Can Lean Media Support Knowledge Sharing? Investigating a Hidden Advantage of Process Improvement

Ned Kock and Robert Davison

***Abstract*—Is there a positive link between the use of collaborative technologies and knowledge sharing? The body of empirical evidence compiled so far suggests a negative answer to this question. Many explanations have been proposed, the most common being that current collaborative technologies do not yet have enough sophistication, or do not yet provide enough media richness, to enable knowledge sharing. This paper presents evidence that not only suggests that this explanation is wrong, but also that simple collaborative technologies can have a positive effect on knowledge sharing in organizations. This paper shows that, when combined with appropriate social processes, collaborative technologies may foster knowledge sharing. It does so by focusing on process improvement as a group process, and showing that: 1) process improvement is a catalyst to knowledge sharing and 2) a lean communication medium, namely e-mail conferencing, has a positive impact on knowledge sharing when used to support process improvement initiatives.**

***Index Terms*—Action research, Brazil, collaborative technologies, electronic communication, knowledge sharing, New Zealand, process improvement.**

I. Introduction

ORGANIZATIONS today operate in an environment that is enduring a substantial state of flux, with successions of new technologies, competitors and market pressures all exerting significant impacts. Increases in productivity, customer satisfaction, and market reach are being achieved, but new competitors are emerging from less well-established domains, such as manufacturing conglomerates in China, Eastern Europe, and Russia. The Internet is shadowing these changes with instantaneous dissemination of information about competitive products and services worldwide, thereby creating huge market pressure for change.

In addition to the accelerated pressure for change, the nature of work becomes more complex and specialized as new knowledge is created and incorporated into the production of goods and services [17], mirroring a larger scale trend toward knowledge specialization and fragmentation [37], [54]. As knowledge becomes more specialized and fragmented, so does the need for knowledge sharing between individuals holding different types of expertise. This need is motivated by the fact that even though knowledge has grown very specialized (or precisely because of this), most organizational processes require the engagement of several individuals, each of them contributing their own expert knowledge:

> The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances which we must use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which separate individuals possess [37].

Continuous organizational knowledge sharing and organizational change are essential in the game of interorganizational competition [14], [15], [24], [32], [33], [70]. However, they may pose a formidable obstacle to organizations [16], [36], [38], [46]. Practitioners and researchers have singled out effective interfunctional knowledge sharing as one of the main challenges in the knowledge intensive economic environment of the 1990s and beyond [9], [10], [63]. Similar to organizational knowledge sharing, organizational change has also been shown to be difficult to achieve in an effective manner [34].

The fragmentation of expertise seen today is not only abstract. It is also reflected in the physical distribution of knowledge holders in organizations. Individuals with different expert knowledge are often departmentalized and isolated from each other by walls and distance, which makes it difficult for them to form organizational change groups, as well as to share expert knowledge. As most business processes are interdepartmental [44], this situation may in many cases lead to suboptimal performance. Given the proliferation of computer-based media in organizations, particularly "lean" media such as e-mail, one way of addressing this problem could involve the use of lean media to support knowledge sharing and business process improvement involving distributed and multidepartmental groups. In this paper, a study of routine organizational processes, as well as of group processes performed by lean-media supported business process improvement groups is described, with a specific research question addressed:

Can Lean Media Support Knowledge Sharing?

Most of the empirical evidence published to date suggests a negative answer to this question. Two well-established theories of computer-mediated communication, namely media richness theory [12] and the social influence model [30], respectively, suggest a negative and a contingent, possibly positive, answer to

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N. Kock is with the E-Collaboration Research Center, College of Business and Economics, Lehigh University, Bethlehem, PA 18015 USA (e-mail: nfk2@lehigh.edu).

R. Davison is with the Department of Information Systems, City University of Hong Kong, Kowloon, Hong Kong (e-mail: isrobert@cityu.edu.hk).

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the question. The empirical data discussed in this paper contrasts with most of the empirical research published so far, and with media richness theory, in that it suggests an affirmative answer to the question. The patterns in the data can, as will be shown later, be partially explained by the social influence model.

This study is premised on the assumption that the mere introduction of technology into an organizational setting seldom leads to predictable outcomes, without an accompanying social process that influences the use of the technology in a particular direction. We focused our investigation on one particular social process, namely business process improvement, through the analysis of process improvement groups. In a nutshell, we demonstrate that:

1) process improvement, as a group process (or meta-process), can function as a **catalyst** to knowledge sharing;
2) a lean communication medium, namely e-mail conferencing, has a **positive** impact on knowledge sharing when used to support process improvement initiatives.

The goal with the first proposition is to show that when the members of an organization engage in process improvement initiatives, in addition to the routine execution of processes, they tend to share more knowledge than when they engage only in the routine execution of processes.

The goal with the second proposition is to show that if a lean medium, such as e-mail conferencing, is used to support process improvement initiatives, it will have a positive impact on knowledge sharing. In doing so, we will succeed in providing an affirmative answer to the question: "Can lean media support knowledge sharing?"

In addition to answering our research question, we will also discuss some basic components of how this can be done—i.e., how industry practitioners can use a lean medium to foster knowledge sharing. This discussion addresses, in general terms, the use of computer-supported process improvement groups as knowledge sharing enablers. A more normative and detailed discussion of an approach to achieve this is beyond the scope of this paper and can be found in [42].

The process improvement groups investigated in this paper focused their efforts on specific processes in their respective organizations. Research data were collected over three years. Three organizations, reflecting different national cultures and organizational backgrounds, participated in the study. One of the organizations was the Brazilian branch of Westaflex, a multinational car parts manufacturer. The second organization was Waikato University, a large university in Waikato, New Zealand. The third organization was MAF Quality Management (MQM), a branch of the Ministry of Agriculture and Fisheries, New Zealand.

II. Organization of This Paper

Following this Introduction, Section III initiates a review of previous empirical studies that investigated the impact of electronic communication technologies on knowledge sharing, as well as relevant theories. Most of the empirical studies reviewed, as well as some theoretical models, suggest that current commercially available electronic media are too "lean" to effectively support knowledge sharing. In Section IV, we present and discuss a basic criterion for the identification of knowledge content in communication exchanges. Section V follows, where we explain how data were collected and analyzed, as well as how threats to reliability and validity were dealt with. Section VI focuses on showing that a particular type of group process, namely "process improvement," is a catalyst to the sharing of knowledge. This is followed by Section VII, which focuses on demonstrating that the use of a lean medium to support process improvement has a positive impact on knowledge sharing. Finally, in Section VIII, we summarize the main findings of our data analysis and compare them with those of the previously reviewed empirical studies and theories, drawing implications for research and practice.

III. Research Background and Motivation

A. Previous Empirical Findings

There has been increasing interest, particularly in the last decade, in the use of collaborative technologies to support work groups in organizations, as well as in collaboration in a more general sense throughout the engineering management discipline [25], [29], [69], [76]. A great deal of this interest has been fueled by the emergence of organizational forms characterized by their low dependence on physical structures for employee interaction [6], [18]. There has also been interest, again especially in the last decade, in organizational structures and processes geared at promoting organizational learning [52], particularly in the development of organizational knowledge structures and group-based knowledge sharing processes. Finally, there has been increasing interest in process-based change, particularly since the rise of the business process re-engineering movement in the early 1990s [34], [77]. However, while computer-supported collaboration, knowledge sharing, and process improvement have been separately the target of intense research, only a few studies have addressed the possibility that combinations of these organizational approaches can lead to synergistic results, that is, that one approach can enhance either or both of the other two.

Dennis *et al.* [21]–[23], Kock and McQueen [45], and Davison and Vogel [19] have conducted field investigations on the impact of collaborative technologies on process improvement. Dennis *et al.*'s [21]–[23] studies were semicontrolled field experiments, and dealt with synchronous group support technologies (group decision support systems). These three studies investigated real-life process improvement situations, with researcher control applied on group process structure (achieved by employing a specific group methodology and providing technology use facilitation). Kock and McQueen's [45] study was markedly low in control (e.g., groups were formed voluntarily and decided whether they would use computer support or not), also dealt with nonsimulated process improvement situations, and focused on the use of an asynchronous group support technology (e-mail conferencing). Davison and Vogel [19] employed a group support system in an action research informed investigation of a single process improvement group with minimal control in an accounting firm in Hong Kong. In spite of differences in research design and

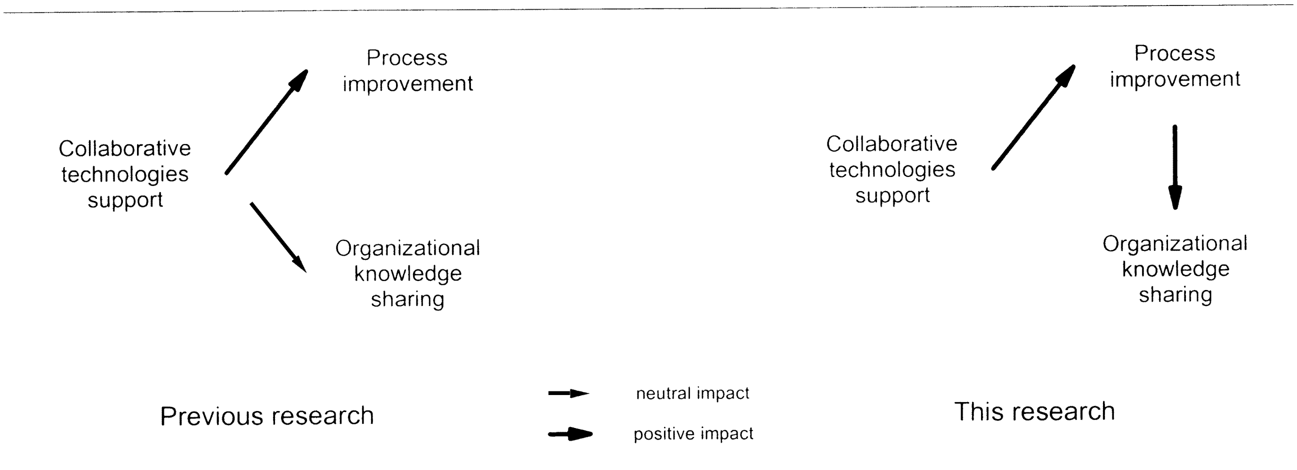

Fig. 1. Illustration of previous research findings *vis-à-vis* what this research tries to show.

collaborative technologies employed, these studies consistently suggest an increase in process improvement efficiency due to computer support (group process productivity), and a neutral impact of computer support on process improvement quality (group outcome quality). These findings are also consistent with Nunamaker *et al.*'s [55] summary of many years of group support systems research.

The impact of collaborative technologies on organizational knowledge sharing has also been the target of research. Early investigations in noncontrolled settings have led to either negative or inconclusive findings. For example, Orlikowski's [57] study of an implementation of an asynchronous computer conferencing system (Lotus Notes) at a large consulting firm concludes that organizational culture and reward systems prevented knowledge sharing among consultants, in spite of the availability of technological support. Ackerman's [1] study of usage patterns and perceptions of an organizational memory system (Answer Garden) by software engineers yielded a mix of positive and negative results regarding knowledge sharing involving experts and users, where the former had been a source of expertise to the latter.

More recent research paints an even more negative picture regarding the impact of collaborative technologies on knowledge sharing. Riggs *et al.* [67], for example, suggest that current collaborative technologies lack the maturity to effectively support the sharing of organizational knowledge. Along the same lines, Neilson's [53] noncontrolled longitudinal study of Lotus Notes' users in a public organization concludes that collaborative technologies do not prevent the departure of knowledgeable employees from having a negative impact on organizational knowledge retention. The same study suggests that, without adequate group processes, technology itself is unlikely to have any conclusive impact on knowledge sharing. This is a theme that has recently been revisited by Tan *et al.* [75], in the context of virtual teams communicating electronically. Their study builds on the assumption that electronic communication does not *per se* facilitate building of shared understanding among team members, and proposes and tests, with positive results, a group process (whose main element is a dialogue technique) to facilitate building of shared understanding in virtual teams.

Neilson's [53] and Tan *et al.*'s [75] findings add relevance to the research question in the current work. They indicate that specific organizational structures, of which specific group processes could be seen as basic elements, should be set in place concurrently with the implementation of collaborative technologies if computer-supported organizational knowledge dissemination is to be achieved. Fig. 1 summarizes the discussion above regarding previous research, and illustrates what this research tries to accomplish. Previous research has investigated the relationship between collaborative technology support and either process improvement or knowledge sharing. This research investigates the link between collaborative technology support and knowledge sharing, with process improvement as a mediating element.

B. Expectations Based on Relevant Theories

A number of theoretical frameworks have been used to explain the effects of collaborative technologies in organizational settings. Examples of such theories are: media richness theory [12]; adaptive structuration theory [61], [62]; systems rationalism [47]; genre-based communication structuration [58], [80]; the affective reward suppression model [64]; and the social influence model [30].

Among these theories, media richness theory is particularly well aligned with the notion, advanced by Riggs *et al.* [67] and others and discussed in the preceding section, that current collaborative technologies lack enough sophistication to support knowledge sharing (especially since, in many cases, "sophistication" is presented as being synonymous with the presence of video, audio, and communication synchronicity). According to media richness theory, different communication media can be positioned along a lean-rich continuum, depending on their ability to support communication in equivocal tasks. The classification scheme proposed by media richness theory places face-to-face as the richest communication medium, and e-mail as a relatively lean medium [12], [30], [48]. Media richness theory hypothesizes that lean media are not appropriate for knowledge communication (or "equivocality" reduction, using the theory's terminology), and claims that the selection of media and the outcomes of its use will always reflect this hypothesis [13], [49]. Several tests of the theory have suggested that its basic tenets generally hold true [66], [78]. Also, media richness theory has often been used in its original form as a basis for the understanding of empirical findings of research on contemporary communication issues in organizations and society as a whole [2], [41], [79].

A key theory that is relevant to this study and that has also played an important role in highlighting limitations of media richness theory is the social influence model [30]. In contrast with media richness theory, which focuses on technology characteristics, the social influence model argues that social influences can strongly shape individual behavior toward technology in ways that are relatively independent of technology traits. Examples of social influences are technology use patterns observed in other individuals [4], whether they lead to positive or negative consequences, as well as formal or informal social norms of accepted behavior followed by a group to which an individual belongs.

A study by Markus [50] shows that social influences can shape individual behavior toward communication media in ways that are inconsistent with media richness theory predictions. The study focused on media choices made by managers at a large risk management services provider and questioned the correctness of the media richness scale, which rates e-mail as being less rich than face-to-face interaction. It suggested that social pressures can change some of e-mail's attributes that are seen as static by media richness theory. For example, the study showed that pressure from senior managers on subordinates to reply quickly to e-mail messages increases e-mail's feedback immediacy, and, therefore, shifts e-mail up from its relative position on the richness scale proposed by media richness theory. More recent studies, such as that conducted by El-Shinnawy and Markus [28], focusing on users' choices between electronic mail and voice mail, provide corroborating evidence and enable one to conclude that a complex set of social factors governs organizational media use in ways that are often inconsistent with media richness theory.

Given these arguments, it is reasonable to expect that certain social activities and norms, such as those related to group-based process improvement, may lead to secondary social influences (e.g., perceived group mandate and expected individual behavior) that could be conducive to knowledge sharing. In addition, these social influences may also induce behavior toward technology that is inconsistent with media richness theory predictions, by creating conditions for effective knowledge sharing through lean media.

C. *Why the Focus on Process Improvement?*

At this point, the reader may be asking: Why process improvement? One may correctly argue that other group processes, such as brainstorming meetings, retreats, and training sessions, may also lead to interfunctional and interdepartmental knowledge sharing. Consequently, why is so much attention being paid to process improvement as a catalyst for knowledge sharing?

Process improvement was chosen because it is a particularly relevant organizational process from a practitioner's perspective. The improvement of organizational processes has long been a desirable end in itself [20], and it is as necessary for effective industry competition as knowledge sharing. Nevertheless, process improvement is less abstract as a concept than knowledge sharing, as its targets (processes) are more closely linked to the day-to-day activities of an organization. Therefore, unlike brainstorming meetings, retreats, training sessions, and other similar types of efforts where increased knowledge sharing is the focus of the group effort, process improvement efforts can be justified by the organizational need to achieve immediate gains in process quality and productivity. It is reasonable to expect that industry practitioners will see such gains, in most cases, as being less abstract goals than group knowledge sharing (when presented as end goals).

IV. If–Then Statements as Indications of Knowledge Content

This research attempts to test the impact of lean media on knowledge sharing in the context created by specific group processes, namely process improvement processes. In doing so, its specific concern lies in one particular component of organizational communication. This component is interfunctional knowledge communication, or the communication of knowledge between different functions (e.g., manager, lathe operator, instructor, etc.) involved in the undertaking of organizational processes.

While face-to-face interaction plays an important role in organizational communication, the proliferation of computer networks has dramatically increased the volume of electronic communication in organizations. It is widely believed that most communication in organizations now occurs through the exchange of written (printed or electronic) documents [72]. A recent empirical study suggests that this is true for production, operations, sales, accounting, and finance information [5].[1] Therefore, any study of knowledge communication patterns must have well-defined criteria for the identification of knowledge in written texts or transcripts of oral communications. Such criteria have to incorporate semantic assumptions based on syntactic structures and patterns. While the development of such criteria has been the focus of many researchers, who have found evidence of syntactic-semantic correspondence patterns in human communication, the current understanding about the human mind seems too limited to serve as the basis for such criteria development [60].

One method of overcoming this limitation in organizational studies is to build knowledge identification criteria based on previous attempts to incorporate knowledge into computer databases. Two main approaches in the broad field of artificial intelligence, the symbolic and connectionist [39], have proven successful in different contexts. While symbolic approaches make use of symbolic representations of knowledge, connectionist approaches employ networks of relatively simple processing units connected by links (also known as neural networks). Due to the inherent characteristics of each approach,

[1]The same study found that communication about strategic planning, human resource, and general personnel issues takes place mostly through nonwritten means, predominantly one-to-one and group face-to-face meetings.

it is the representations generated by the symbolic approach that best resemble typical language structures found in written communication. The rules of inference used in instances of the symbolic approach typically follow the framework provided by propositional or first-order logic [68], which allow knowledge to be identified and partially represented by logical implications of the type: *If (conditions) then (consequences) else (other consequences)*. We adopt a similar approach for the identification of knowledge content in communication exchanges, which will be explained later in the paper.

V. Data Collection Context

A. Research Methodology Used: Action Research

This study made use of interviews and electronic communication data collected in the context of action research studies at Westaflex, MQM, and Waikato. Action research, as a method of inquiry, has been broadly employed in studies of organizational behavior, management development, and information systems. Action research seeks to introduce changes with positive social values in an organizational problem context, so as to improve the circumstances for organizational stakeholders, while at the same time providing the researcher with an opportunity to apply and reflect upon theories relevant to the problems. [3], [7], [8], [27]. The action researcher is required to *intervene* in the problem situation, introducing theory-informed changes, and assessing the impacts of these changes. Thus, the action researcher has the responsibility to contribute both to research through the validation or improvement of existing theories and to practice introducing practical improvements in the problem situation investigated [11], [27]. The nature of the intervention may involve controversy, threatening the status quo in the organization [26].

Action research typically involves an iterative cycle of the following five activities [74].

1) First, the researcher *analyzes* the situation with a view to *diagnosing* problems that may exist.
2) This analysis and diagnosis then feeds into a theory-informed *plan* of how to act.
3) The researcher then *intervenes* according to the plan, attempting to solve the problem and/or manage the change process.
4) Data on the situation or phenomenon is then gathered and *evaluated*.
5) The following *reflection* involves interpreting the data, identifying lessons learned and informing the future cycles of activities that will continue to take place until the problem has been resolved.

These five activities are concurrently informed by a researcher-client infrastructure, an operational framework which outlines the scope and character of the project, and includes details of the researcher–client relationship, and protocols describing the nature of researcher interaction and involvement in the project.

Process improvement projects provided the contexts in which the researcher tried to improve the three participant organizations of this study, primarily by providing technology support to groups participating in those projects. The research was initially designed to be conducted in two organizations, one in Brazil and one in New Zealand, where the focus of investigation would be computer-supported process improvement groups. The criteria for selecting participating organizations included commitment to process improvement (demonstrated by the existence of at least one formal organization-wide process improvement program), initial absence of computer support for process improvement activities, and representation of two distinct economic sectors (e.g., manufacturing and service). As interviews were expected to be one of the sources of research data, the first and second criteria were aimed at increasing internal validity, as they ensure that computer-supported process improvement group participants have a noncomputer-supported experience basis (for comparison) on which to form their perceptions regarding computer support effects. The third criterion was aimed at increasing external validity, by reducing the influence of sector-specific factors on the research results.

B. Research Project Difficulties and Related Decisions

As this project was funded in part by both Brazilian and New Zealand organizations, and involved researcher trips funded by the New Zealand government, a deadline was set for the completion of the research phase in Brazil as well as in New Zealand. Several organizations in Brazil that met our selection criteria were identified and contacted. After a number of attempts, access to Westaflex was gained based on an action research plan detailing the organization's and researcher's responsibilities. One of the researcher's responsibilities was to manage the installation of a local area network and an asynchronous computer support tool for process improvement groups.

A combination of political and economic problems, however, led to an increasing involvement of the researcher in a face-to-face process improvement program under way at Westaflex prior to the beginning of the action research project. This was motivated, among other things, by pressure from Westaflex's main customers (large automakers such as Ford and Volkswagen) for it to obtain ISO 9001 certification. After several months, it became clear that the computer support "component" of the action research project at Westaflex would not be completed on time. Given this and the fact that we had already collected a considerable amount of process-related data through interviews, we decided to use data collected from a group of processes obtained from Westaflex to enrich the sample of processes analyzed here. Since this decision would probably limit the amount of data collected about computer-supported process improvement groups, of which none were conducted at Westaflex, we also decided to conduct the New Zealand phase of our research with two New Zealand organizations that met our criteria (MQM and Waikato), in a concurrent way.

The researcher's direct involvement with the organizations allowed for in-depth analyses of organizational processes in the three organizations. Twelve computer-supported process improvement groups provided the context for research data collection on the impact of computer support on knowledge sharing. At Westaflex, the researcher focused on developing quality system manuals (with some computer support) for the company, so that it could successfully undergo audits associated with ISO 9001 certification. At MQM and Waikato, the researcher set up, maintained, and provided training to process improvement groups on the use of an e-mail conferencing system.

C. Process Types: Routine and Improvement

Twenty-seven organizational processes within Westaflex, MQM, and Waikato were investigated. Among these, 15 were typical routine organizational processes (e.g., product design, parts manufacturing, computer and software support, course teaching). The remaining 12 processes were improvement processes, carried out by groups engaged in the improvement of existing routine processes at their respective organizations. While routine process data were obtained from the three organizations, improvement process data were obtained only from MQM and Waikato. All 27 processes consisted of a set of interrelated activities carried out by a group of people with the goal of turning certain inputs into value-added outputs (in the case of improvement processes, the outputs were improved process designs). These features form the very definition of "business process" [59].

Self-appointed leaders initiated and convened process improvement groups, which selected, modeled, analyzed, and redesigned routine organizational processes. Group members interacted almost exclusively through an e-mail conferencing system implemented with Groupwise (Novell Corporation) macros. Due to the availability of Groupwise licenses at both MQM and Waikato, all groups used the same system, implemented separately at each organization. The interaction in the groups was asynchronous and distributed. The system allowed several file formats to be easily attached to group postings, and read with minimal effort by other group members.

In spite of the researcher's direct involvement with the organizations in this study, in no organization did the researcher contribute to, or directly influence, the contribution of research data. That is, the researcher's intervention was restricted to technology support, and veered away from directly influencing the content of the discussions conducted by process improvement groups (this content is, as will be seen later, one of the foci of the data analysis). Written permission to use these research data for analysis was sought and obtained from the management of each organization, as well as from each individual contributor.

VI. Phase I of Data Analysis: Showing That Process Improvement is a Catalyst to Knowledge Sharing

Depending on how an organizational process is looked at, different facets may emerge. One of these is the pattern of flow of "products" between those who perform the individual activities of a process. Medina-Mora *et al.* [51] pointed out that such a flow of "products" could be split into two main components—*material* flow and *communication* flow. The *material* flow component refers to the flow of "hard" material items (e.g., parts, equipment, raw materials). The *communication* flow (also known as the *information* flow) component refers to the flow of communication-related items such as forms, memos, printed reports, electronic files, etc. All 27 processes investigated had their flow of products split into these two main categories.

The sampling procedure involved data collection about one instance of each communication exchange between two organizational functions in each process—e.g., control charts with accompanying handwritten notes, delivery forms, inventory check memos, fax orders, e-mails with new product descriptions, etc. The main goal was to find out whether the occurrence of knowledge-bearing exchanges differs for improvement and routine processes, and which type of process presented the highest level of knowledge exchanges.

A. More Knowledge Exchanges Occur in Improvement Than Routine Processes

Each communication exchange was analyzed regarding the presence of knowledge content. The basic criterion used for knowledge content identification was that if an "if–then statement" (see previous discussion of if–then statements as units of knowledge) could be *extracted* from a communication exchange using protocol analysis [56], then that communication exchange had "some" knowledge content. Table I provides examples of communication exchanges from which if–then statements can and cannot be extracted.

This phase of the analysis was concerned only with the identification of the existence of knowledge content in communication exchanges, which were then counted and compared across processes. The knowledge identification criterion, while obviously not comprehensive, was, in our opinion, a reliable one for the identification of knowledge content. The criterion was tested for reliability by three different researchers, each checking the knowledge content of a subsample of 178 communication exchanges, with a match in over 90% of the cases. The results of knowledge content analysis employing this criterion are shown in Table II, along with relevant descriptive statistics.

The first column of Table II shows a brief description of each of the processes studied. The second column of shows process types. The remaining columns show (from left to right) the organization the processes came from, the absolute number of nonknowledge (NK) and knowledge (K) exchanges (i.e., nonknowledge-bearing and knowledge-bearing exchanges), and the percentage of knowledge exchanges, calculated as $K/(K+NK)$. The last column shows the normalized variation of $K/(K+NK)$ around the $K/(K+NK)$ means for routine and improvement processes, respectively ($NormVar$). The ratio $K/(K+NK)$ is a measure of the relative amount of knowledge content exchanged within each process. Given that several knowledge content counts yielded "zero," we also generated another table in which one unit of measurement (i.e., the number "1") was added to knowledge and nonknowledge content counts, and performed a separate statistical analysis. Differences between the results of this analysis and those shown in Table II were insignificant; thus, our discussion is based on the figures shown in Table II. The normalized variation of the measure $K/(K+NK)$, referred to as $NormVar$, was calculated using the following:

$$NormVar = (K/(K+NK) - \mu_t)/SD.$$

TABLE I
EXAMPLE OF KNOWLEDGE CONTENT IDENTIFICATION

Communication exchange	"If-then" statement extracted	Knowledge content
The fact that international students do not have special support from our university, leads to them sharing their negative feelings with their cultural communities and their home countries. In New Zealand's multicultural society, this means that we might be losing customers to other universities better prepared to provide support to international students.	*If* international students do not receive special support from our university, *then* we may lose students from their home countries to competing universities in New Zealand.	Yes
The majority of our international students last year was from Thailand, with Singapore coming in second place. We haven't had many students from Latin America in the last three years.	(None possible)	No

Note: Facts alone cannot be accurately interpreted without knowledge and "if–then" statements, as well as other facts. For example, the facts in the second row of the table could be interpreted as "good" and not requiring changes in recruitment policy, *if* we assume that students from Latin America are not good students, or "bad" and requiring policy recruitment changes, *if* we assume the opposite.

TABLE II
KNOWLEDGE CONTENT IN THE PROCESSES STUDIED

Process	Type	Organization	Non-knowledge (NK)	Knowledge (K)	K/(K+NK)	NormVar
Communication of a pest/disease outbreak	Routine	MQM	6	5	45.5%	1.72
Equipment adaptation for new product	Routine	Westaflex	7	5	41.7%	1.51
Quality management consulting	Routine	MQM	7	3	30.0%	.86
Product design	Routine	Westaflex	14	3	17.6%	.17
IT users support	Routine	MQM	8	1	11.1%	-.20
Raw material purchase	Routine	Westaflex	12	1	7.7%	-.39
Parts manufacturing	Routine	Westaflex	3	0	0.0%	-.82
Order delivery	Routine	Westaflex	14	0	0.0%	-.82
University course preparation	Routine	Waikato	6	0	0.0%	-.82
University course teaching	Routine	Waikato	8	0	0.0%	-.82
Quality inspection of parts/materials	Routine	Westaflex	4	0	0.0%	-.82
Plant machinery maintenance	Routine	Westaflex	2	0	0.0%	-.82
Software support for users	Routine	MQM	2	0	0.0%	-.82
Internal newspaper editing	Routine	MQM	5	0	0.0%	-.82
Staff training and development	Routine	MQM	7	0	0.0%	-.82
Newsletter editing improvement	Improvement	MQM	9	7	43.8%	.53
Pest/disease outbreak communication improvement	Improvement	MQM	3	2	40.0%	.32
Student computer support improvement	Improvement	Waikato	23	15	39.5%	.29
International student adaptation support improvement	Improvement	Waikato	14	9	39.1%	.27
Student assignment handling improvement	Improvement	Waikato	15	9	37.5%	.18
Quality management consulting improvement	Improvement	MQM	14	8	36.4%	.11
University course improvement	Improvement	Waikato	21	11	34.4%	.00
IT users support improvement	Improvement	MQM	23	11	32.4%	-.11
Undergraduate academic support improvement	Improvement	Waikato	28	12	30.0%	-.24
Software support improvement	Improvement	MQM	7	3	30.0%	-.24
International graduate student support improvement	Improvement	Waikato	17	7	29.2%	-.29
Staff training and development improvement	Improvement	MQM	6	0	0.0%	-1.91

Mean K/(K+NK): Routine=14.6%, Improvement=34.3%; StDev K/(K+NK): Routine =16.1%, Improvement=11.3%; Overall StDev=17.9%

Results of t test (N=27, 2-tailed, homoscedastic): t=4.08, P<.001

The symbol μ_t represents the mean $K/(K+NK)$ for a process of type t, where t can be either a *routine* or *improvement*. The symbol SD represents the standard deviation for the whole sample of 27 processes. $NormVar$ shows how much the measure $K/(K+NK)$ varies around the mean $K/(K+NK)$ for either improvement or routine processes, in standard deviations (hence, it is referred to as a "normalized" variation). A $NormVar$ equal to or greater than 1 suggests an exception to an aggregate pattern evidenced by a low P in a t test of independence of samples.

The bottom of the table suggests a large difference, also illustrated in Fig. 2, between mean $K/(K+NK)$ measurements for routine (14.6%) and improvement (34.3%) processes of approximately 1.1 standard deviations, calculated as (34.3%–14.6%)/17.9%. That is, the knowledge content in the improvement processes studied was, on average, con-

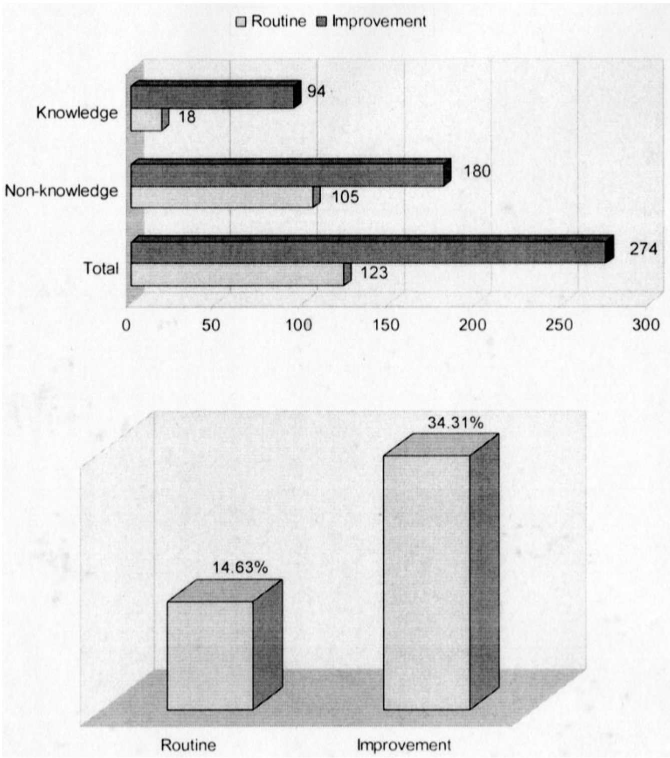

Fig. 2. Exchanges in routine and improvement processes (Top: Absolute numbers of exchanges. Bottom: Percentages of knowledge-bearing exchanges.)

siderably higher than that found in routine processes. The results of a two-tailed t test suggest that the difference between improvement and routine processes is statistically significant ($P < 0.001$) when compared with the differences observed within each process set.

$NormVar$ figures suggest the existence of three exceptions to the pattern in the sample studied. Although a purely statistical analysis might ignore these exceptions, given the low overall P obtained in the t test, the process-specific data collected in the action research interventions allow for a further investigation of these exceptions (this is done next, in the "Discussion of Phase I of data analysis" section). The exceptions are the routine processes *communication of a pest/disease outbreak* ($NormVar = 1.72$) and *equipment adaptation for new product* ($NormVar = 1.51$), as well as the improvement process *staff training and development improvement* ($NormVar = -1.91$). The two routine processes presented a larger knowledge content flow than other routine processes, while the improvement process had an unusually low knowledge-content flow in comparison with other improvement processes.

B. Discussion of Phase I of Data Analysis

The knowledge content analysis indicates a marked increase in knowledge-bearing exchanges in improvement processes compared with routine processes. Such an increase was consistent across different processes, which is evidenced by the results of the t test. There were, however, three outlying processes, of which two were routine processes and one was an improvement process.

The first outlying routine process, *communication of a pest/disease outbreak*, involved reporting agricultural pest/disease outbreaks to the New Zealand public and providing explanations as to why the outbreaks happened. As MQM has several large offices spread throughout the country, the communication consultants involved in the process had to discuss the explanations among themselves, before the explanations were presented to the public. Explanations are likely to have a high knowledge content as sentences of the type *(consequences) because (conditions)* are logically equivalent to sentences of the type *if (conditions) then (consequences)*. Therefore, it is easy to see why this process has a high associated $NormVar$.

The second outlying routine process, *equipment adaptation for new product*, involved making changes in a car part (usually a corrugated aluminum exhaust pipe, Westaflex's best-selling product) and discussing these changes with operations and marketing personnel. In some cases, such discussions involved the CEO and members of the board of directors. These discussions involved attempts to predict market response and possible production problems, as well as explaining why such predictions were likely. Thus, for reasons similar to those discussed above, a high $NormVar$ is to be expected.

The outlying improvement process, *staff training and development improvement*, involved improving the process whereby personnel responsible for plant and food inspection and related consulting services were trained at MQM. The key point to understand the large negative $NormVar$ for this process is that the process improvement discussion had not gone beyond its initial stage, where information about perceived process-related problems and a possible target routine process to be improved were shared among process improvement group members. After the initial stage, the group was discontinued as the group leader perceived a lack of agreement among members. Its leader and some of its members saw this group as a failure from a process improvement perspective.

The previous discussion, and the fact that outlying processes made up only 11% of the total sample of processes analyzed, suggest that the discrepancies found are atypical of the routine and (particularly) improvement processes in the sample. This, in turn, adds to the external validity of the findings regarding knowledge content patterns. However, such findings refer to patterns of syntactic, not semantic, elements. They relate to knowledge *exchanges*, and tell little about knowledge *communication*. This issue can only be fully addressed through further investigation regarding semantic patterns, such as knowledge sharing-related *perceptions* by those involved in the communication exchanges. This is described next.

VII. Phase II of Data Analysis: Showing That the Use of a Lean Medium to Support Process Improvement Has a Positive Impact on Knowledge Sharing

According to the media richness theory and its communication media classification scheme, e-mail conferencing is considerably leaner as a medium for equivocal communication than face-to-face interaction [12], [30], [48]. It follows then, according to the theory, that it is less appropriate than face-to-face interaction for supporting knowledge sharing. If this is true, then a comparison between process improvement efforts conducted primarily face-to-face and through e-mail conferencing should yield different outcomes, with more positive outcomes occurring in the face-to-face scenario.

How can this comparison be conducted with the data collected in this study, particularly since there were no experimental control groups (i.e., face-to-face process improvement groups)? As discussed previously, key criteria for selecting organizations to participate in the study included commitment to process improvement, demonstrated by the existence of at least one formal organization-wide process improvement program, and initial absence of computer support for process improvement activities. Since both MQM and Waikato fit these criteria, the possibility of comparing process improvement efforts before and after the introduction of e-mail conferencing became possible. In fact, it presented itself as a unique opportunity to compare relevant field situations where the key difference was the presence of technology, without forcing us to resort to controlled field experiments.

However, this unique opportunity also entailed three key difficulties. One was that the face-to-face and computer-supported process improvement groups (conducted prior to and during this study, respectively) targeted different processes, possibly with different levels of complexity. Secondly, given the different foci of face-to-face and computer-supported efforts, it would be difficult to identify domain experts to evaluate specific aspects and outcomes of different process improvement efforts. The third difficulty was associated with confidentiality agreements and constraints on how much information could be disclosed about the deliberations made by process improvement groups to individuals who had not been members of those groups (e.g., expert evaluators).

These difficulties were addressed by focusing data collection on the process improvement group members themselves, who were interviewed regarding differences between face-to-face and process improvement groups in which they had participated. To avoid perception bias, interviewees were probed deeply for rationale, personal motivations, and other factors that could bias perceptions. Sixty-two semi-structured, in-depth interviews were conducted based on open-ended questions [71]. Each lasted 45–150 min, and was taped for later transcription.

The questions used in the structured interviews (listed in part in Appendix A) were developed based on the group support systems and computer-mediated communication literature, partially reviewed earlier in this paper. Interview questions were worded in a neutral way so as not to induce any specific answer. They were accompanied by the follow up question "Why?" and other related questions to clarify the interviewees' motivations for their answers, allow for the screening and elimination of ambiguous answers, and generate perception-related qualitative data that could be used for content analysis. The findings summarized next are based on the analysis of these interviews. The frequency distributions observed in interviews were consistent for both Waikato and MQM (Cronbach Alpha = .72).

A. Computer Support Increases Perceived Knowledge Sharing

As can be seen in Table III, 51.6% of participants felt that knowledge sharing had been increased by computer support. Group members independently provided two key justifications

TABLE III
FREQUENCY DISTRIBUTION OF ANSWERS REGARDING PERCEIVED KNOWLEDGE SHARING

Answer	Frequency	Percentage
Increased	32	51.6%
Decreased	13	21.0%
Had no effect	15	24.2%
I don't know	2	3.2%
Chi-Square	10.61	
P	< .01	

Chi-square parameters: N=62, df=2
("I don't know" answers were disregarded)

to explain why computer support had increased knowledge sharing. First, there was a higher level of departmental heterogeneity than in similar face-to-face process improvement initiatives, enabled by the computer system. That is, having more people from different departments broadened the knowledge base that had to be shared by the participants before they could effectively contribute process improvement suggestions, which led to increased knowledge sharing. The second reason related to the better quality of individual contributions created through the computer system in comparison with similar contributions in face-to-face situations.

As mentioned before, interviews were semi-structured and in-depth. Therefore, the previous reasons were not selected by respondents from a set of predefined alternatives, but emerged from the content analysis of interview transcripts through axial and selective coding [31], [73]. The follwing quotes from interviews are illustrative of the explanations provided by group members. Job title, organization, and explanation type are provided below the quotes.

> *… [computer support] improved my learning…I could e-mail someone in the South Island … You learn that way and you learn a lot … You learn a lot from other people, but not in a [face-to-face] group.*
>
> [Computer Consultant, MQM, departmental heterogeneity]
>
> *When I write, my thinking process from formulating the ideas in my head to getting them down becomes more elaborate. I have to take much more time over that than I would if I was speaking. I think that, because one is forced to do that by writing the answer down, then the written answer you get is much more focused. So I think that is an advantage. It requires more time from the participants, because they have to focus their writing, but, as a result, you get [better individual contributions].*
>
> [Adjunct Professor, Waikato, individual contribution quality]

Further evidence of positive impacts on knowledge communication can be gauged through an analysis of perceptions regarding group outcome quality. Since most processes analyzed cut across different departments, it is plausible to assume that, if knowledge communication had been negatively affected by the use of a lean communication medium, so too would the quality of process redesign proposals (group outcomes). This analysis is performed next.

TABLE IV
FREQUENCY DISTRIBUTION OF ANSWERS REGARDING PERCEIVED QUALITY

Answer	Frequency	Percentage
Increased	27	43.5%
Decreased	13	21.0%
Had no effect	16	25.8%
I don't know	6	9.7%
Chi-Square	5.84	
P	.05	

Chi-square parameters: N=62, df=2
("I don't know" answers were disregarded)

B. Computer Support Increases Perceived Group Outcome Quality

Table IV shows that perceived group outcome quality, or the quality of the process redesigns generated by process improvement groups, was perceived by 43.5% of the participants as having been increased by the provision of computer support.

The two main reasons independently provided by group members to explain why computer support had increased group outcome quality were the same as those provided for increased knowledge sharing in the previous section, but their order was reversed. That is, the most popular reason was the improved quality of individual contributions while the higher level of departmental heterogeneity than in similar face-to-face process improvement initiatives was judged next most important, both seen as enabled by the computer system. The quote provided below is illustrative of the explanations provided by group members regarding individual contribution quality.

> *You think more when you're writing something, so you produce a better quality contribution. Take for example what [member's name -removed] wrote, she wrote a lot and it seemed that she thought a lot about it before she e-mailed it to the group. She wasn't just babbling off the top of her head, she tended to think out what she was writing. I know I did it a lot, specially my first message. I really thought a lot to put it together.*
>
> [Division Manager, Waikato, individual contribution quality]

Table V addresses departmental heterogeneity in improvement processes (measured by the number of departments represented in improvement processes) in particular, and shows that 83.9% of the respondents perceived an increase in departmental heterogeneity due to computer support. The decision to address departmental heterogeneity, which also emerged through axial coding of interview responses, through a specific question in interviews was based on one key assumption, viz.: a possibly larger departmental representation in improvement processes will lead to a broader scope of knowledge communication, as people working in the same department may already share organization-related knowledge.

Group members provided essentially only one underlying reason to explain the perceived increase in departmental heterogeneity. This was the lower level of disruption afforded by the asynchronous and distributed mode of communication supported by the computer system—i.e., the fact that it allowed group members to interact in a time-disconnected manner, with less disruption to their routine activities.

TABLE V
FREQUENCY DISTRIBUTION OF ANSWERS REGARDING DEPARTMENTAL HETEROGENEITY

Answer	Frequency	Percentage
Increased	52	83.9%
Decreased	1	1.6%
Had no effect	4	6.5%
I don't know	5	8.1%
Chi-Square	> 100	
P	< .001	

Chi-square parameters: N=62, df=2
("I don't know" answers were disregarded)

C. Discussion of Phase II of Data Analysis

The interview data analyzed in this section suggests a few perception trends. Process improvement group members generally perceived computer support as having increased knowledge sharing in process improvement discussions and the quality of the process redesigns that emerged from these discussions. They explained these increases, which both point to a possible increase in knowledge sharing, by higher departmental heterogeneity and individual contribution quality caused by computer support.

It can be inferred from the reasons given by process improvement group members to explain their perceptions about computer support that the asynchronous nature of the technology used, allowing for time-disconnected communication, was the key factor in the perceived increase in departmental heterogeneity. Such an increase, in turn, combined with better quality individual contributions, led to increased knowledge sharing.

VIII. CONCLUSION

This paper began with the research question: *Can lean media support knowledge sharing?* The data analysis, split into Phases I and II, indicates a positive answer to the question. Knowledge content analysis of exchanges in routine and improvement processes, conducted in Phase I, suggests that individuals participating in process improvement efforts tend to engage in over twice as many knowledge-bearing exchanges as individuals conducting activities in routine processes. Phase II of the data analysis suggests that computer support has a positive effect on knowledge sharing in the context of process improvement groups. These findings indicate that knowledge sharing can occur over lean media if an appropriate group process is used, process improvement being one example of an appropriate group process.

The results of this study contradict those in most of the published empirical research on the impact of computer support on knowledge sharing, including the seminal studies conducted by Ackerman [1], Neilson [53], and Orlikowski [57]. Arguably, the computer system used in this study, a simple adaptation of e-mail, was less sophisticated than the ones investigated in those studies. Orlikowski and Neilson studied implementations of Lotus Notes, while Ackerman studied an application called Answer Garden that was built specifically to support organizational knowledge sharing. This also casts doubt on arguments such as those made by Riggs *et al.* [67] that current computer systems usually fail to support the sharing of organizational knowledge because they lack sufficient technological sophistication.

The "lack of technological sophistication" argument is analogous to the "lack of richness" argument proposed by media richness theory to explain why most users, managers, and professionals in particular, favor rich over lean media for knowledge communication [12], [13], [49]. Not only does this study contradict media richness theory in that respect, but it also does so in ways that are different from previous studies. Most of the previous studies showing the flaws of media richness theory have focused on media selection and use [28], [48], [50], [65]. This study focused on task outcomes and, to some extent, on communication content.

Another influential theoretical framework, the social influence model [30], [50], is much better aligned with the findings of this study. The social influence model was used by Markus [50] to show that social influences can shape individual behavior toward communication media in ways that are inconsistent with media richness theory predictions. The empirical evidence in this study adds to and qualifies that claim in the particular context of knowledge sharing. The process improvement groups in this study were formed by their members with the objective of exchanging process-related knowledge among different departments. Arguably, this led to secondary social influences (e.g., perceived group mandate, expected individual behavior) that were conducive to knowledge communication, even over lean media.

The perceived increase in the quality of individual member contributions linked to computer support reported by process improvement group members, on the other hand, cannot easily be explained based on the social influence model. This is contradictory to the belief that leaner media are associated with higher conversational ambiguity [12]. Also, this perception trend cannot be explained based on the hypothesis that previous knowledge shared by the group members can allow them to engage in rich communication through lean media [40], [48], since several of the process improvement groups studied involved people from different departments with no previous history of interactions. This perception trend is nevertheless consistent with the hypothesis that people interacting through a leaner medium will adapt their behavior in order to overcome communication constraints posed by the leanness of the medium [43]. This leads to the paradoxical conclusion that the leanness of the communication medium "contributed" to knowledge sharing, though this should be carefully investigated in future research as it can be only presented as a tentative conclusion based on this research.

An implication of this study for organizations is that the use of simple asynchronous collaborative technologies to support process improvement initiatives is likely to stimulate knowledge sharing among those engaged in interfunctional organizational processes. Knowledge sharing is likely to happen automatically, with no extra resource commitment required from the organization other than that already committed to support process improvement activities. As indicated by this and previous studies, the use of collaborative technologies will also have positive effects on process improvement efficiency and effectiveness. While this study has focused on lean media, there is no reason why richer media should not also be conducive to the sharing of knowledge. The critical issue is not media richness, but the extent to which group members are involved in a process that is appropriately configured so as to encourage and support knowledge transfer. Thus, we recommend that organizations looking for ways to stimulate knowledge sharing consider establishing well-coordinated process improvement programs. Simple asynchronous collaborative technologies, such as e-mail, are likely to be just as effective in supporting these process improvement programs as more complex technologies, but substantially cheaper and easier to maintain.

Unlike the predominantly manufacturing-based economy of the pre-1990 years, where processes were arguably less "dynamic" than they are today, the environment in which organizations find themselves now requires focused strategies to deal with change and ensure that distributed knowledge is shared, at least to the extent necessary for optimal or quasi-optimal process execution. While e-mail and "variants" (e.g., e-mail conferencing, e-mail-based collaborative writing) can enable these strategies and are likely to be easy and cheap to implement, more complex collaboration technologies can also be successfully devised to enable such strategies. Our study has implications for the development of more complex collaboration technologies that facilitate change management and knowledge sharing. It can be argued, based on the results presented here, that such collaboration technologies could be successfully designed around a "process improvement paradigm" (i.e., they could be designed specifically to facilitate process improvement) and used regularly for the combined purposes of process improvement and knowledge sharing. Although a clear blueprint to accomplish that goal is beyond the scope of this paper, we believe that a first step in the development of those collaboration technologies could be taken by incorporating established process improvement approaches, such as those proposed by Harrington *et al.* [35] and Kock [42], into them. This, in turn, could be undertaken through the development of collaboration "engines" built on workflow automation environments such as Domino and Lotus Notes, which seems to be a fertile area for future research.

Appendix A
Structured Interview Questions

Notes:

1) Respondents reported having participated in face-to-face process improvement groups prior to answering the questions below.
2) Waikato and MQM had recently conducted face-to-face organization-wide process improvement efforts by the time this study was began.
3) The questions below are only part of a larger list of questions used in semistructured interviews. Minor rewording took place during interviews when respondents expressed difficulty understanding the meaning of the questions.

A. Knowledge Sharing

Sometimes individuals share knowledge as a result of the discussion that takes place in process improvement groups. Shared knowledge may relate their organization's formal and informal structure, organizational culture, and day-to-day activities. Did computer support increase or reduce knowledge sharing in your group? Why?

B. Quality

Did computer support increase or reduce the quality of the process improvement proposals generated by your group? Why?

C. Departmental Heterogeneity

Sometimes it is difficult to gather people from different departments to work together in a process improvement group. Did computer support make it easier or harder to have members of different departments cooperating in your group? Why?

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Ned Kock received the Ph.D. degree in information systems from the University of Waikato, Waikato, New Zealand.

He is currently the Class of 1961 Associate Professor and Director of the E-Collaboration Research Center, College of Business and Economics, Lehigh University, Bethlehem, PA. He is the author/co-author of four books, including *Process Improvement and Organizational Learning: The Role of Collaboration Technologies* (Hershey, PA: Idea Group, 1999). His research interests include electronic communication tools and their effects on groups performing complex, knowledge-intensive tasks. He is currently developing a theoretical framework that tries to explain behavior toward electronic communication technologies based on a Darwinian evolutionary perspective.

Robert Davison received the B.A. and M.A. degrees from the University of Nottingham, Nottingham, U.K., and the Ph.D. degree from the City University of Hong Kong.

He is currently an Assistant Professor of Information Systems at the City University of Hong Kong. His research interests span the academic and business communities, examining the impact of various groupware technologies, including GSS and web-based tools to support virtual teams, on group decision making and communication problems, particularly in cross-cultural settings. Much of this research is informed by an interpretivist epistemology and an Action Research perspective. He has recently guest edited a special issue of *Communications of the ACM* on the Global Applications of Collaborative Technology. He serves as Editor in Chief of the *Electronic Journal of Information Systems in Developing Countries*, and as Associate Editor of the *Information Systems Journal*. He manages various webpages for the ISWORLD community, including IT in Developing Countries and Professional Ethics. His work has appeared in the *Communications of the ACM*, *Information Systems Journal*, *Decision Support Systems*, *Information and Management*, *Group Decision and Negotiation* and *Information Technology & People*.

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