participants preferring to only read messages. Analysis of the knowledge results indicates that despite a low level of posting, the participants who only read the posts of others increased their own knowledge scores. Wenger et al. (2002) suggest that the learning of "lurkers" may be of significant advantage in some online communities. Although not included in the original goals of this study, further analysis of the behavior and learning of lurkers in a social network should be conducted.

Conclusions and Future Work

Findings from this study have indicated that the introduction of an online discussion tool had significant effects on the social network and learning of officers working with a booking module of the RMS at the Honolulu Police Department. Results supported the hypothesis that there would be an increase in collaboration between participants in different districts in which the online discussion tool was available compared to participants in districts where the tool was not available. The results did not support the hypothesis that there would be an increase in collaboration frequency between participants. However, results supported the hypothesis that there would be an increase in knowledge for participants who used the online discussion tool compared to participants who did not use the tool. These results along with the lack of knowledge gain in a district that increased its internal social networking without CMC (the exceptions are individuals who had outside contacts) suggest that increased interaction within a group has less influence on knowledge gains than the expanded size of a social network enabled by CMC. This finding might be explained by the greater cognitive diversity of a larger network. The nature of the media must also be considered: while a quantitative social network analysis counts contact through volatile media (such as face to face speech or telephone) the same as contact through persistent media (such as a discussion board), persistent media can reach more people over time and support reflection on the contributions. Content analysis and the finding that lurkers achieved knowledge gains also suggest that the discussion tool supported information sharing and coordination of action over time and space. In general, CMC's value to an organization should not be judged merely based on whether interaction becomes more frequent: benefits also lie in increased connectivity and persistence of information.

This study has shown that it is possible to change the social network structure from one that presents barriers to knowledge sharing to one that promotes learning. However, it is clear that introduction of a collaboration tool is not sufficient by itself. For example, it is necessary to maintain activity in the online discussion tool in order to create value that encourages further participation, which in turn creates further value. Participants need support in learning how to use the new collaboration technology, and how to adapt it to work processes and social processes. Technology supported media can be used to enable collaboration between participants who would not necessarily collaborate through any other type of media, but the CMC does not operate in isolation. Various media support collaboration within the social network, and synergy with communication in other media may amplify the impact of the CMC tool.

This study was conducted over a six-week period due to time constraints imposed in part by movement of the participating police officers. It would be useful to evaluate the results of a similar study held over a longer period of time. Further research could examine other independent variables, such as the introduction of different media types, or dependent variables, such as how the nature of the interaction changes between participants in the social network. Studies conducted in different types of organizations and environments and examining how different media are used for different work and social process would be of value. In general, the objective is an empirically grounded theory that can predict how the introduction of different media types and practices surrounding their use would affect social networks and their implications for knowledge building within a community of practice.

Acknowledgements

References

Bogenrieder, I. (2002). Social architecture as a prerequisite for organizational learning. *Management Learning*, 33 (2), 192-212.

Borgatti, S., Everitt, M. & Freeman, L. (1996). *UCINET IV Version 1.64*. Natick, MA: Analytic Technologies.

Chan, C., Lee, E. & Van Aalst, J. (2001). Accessing and fostering knowledge building inquiry and discourse. Presented at the *9th Biennial Meeting of the European Association for Learning and Instruction*, Switzerland.

Cummings, J. N. & Cross, R. (2003). Structural properties of work groups and their consequences for performance. *Social Networks*, 25, 197-210.

Doise, W. & Mugny, G. (1984). *The Social Development of the Intellect*. Oxford: Pergamon Press.

Kerlinger, F. & Lee, H. (2000). *Foundations of Behavioral Research*. 4th ed. Harcourt College Publishers.

Krackhardt, D. & Haythornthwaite, C. (1998). A social network study of the growth of community among distance learners. *Information Research*, 4 (1). Available at: http://informationr.net/ir/4-1/paper49.html.

Kraut, R. & Attewell, P. (1993). Electronic Mail and Organizational Knowledge. Working paper, Department of Social and Decision Sciences, Carnegie Mellon University.

Liang, D., Moreland, R. & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin*, 21, 384-393.

Moreland, R. L. & Myaskovsky, L. (2000). Exploring the performance benefits of group training: Transactive memory or improved communication. *Organization Behaviour and Human Decision Processes*, 82, 117-133.

Preece, J. (2000). *Online Communities: Designing Usability and Supporting Sociability*. John Wiley & Sons.

Resnick, P. (2002). Beyond bowling together: SocioTechnical capital. In *HCI in the New Millennium*, edited by John Carroll. (647-672.) New York: Adddison-Wesley.

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

Rubin, K. & Goldberg, A. (1992). Object behaviour analysis. *Communications of the ACM,* 35 (9), 48-62.

Scardamalia, M. (2000). *Principles of Knowledge Building*. Fourth Knowledge Building Institute, Toronto, Ontario, August 9-12, 2000.

Scardamalia, M. & Bereiter, C. (1996). Rethinking learning. In Olson, D. R. & Torrance, N. (Eds.), *The Handbook of Education and Human Development: New Models of Learning, Teaching and Schooling,* Cambridge, MA: Basil Blackwell, 485-513.

Sha, L. & Van Aalst, J. (2003). An application of social network analysis to knowledge building. Paper presented at the *Annual Meeting of the American Educational Research Association*, Chicago, April 21-25, 2003.

Suthers, D. (2006). Technology affordances for intersubjective meaning-making: A research agenda for CSCL. To appear in *International Journal of Computer Supported Collaborative Learning*, 1 (3).

Valente, T. (1995). *Network Models of Diffusion of Innovations*. Hampton Press, Cresskill, NJ.

Wasserman, S. & Faust, K. (1995). *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.

Wellman, B. (1996). *For A Social Network Analysis of Computer Networks: A Sociological Perspective on Collaborative Work and Virtual Community*. Center for Urban and Community Studies, University of Toronto, Canada.

Weber, M. (2000). *Modeling Technological Change under Uncertainty in Integrated Assessment Models for Climate Change*, retrieved January 7, 2004 from http://www.mpimet.mpg.de/~weber.michael/modeling_tc.html.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning and Identity.* Cambridge: Cambridge University Press.

Wenger, E., McDermott, R. & Snyder, R. (2002). *Cultivating Communities of Practice: a Guide to Managing Knowledge*. Boston: Harvard Business School Press..