Facilitating Knowledge Sharing Through a Boundary Spanner

Research Article

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***Abstract*—Research problem:** *The purpose of the study was to explore how a boundary spanner can successfully facilitate knowledge sharing across functional and geographical boundaries. The main research questions are: (1) Does matching the complexity of knowledge boundary with the knowledge-sharing process lead to successful knowledge sharing? and (2) What are the key factors that influence a boundary spanner when deciding how to facilitate the knowledge sharing across functional and location boundaries?* **Literature review:** *The purpose of the literature review was to better understand the existing knowledge-sharing frameworks. Finding no framework that can directly address the research problem, the researchers decided to build on the closest one which is a framework for knowledge sharing across functional boundaries. By not taking into consideration knowledge sharing across location boundaries, the framework assumes collocated and synchronous knowledge-sharing interaction. To understand the potential supporting media for knowledge-sharing interaction across functional and geographical boundaries, the researchers consulted the Media Naturalness Theory. Media naturalness is the ability of the media to support a sense of collocated and synchronous interaction.* **Methodology:** *The researchers conducted a qualitative exploratory case study in the IT department of a Fortune 500 multinational finance company. Researchers selected a boundary spanner and observed her facilitation of knowledge-sharing interactions for four months. A total of 78 knowledge-sharing interaction logs were collected during the period of observation from five data sources: wiki, email, instant messaging, teleconference, and face-to-face interactions. Data analysis was carried out through template coding.* **Results and discussion:** *The researchers found that matching the knowledge boundary with the knowledge-sharing process is an essential yet insufficient condition for successful knowledge sharing. A boundary spanner should also pay attention to the boundary objects and media used to support the knowledge-sharing interaction. Spatial dispersion and knowledge commonality between the source/recipient and boundary spanner affected the media selection which, in turn, influenced the selection of the boundary objects. The implication of the study is that there are three important factors that the boundary spanner should consider when deciding how to facilitate knowledge sharing (i.e., knowledge boundary, spatial dispersion, and knowledge commonality). The main limitations of the study were the relatively short observation period of the knowledge-sharing interactions via a boundary spanner. Future research should quantitatively validate the proposed optimal knowledge-sharing designs to test the generalizability of the findings with a survey and profile deviation analysis.*

***Index Terms*—*Boundary objects, boundary spanner, knowledge sharing, media.*

INTRODUCTION

In today's knowledge-intensive economy, knowledge is an important resource that needs to be continuously managed within an organization [1]. One of the most critical knowledge activities is knowledge sharing, which is an essential medium for employees to exchange and exploit knowledge and contribute to their organization's innovation process [2]. The ability to facilitate knowledge sharing has become increasingly critical, particularly for multinational companies (MNCs). Knowledge sharing is deemed successful when the outcome and process are satisfactory (i.e., the target knowledge is shared and the individuals involved are satisfied with the knowledge-sharing process [3]).

It becomes more challenging to attain successful knowledge sharing when the sharing occurs across not only functional but also geographical boundaries. Previous researchers have highlighted numerous factors that could be attributed to unsuccessful knowledge sharing among geographically dispersed employees, such as the lack of mutual knowledge and common backgrounds [4], unevenly distributed information, different understanding or interpretations of provided information, lack of trust [5], and difficulty in recognizing the relevance between local and remote knowledge [6]. The International Data Corp. (IDC) has estimated that at least US$31.5 billion is lost each year by Fortune 500 companies due to unsuccessful knowledge sharing [7].

To improve the success rate of knowledge sharing across boundaries in MNCs, boundary spanning is increasingly being adopted as a promising

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approach [8]. Boundary spanners link people across boundaries (location, hierarchy, and/or function), and serve in building relationships as well as creating shared understanding and trust across boundaries [9]. As boundary spanners, professional and technical communicators, such as those in the R&D departments [10], need to facilitate the transfer of knowledge from the source to the recipient in the verbal and/or written forms. Most important, their communication techniques have to enable the knowledge recipients to understand and use the transferred knowledge [11], [12].

Early boundary spanning studies focused on knowledge sharing with external agents as boundary spanners [13]. In the 1990s, researchers were focusing on knowledge sharing via boundary spanners within the organization [14], [15]. In recent years, there have been a growing number of studies on knowledge sharing via individual boundary spanners [16], [17]. These studies mainly focus on the boundary spanner's roles [18], positions [17], characteristics [19], and the situations in which a spanner is to be used [20]. Reviewing research on knowledge sharing between 1999 and early 2008, from several disciplines, such as management, organizational behavior, human resource development, applied psychology, and information systems, Wang and Noe [21] raised the following question: *How does a boundary spanner facilitate knowledge sharing?*

Several frameworks for successful knowledge sharing have been proposed in the literature, such as a framework for knowledge sharing within a company based on the company's domain of knowledge [22], an integrative framework for knowledge sharing within a company based on the support structure, knowledge recipients' characteristics, and type of knowledge [23], as well as a framework for knowledge sharing across functional boundaries based on the complexity of the knowledge boundaries [24], [25]. Neither of these frameworks, however, can directly address the issue of how a boundary spanner should facilitate knowledge sharing across geographical and functional boundaries. Attempting to address this important issue, we decide to build on Carlile's [24], [25] proposed framework for knowledge sharing across functional boundaries as the conceptual foundation of our study. Carlile [24], [25] proposed three progressively complex knowledge-sharing processes (i.e., *transfer*, *translation*, and *transformation*). Transfer is the process of creating a common lexicon, translation is the process of creating common meanings, and transformation is the process of creating common interests. It is proposed that for a successful knowledge-sharing interaction, the progressively complex knowledge boundaries should be matched with the corresponding progressively complex knowledge-sharing processes. In particular, the *syntactic* boundary should be matched with the transfer process, the *semantic* boundary needs the translation process and, finally, the *pragmatic* boundary requires the transformation process. While his study is comprehensive, Carlile [25] cautions that: "The case itself, although illustrative, does not in any way test the framework being developed." [25, p. 566].

Our study aims to explore the proposed framework in a real organizational environment where an employee acts as a boundary spanner for knowledge sharing between other employees holding different positions/functions and dispersed in different locations, within the same organization. The specific research questions that we attempt to answer are: Does matching the complexity of knowledge boundary with the knowledge-sharing process lead to successful knowledge sharing? What are the key factors that influence a boundary spanner when deciding how to facilitate the knowledge sharing across functional and location boundaries?

This paper begins by discussing the important literature and concepts chosen as the basis of the study, such as the concept of knowledge boundary and boundary objects, which follows the explanation of the research methodology. The next section of this paper presents the key findings of the study and the closing section presents conclusions, limitations, and suggestions for future research.

LITERATURE REVIEW

In this section, we will elaborate on the framework of knowledge sharing across functional boundaries [24], [25], which consist of progressively complex knowledge boundaries and knowledge-sharing processes. The objects used to share the knowledge (e.g., database and sketches [26]) will also be discussed. All of these serve as the background for understanding how knowledge sharing across functional and location boundaries through a boundary spanner can be successful. In addition, we will expound the Media Naturalness Theory to aid the perception of how knowledge sharing across functional and location boundaries through a boundary spanner can be optimally mediated [27].

Selection of Literature Before proceeding to the explanations of the underlying frameworks and concepts of the study, we deem it important to explain how we selected them. We began the search for relevant frameworks with a list of journals used by the *Financial Times* in compiling the Business School research rank [28]. The search keywords are knowledge sharing and boundary. The aim is to search for frameworks that we can build on to investigate knowledge sharing across functional and location boundaries through a boundary spanner. Often, we went through the articles' references for further reading.

Through careful reading, we found three notable frameworks that have been proposed by prior studies for successful knowledge sharing. The first one is a framework for knowledge sharing within a company based on the company's domain of knowledge [22]. The second one is an integrative framework for knowledge sharing within a company based on the support structure, knowledge recipients' characteristics, and type of knowledge [23]. The third one is a framework for knowledge sharing across functional boundaries based on the complexity of the knowledge boundaries [24], [25].

Although neither of these frameworks can directly address the issue of how a boundary spanner should facilitate knowledge sharing across geographical and functional boundaries, we decided to build on the closest one which is Carlile's [24], [25] proposed framework for knowledge sharing across functional boundaries. By not taking into consideration knowledge sharing across location boundary, the framework assumes collocated and synchronous knowledge-sharing interactions. When a boundary spanner facilitates knowledge sharing across a location boundary in addition to the functional boundary, it becomes an important task to decide which media should be used to support the knowledge-sharing interaction. To understand the characteristics of the potential supporting media for knowledge-sharing interaction across functional and location boundaries, we refer to the Media Naturalness Theory [27]. Media naturalness refers to the ability of the media to support a sense of collocated and synchronous interactions by employing facial expressions, body language, and speech [27], [29]. The Media Naturalness Theory has been utilized to understand human behavior toward technology in various contexts, including the knowledge-sharing context [31]. We will explain each of the underlying frameworks and concepts in the following subsections.

TABLE I
MATCHING KNOWLEDGE BOUNDARIES AND KNOWLEDGE-SHARING PROCESSES

Knowledge Boundary (progressively complex from left to right)		
Syntactic	**Semantic**	**Pragmatic**
Differences and dependencies across boundaries are known	Some differences and dependencies are indistinct - different interpretations exist	Different interests between individuals impede the ability to share knowledge
Knowledge-Sharing Process (progressively complex from left to right; the process at a more complex boundary still requires the capacities of those that are less complex)		
Transferring	**Translating**	**Transforming**
Creating a **common lexicon**	Creating **common meanings**	Creating **common interests**

Knowledge Sharing across Functional Boundaries Carlile [24] proposed three progressively complex knowledge boundaries: syntactic, semantic, and pragmatic. A syntactic boundary indicates known differences and dependencies, while a semantic boundary marks indistinct differences and dependencies that can cause varied results in interpretation, and the pragmatic boundary reveals different interests that can impede the ability to share knowledge. For successful knowledge sharing, these three progressively complex knowledge boundaries need to be matched with three progressively complex knowledge-sharing processes (i.e., transferring, translating, and transforming). Transferring is a process of creating a common lexicon to sufficiently share and assess knowledge at a boundary. Translation is the process of creating common meanings to address interpretive differences and provide an adequate means of sharing and assessing knowledge at a boundary. Finally, transformation is the process of creating common interests to transform knowledge and interests and provide an adequate means of sharing and assessing knowledge at a boundary. Table I shows the ideal match between the progressively complex knowledge boundaries and the knowledge-sharing processes for attaining successful knowledge sharing. Knowledge sharing is successful when there is *outcome satisfaction* (the target knowledge is shared) and *process satisfaction* (the individuals involved are satisfied with the knowledge-sharing interaction) [3].

During the knowledge-sharing process, a boundary object is used as a support tool to demonstrate the relevant knowledge [26]. Although there is a match between a knowledge boundary and the knowledge-sharing process, knowledge sharing can be unsuccessful when the boundary object is used inappropriately.

Boundary Objects Boundary objects are objects that establish a shared context that "sit in the

TABLE II
SUMMARY OF CARLILE'S PROPOSED KNOWLEDGE-SHARING DESIGNS

Knowledge Boundary	Optimal Knowledge-Sharing Process	Optimal Boundary Object(s)
Syntactic	Transfer	Repository or Standard Form/Method or Model/Map
Semantic	Translate	Standard Form/Method or Model/Map
Pragmatic	Transform	Model/Map

middle" of knowledge-sharing processes [26]. There are four types of boundary objects: repositories, standardized forms or methods, objects or models, and maps of boundaries. The significance of each object is reflected in the name. Repositories provide shared definitions and values (e.g., wiki page, databases, etc.). Standardized forms or methods provide a shared format across functions that help to define and categorize differences (e.g., problem-solving methods). Objects or models can be observed and then used to demonstrate current or possible differences and dependencies (e.g., sketches, software, etc.). Maps of boundaries can also be observed; they represent the dependencies and boundaries that exist at a more systemic level (e.g., process maps). Due to their similarity, the last two categories are normally classified together [24]. Accordingly, in our study, we will analyze the boundary objects as: repositories, standardized forms or methods, and models or maps of boundaries.

In our study, we attempt to find out how to match appropriate boundary objects to knowledge-sharing processes. Carlile [24] suggested that all boundary objects can be used to support knowledge transfer, stressing that either standardized forms or models can be used to support knowledge translation, and, furthermore, that models should be utilized to support knowledge transformation. Table II summarizes Carlile's [24], [25] proposed knowledge-sharing designs across functional boundaries.

It is important to note here that this matching is proposed for knowledge sharing across functional boundaries. When the spatial, temporal, or other characteristics of the boundaries become important, the matching rules may no longer apply. For example, in the case of knowledge sharing across a geographical boundary, it may be difficult to utilize models. The ability to utilize models depends on the media used to support knowledge sharing across geographical boundaries (e.g., it may not be possible to use any boundary object when the knowledge-sharing process is solely mediated by teleconferencing). To understand the characteristics of the supporting media, we refer to the Media Naturalness Theory.

Media Naturalness Theory The Media Naturalness Theory extends the concept of media richness and refers to the ability of the media to support a sense of collocated and synchronous interaction by employing facial expressions, body language, and speech [27], [29]. The Media Naturalness Theory has been utilized to understand human behavior toward technology in various contexts, such as education [30], knowledge sharing [31], and communication in virtual environments [32]. Knowledge sharing across functions and locations via a boundary spanner can be supported by various media ranging from face-to-face communication (when people from different locations gather together in one location), synchronous communication technology (e.g., videoconferencing, teleconferencing, instant messaging), asynchronous communication technology (e.g., email), and repositories (e.g., wiki). Naturalness progressively decreases in the order that they are presented in the previous sentence. The lower the naturalness of the medium, the higher the mental effort involved in the knowledge-sharing process, and the greater the possibility of misinterpreting the communication during the knowledge-sharing process. From another point of view, the lower the naturalness of the medium, the greater is the possibility of storing the knowledge shared permanently, and the easier it would be to retrieve the knowledge shared. As the most complex of the knowledge-sharing processes, transformation may need to be mediated by the more natural synchronous communication technology instead of the less natural asynchronous technology to reduce the mental effort and possibility of misinterpreting shared communication. On the other hand, the least complex knowledge-sharing process (i.e., knowledge transfer) could be sufficiently mediated by the least natural medium (i.e., the repository).

METHODOLOGY

This study aims to answer the following questions: Does matching the complexity of knowledge boundary with the knowledge-sharing process lead to successful knowledge sharing? What are the key factors that influence a boundary spanner in deciding how to facilitate the knowledge sharing across functional and location boundaries?

In this section, we will explain the methodology used to answer these questions in an effort to help other researchers and practitioners gain a

TABLE III
ORIGINAL TEMPLATES

Category	Subcategory	Definition
Types of knowledge boundary	**Syntactic**	Differences and dependencies across a boundary are known
	Semantic	Some differences and dependencies are indistinct – different interpretations exist
	Pragmatic	Different interests between individuals impede the ability to share knowledge
Knowledge-sharing processes	**Transferring**	Creating a common lexicon
	Translating	Creating common meanings
	Transforming	Creating common interests
Boundary object	**Repositories**	Supplying a common reference point for data, measures, or labels across functions that provide shared definitions and values
	Standard forms or methods	Providing a shared format as a method of common communication
	Models or maps of boundaries	Demonstrating current and possible differences and dependencies in a boundary
Media	Information and communication technologies used to mediate the knowledge-sharing processes	
Satisfaction with the process	**Successful**	Knowledge recipient(s) is(are) fully satisfied with the knowledge-sharing process
	Partial	Knowledge recipient(s) is(are) not fully satisfied with the knowledge-sharing process
	Failed	Knowledge recipient(s) is(are) not fully satisfied with the knowledge-sharing process
Satisfaction with the outcome	**Successful**	The target knowledge is fully shared
	Partial	The target knowledge is partially shared
	Failed	The target knowledge is not shared

better understanding of how the study results were arrived at and in which conditions/environments the results found in this study can be used. This section starts with our choice of research methodology, followed by a description of the research design and data collection, and concludes with an explanation of the data analysis.

Choice of Research Methodology Research methodology is the basis of knowledge production in any given field [28]. Different research topics require different research methodologies. The quantitative research methodology focuses on testing a statistical model and is normally utilized when there is already a parsimonious research model of the phenomenon of interest. On the other hand, the qualitative research methodology focuses on the contextual details and is normally utilized when there is limited prior knowledge of the phenomenon of interest. Another research methodology (i.e., the critical research methodology) typically positions the phenomenon of interest in a wider context to disrupt the ongoing social norms. Since our interest lies in the contextual details of knowledge sharing across functional and location boundaries and there is scanty previous knowledge on this issue, we adopted the qualitative research methodology. Holistic investigation, one of the main characteristics of case study research, is best suited for the need to understand complex and ubiquitous interactions among organizations, technologies, and people, for knowledge sharing [33]. With the framework of knowledge sharing across functional boundaries [24], [25], and the Media Naturalness Theory [27] serving as the background for understanding how knowledge sharing across functional and location boundaries through a boundary spanner can be successful, we conducted an exploratory case study research. The suggested guidelines of the research design, data collection, and data analysis from Dube and Pare [33] were followed to ensure rigor in our research.

Research Design and Data Collection This study was conducted in the IT department of a Fortune 500 multinational finance company, where

we followed an individual boundary spanner over a four-month period, with the approval of the company's IT department. The selected boundary spanner, with a background in IT and finance, was thus capable of professional and technical communication skills. She had worked across different functions and countries for several projects. All knowledge sharing relevant to the projects occurred through the boundary spanner.

Each knowledge-sharing interaction via the boundary spanner served as a unit of analysis for this study. Since all employees, including the boundary spanner, were provided with email, teleconferencing, videoconferencing, instant messaging, and wiki technologies for interaction, we collected the logs of knowledge-sharing interactions via the particular boundary spanner from all of these communication media. The multiple data sources added richness and allowed for triangulation of evidence. All email and instant messaging logs, as well as wiki pages were collected and stored. We did not physically follow the boundary spanner during most of the knowledge-sharing interactions. In fact, 80% of teleconferencing and face-to-face interactions were recorded with a voice recorder and transcribed. Detailed notes were taken for 20% of the unrecorded teleconference and face-to-face interactions.

Data Analysis Data analysis was carried out through template coding [34] on all of the communication logs, transcriptions, notes, and documentation. To structure the analysis, template coding requires developing a priori categories and subcategories [34]. Based on our literature review, the original template with the predefined categories and subcategories for the study is shown in Table III. The sample logs of evidence for each category and subcategory are shown in Appendix A, shown at http://ieeexplore.ieee.org.

At the end of the template coding, we discovered that in most cases, when there was no satisfaction with the knowledge-sharing process, the knowledge-sharing outcome would be unsatisfactory as well. Based on this, we deleted the *Satisfaction with the process* category and renamed the *Satisfaction with the outcome* category as *knowledge-sharing results (i.e., fully successful, partially successful, and failed)*. To ensure the trustworthiness and credibility of the data, we consulted the selected boundary spanner after the data-analysis process.

RESULTS

In this section, we will present the case details and discuss the key findings of the study to provide readers with an overview of the context in which the findings emerged. This section starts with a description of the case details, followed by a summary of the findings.

Case Details This study was conducted in the IT department of a Fortune 500 multinational finance company, where we followed an individual boundary spanner over a four-month period. Her main task was to acquire the knowledge of a new application platform from the company's developers in the United Kingdom (UK) and then to share it with the developers in Switzerland, where she was located. The new application platform was originally developed in the UK and subsequently gained popularity in the UK and the US. While wishing to adopt it as well, no one in the IT department in Switzerland had possessed any experience with the new platform. In addition, the commodity and banknotes trading department in Switzerland had insisted that the IT department develop an application on the new platform to check the market price of commodities. They later discovered that a tool developed and used in the US could fulfill this demand. However, there were no user guidelines for the application in the US. Moreover, the business environments in Switzerland, the UK, and US were diversely different, thus requiring the modification of the framework and the application to adapt it to the business environment in Switzerland. All knowledge sharing occurred through the boundary spanner. The boundary spanner was tasked to acquire the knowledge from the UK and US teams and then share it with the Swiss team. Each team has different functions. The UK team works for all business units related to the new application platform, while the US team supports the MNC's equities business unit, whereas the Swiss team supports the risk management, commodities, and banknotes business units. In addition, the boundary spanner was also required to interact with the trading team in Switzerland to clarify the business requirements. Fig. 1 shows the knowledge-sharing interaction structure between the different teams and the boundary spanner. The details of the teams are shown in Table IV.

A total of 78 knowledge-sharing interactions (named KS_01 to KS_78) were mediated by various technologies. Table V details the data sources.

The first aim of the study is to verify if Carlile's [24], [25] framework for successful knowledge

TABLE IV
DETAILED INFORMATION OF THE TEAMS INVOLVED IN KNOWLEDGE SHARING

	U.K. IT team	U.S. IT team	Swiss IT team_1	Swiss IT team_2	Swiss IT team_3	Swiss trading team
Function	Support all business units for the new IT platform	Support equity business unit	Support risk mgt. business unit	Support business unit for commodities	Support business unit for banknotes	Commodity and traders of banknotes
Size	5 (UK_01 to 05)	5 (US_01 to 05)	7 (CH_01 to 07)	12 (CH_08 to 19)	7 (CH_20 to 26)	6 (CH_27 to 32)

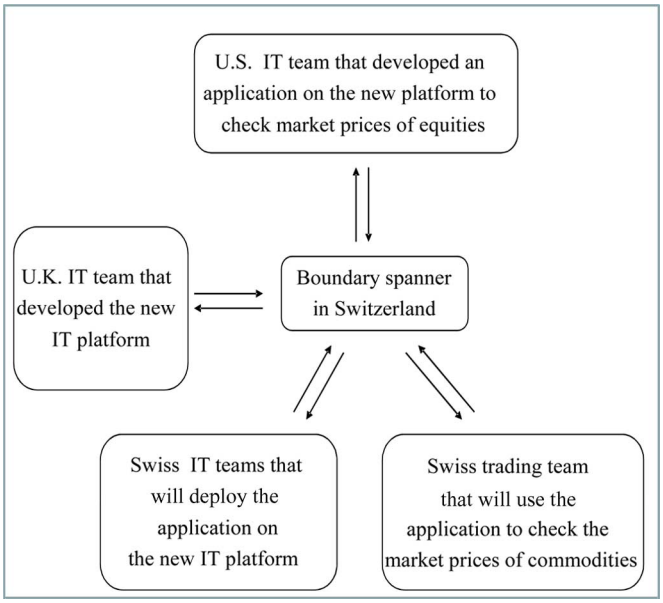

Fig. 1. Knowledge-sharing interaction structure.

TABLE V
DATA SOURCES

Date Sources	Number of Knowledge-Sharing Interactions
Wiki interactions	18
Email interactions	10
Instant messaging interactions	16
Teleconference interactions	4
Face-to-face interactions	30

sharing across a functional boundary is applicable to knowledge sharing across functional and geographical boundaries through a boundary spanner. Table VI summarizes the results.

Based on Table VI, it is apparent that if there is a mismatch between Carlile's [24], [25] proposed knowledge-sharing process and knowledge boundary, the result would most probably be unsuccessful (i.e., it would be either partially successful, or have failed). However, it is important to note here that even when there was a match, there was still a possibility that the knowledge-sharing process was unsuccessful. How could this be possible? We observed that besides the complexity of the knowledge boundary, there were two other factors influencing the success rate of a knowledge-sharing process (i.e., spatial dispersion and knowledge commonality between the source/recipient and boundary spanner). Accordingly, we added them as two additional categories. (See Table VII.)

After the template coding, we conducted another investigation on each of the knowledge-sharing interactions separately to evaluate a distinctive pattern. Following this, we analyzed the patterns across 78 knowledge-sharing interactions to look for larger patterns over time. Next, we will elaborate on our findings.

Summary of the Findings Three important findings emerged from our data: (1) when the knowledge-sharing process did not match the respective knowledge boundary, knowledge sharing was not fully successful; (2) spatial dispersion and knowledge commonality were two important factors determining the optimal media to support a knowledge-sharing process; and (3) the type of media supporting a knowledge-sharing process influences the choice of boundary objects. (See Fig. 2.)

Finding 1: Knowledge Boundary and Knowledge-Sharing Processes: For successful knowledge sharing, Carlile [24] proposed matching three progressively complex knowledge boundaries (i.e., the syntactic, semantic, and pragmatic boundaries), with three progressively complex knowledge-sharing processes (i.e., transferring, translating, and transforming). We discovered that when there was a mismatch between boundary and process, knowledge sharing would be unsuccessful

TABLE VI
RESULTS OF MATCHING THE KNOWLEDGE-SHARING PROCESS WITH THE KNOWLEDGE BOUNDARY

Knowledge Boundary	Syntactic (45)	Semantic (27)		Pragmatic (6)
Proposed knowledge-sharing process	Match (45)	Match (18)	Mismatch (9)	Match (6)
Knowledge-sharing results	41 fully successful, 3 partially successful, 1 failed	15 fully successful, 2 partially successful	8 partially successful, 1 failed	4 fully successful, 2 partially successful

TABLE VII
ADDITIONAL TEMPLATES

Category	Subcategory	Definition	Example
Spatial dispersion	**Low**	Individuals are collocated within the same city	KS_14 CH_08 and BS are located in Switzerland
	High	Individuals are located in two different cities/countries	KS_76 US_01 works in the United States whereas BS works in Switzerland
Knowledge commonality between source/ recipient and boundary spanner	**Low**	The source/recipient and boundary spanner did not have similar prerequisite knowledge prior to their knowledge-sharing interaction	KS_01 BS and CH_01 did not have similar prerequisite knowledge about the framework prior to KS_01.
	High	The source/recipient and boundary spanner had similar prerequisite knowledge prior to their knowledge-sharing interaction	KS_60 BS and US_01 had similar prerequisite knowledge prior to KS_60.

(i.e., they either completely failed or were partially successful).

In our study, there were eight cases of unsuccessful knowledge sharing when the knowledge boundary (i.e., semantic) was more complex than the utilized knowledge-sharing process (i.e., knowledge transfer). We also found one case of unsuccessful knowledge sharing when the knowledge boundary (i.e., semantic) was less complex than the utilized knowledge-sharing process (i.e., knowledge transformation).

During the knowledge-sharing process, the media and boundary objects were used as support tools. Although there was a match between the knowledge boundary and knowledge-sharing process, knowledge sharing could be unsuccessful when the media and boundary objects used were not appropriate. We discovered that spatial dispersion and knowledge commonality between the source/recipient and boundary spanner affected the media selection which, in turn, influenced the selection of the boundary objects.

Finding 2: Spatial Dispersion, Knowledge Commonality, and Media Choice: Spatial dispersion refers to the geographic distance between the employees within an organization. The larger the spatial dispersion, the more difficult it is to engage in spontaneous communication and the more unlikely is the use of the most natural medium (i.e., face to face) for knowledge-sharing interactions [35]. Besides spatial dispersion, we found that knowledge commonality could also influence the media used to mediate the knowledge-sharing process between the knowledge source/recipient and boundary spanner. When the *spatial dispersion is low, and the knowledge commonality among them is also low*, the face-to-face medium should be

most effective for mediating the knowledge-sharing process. This is because in this scenario, the face-to-face medium can be easily accessed and is the most natural medium for minimizing the cognitive effort (which is already stressed out by the low knowledge commonality). Moreover, we found that with *low spatial dispersion and high knowledge commonality*, the face-to-face medium is also the most effective medium for mediating the knowledge-sharing process simply because it can be easily accessed. The situation becomes more complex when the spatial dispersion is high and the knowledge commonality is either low or high.

In total, there were 49 cases of *high spatial dispersion and low knowledge commonality*. Among these, only those mediated by a combination of email and instant messaging (22 cases) were consistently successful. Those that were mediated by face-to-face communication (8 cases), wiki (16 cases), and a combination of netMeetings and teleconferences (3 cases) were not consistently successful (i.e., some were partially successful or had failed). Due to the relatively high spatial dispersion between the knowledge recipient/source and boundary spanner, it was difficult for the boundary spanner to arrange for knowledge sharing via synchronous media (i.e., via face-to-face communication, netMeeting, or teleconferencing). When the boundary spanner could finally arrange it, the recipient/source always tried to expedite the knowledge-sharing process. While this may work well with individuals having high knowledge commonality, it is definitely not effective when the individuals have low knowledge commonality and need more time to share their knowledge. Thus, it is difficult to rely solely on synchronous media for knowledge sharing when the spatial dispersion is high and knowledge commonality is low. In such a situation, we also found that the boundary spanner should not solely rely on asynchronous media for knowledge sharing (i.e., via wiki) as well. In the cases under study, the knowledge recipients misunderstood the knowledge shared via wiki either because they had read the yet-to-be-updated wiki page or they did not understand some sentences in the wiki page. Based on these findings, it appears that when there is high spatial dispersion and low knowledge commonality, the boundary spanner should use a combination of asynchronous and synchronous media to mediate the knowledge-sharing process since the asynchronous media can facilitate initial knowledge sharing to expedite the knowledge-sharing process via synchronous media.

There were 11 cases of *high spatial dispersion and high knowledge commonality*. Four cases relied solely on the face-to-face medium, two cases used a combination of netMeeting and teleconference media, two cases utilized a combination of email and instant messaging, and three cases relied solely on instant messaging. We found that only those who used instant messaging were consistently successful. According to the boundary spanner:

> The instant messaging is becoming popular in the company. I discovered that when both the dispersion and knowledge commonality are relatively high, there is no need to spend time arranging a face-to-face interaction or even netMeeting and teleconference interactions. We could simply have a *brief* chat via an *instant* message.

While media facilitates knowledge-sharing interactions between the boundary spanner and knowledge recipient/source, boundary objects are the objects used to share the knowledge. Our next discussion is based on our finding that the choice of media affects the choice of boundary objects.

Finding 3: Media Choice and Boundary Objects: Boundary objects serve as interfaces that "sit in the middle" and contain necessary content to support knowledge sharing [26]. There are three types of boundary objects: repositories, standard forms or methods, and models or maps of boundaries [26]. A knowledge-sharing process may utilize more than one boundary object. Our findings consistently show that the choice of media affects the choice of a boundary object. The boundary spanner remarked:

> It is not possible to bring everything, e.g., applications, models, etc., to a face-to-face interaction. Normally, we simply print some key information. But sometimes, knowledge sharing does not work with just the printed documents. The boundary objects need to be observed and operated to effectively share the knowledge. Otherwise, knowledge sharing is a waste of time

> We want to understand the format defined by the team in the USA. Since we utilized wiki, a sample document was used. The result was a huge misunderstanding about the format. The one we interpreted from the sample document was completely different from what they had defined.

Based on our findings, we summarize the following knowledge-sharing designs that were

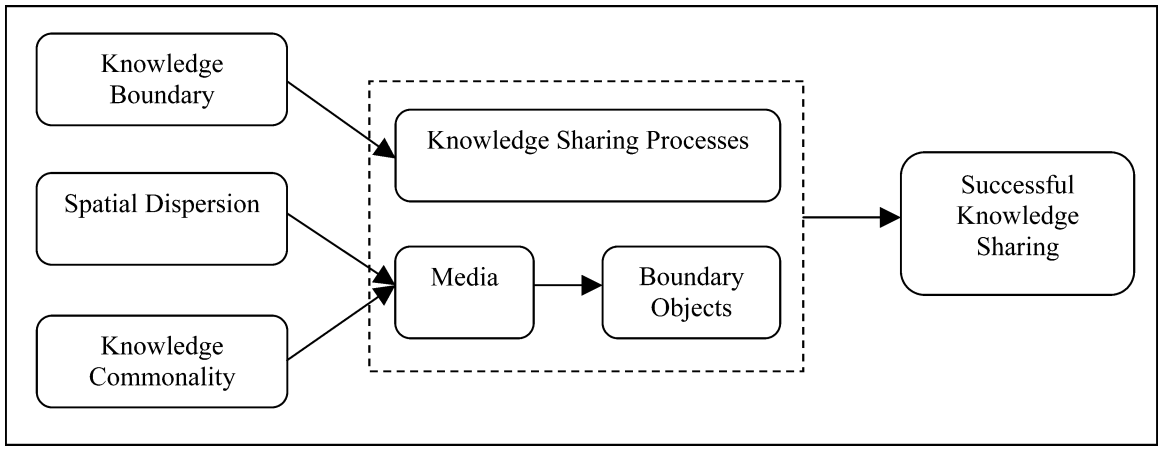

Fig. 2. Illustration of the findings.

TABLE VIII
SUMMARY OF THE KNOWLEDGE-SHARING DESIGNS FOUND TO BE CONSISTENTLY SUCCESSFUL

Knowledge Boundary	Spatial Dispersion	Knowledge Commonality	Optimal Knowledge-Sharing Process	Optimal Boundary Object(s) and Media	
				Media	Boundary Object(s)
Syntactic	Low	Low	Transfer	Face to face	Repository + Model/Map
Syntactic	Low	High	Transfer	Face to face	Repository or Model/Map
Syntactic	High	Low	Transfer	Email + instant messaging	Repository + Standard Form/Method or Repository + Model/Map
Semantic	High	Low	Translate	Email + instant messaging	Repository or Model/Map
Pragmatic	High	High	Transform	Instant messaging	Repository

consistently successful in the cases under study. (See Table VIII.)

The main research questions that we attempted to answer are: Does matching the complexity of knowledge boundary with the knowledge-sharing process lead to successful knowledge sharing? What are the key factors that influence a boundary spanner when deciding how to facilitate the knowledge-sharing across functional and location boundaries? With regard to the first research question, we found that although there was a match between the knowledge boundary and knowledge-sharing process, knowledge sharing could be unsuccessful when the media and boundary objects used were inappropriate. However, when the knowledge-sharing process did not match the respective knowledge boundary, knowledge sharing was definitely not going to be fully successful. Regarding the second research question, we found that spatial dispersion and knowledge commonality between the source/recipient and boundary spanner affected the media selection which, in turn, influenced the selection of the boundary objects.

CONCLUSIONS, LIMITATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

This section concludes this paper. After presenting the conclusions, it identifies the limitations of this study and suggests future research.

Conclusions This study has implications for practice as well as contributions to research.

Implications for Practice: Knowledge sharing is a critical activity in today's knowledge-intensive economy. It becomes more challenging for organizations to attain successful knowledge sharing when the sharing occurs across not only functional but also geographical boundaries. Unsuccessful knowledge sharing can be costly. The sharing costs vary from 2% to 59% of total project cost [38]. Thus, successful knowledge sharing is an important prerequisite for satisfactory financial performance [39]. Boundary spanning is the latest approach adopted by many organizations to improve the success rate of knowledge sharing [8], [21], [40], [41]. Professional and technical communicators have the capability to serve as potential boundary spanners to facilitate knowledge sharing. For example, Allen [10] showed how critical technical communication within the laboratory is for R&D performance, and emphasized the importance of the boundary spanners. While previous studies focus on the boundary spanner's role, position, and characteristics, this study contributes by suggesting some optimal knowledge-sharing designs as references for boundary spanners. (See Table VIII.)

Specifically, there are three important contexts that the boundary spanner should consider when deciding how to share knowledge (i.e., knowledge boundary, spatial dispersion, and knowledge commonality). While the complexity of a knowledge boundary determines a corresponding knowledge-sharing process (i.e., transferring, translating, or transforming), the spatial dispersion and knowledge commonality between the boundary spanner and knowledge recipient/source affect the choice of media which, in turn, influences the choice of boundary objects. Together, the combination of the knowledge-sharing process, media, and boundary objects determine the success rate of a knowledge-sharing transaction. Knowledge sharing will not be fully successful if the boundary spanner utilizes less appropriate media and boundary objects, even if there is a match between the knowledge-sharing process and the knowledge boundary. For example, if the spatial dispersion is high and knowledge commonality is low, knowledge sharing may not be successful if the boundary spanner uses wiki as the supporting media for interaction. As a less natural medium, wiki may further increase the cognitive effort which is already stressed out by the low knowledge commonality.

As the key communicator in knowledge sharing, when selecting the communication technologies to mediate knowledge-sharing processes, a boundary spanner should consider the degree of the spatial dispersion and knowledge commonality. The findings in this study provide some guidelines. First, regardless of the degree of knowledge commonality, when the spatial dispersion between the boundary spanner and knowledge recipient/source is low, face-to-face medium is the most effective for mediating the knowledge-sharing process simply because it can be easily accessed. Second, when the spatial dispersion is high and knowledge commonality is low, a combination of asynchronous and synchronous media, such as a combination of email and instant messaging, is recommended to mediate the knowledge-sharing process. This is because when the spatial dispersion is high, it is difficult for the boundary spanner to arrange for knowledge sharing via synchronous media. When the boundary spanner could finally arrange it, the recipient/source has a tendency to expedite the knowledge-sharing process, which means that there could be insufficient time for individuals with low knowledge commonality to share knowledge with each other. When the time duration of the knowledge sharing via synchronous media is limited, initial knowledge sharing via asynchronous media is needed to improve the success rate. Finally, when the spatial dispersion and knowledge commonality are high, the boundary spanner could solely rely on synchronous media, such as instant messaging, to mediate the knowledge-sharing process. Although high spatial dispersion makes it difficult to arrange for knowledge sharing via synchronous media, and the recipient/source has a tendency to rush through the process, knowledge sharing via synchronous media alone may still be successful when there is high knowledge commonality.

Contributions to Research: Due to the complexity of knowledge sharing across functional and geographical boundaries, many organizations are employing individual boundary spanners for successful knowledge sharing across such boundaries [8]. While there has been extensive research on knowledge sharing through an individual boundary spanner [16], [17], none of the studies provides an answer to the question: *How does a boundary spanner facilitate knowledge sharing?* [21]. This study provides answers to this question.

Building on Carlile's [22], [24] framework of knowledge sharing across functional boundaries, this study found two additional contextual factors besides the proposed knowledge boundary. They are the spatial dispersion between recipient/source and

boundary spanner, and the knowledge commonality among them. Although there could be other factors that influence the success of knowledge sharing [31], in our study context (knowledge sharing across functional and geographical boundaries via an individual boundary spanner), the knowledge boundary, spatial dispersion, and knowledge commonality were found to be the important contextual factors.

We further discovered that when the knowledge-sharing process and knowledge boundary fail to match in terms of their complexities, knowledge sharing will not be fully successful. However the converse may not be true. When the knowledge-sharing process and knowledge boundary match, knowledge sharing may not be fully successful because of the degree of spatial dispersion and knowledge commonality between the boundary spanner and knowledge recipient/source. Hence, the matching between the knowledge boundary and knowledge-sharing process is an essential yet insufficient condition for successful knowledge sharing across geographical and functional boundaries via a boundary spanner.

With the Media Naturalness Theory as a basis [36], this study highlighted media as an additional design factor besides the boundary object. Spatial dispersion and knowledge commonality are two important factors determining the optimal media for supporting the knowledge-sharing process. Furthermore, we perceived that the form of media supporting the knowledge-sharing process influences the choice of boundary objects. Accordingly, when the media used is suboptimal for a particular knowledge-sharing process, the boundary object used will also be suboptimal which, in turn, results in an unsuccessful knowledge-sharing process. For example, it would be difficult to use a model as a boundary object if teleconferencing is the medium selected to support a knowledge-sharing process.

Limitations As with any research work, there are some limitations with the current study. The aforementioned findings should be viewed in the light of these limitations. First, the findings in this study are limited to the observed cases. Some combinations of contextual factors are not found in the cases and, thus, are not discussed. Second, findings of this study are derived by analyzing the logs of knowledge-sharing interactions of a boundary spanner for only four months. There could possibly be some additional findings that emerge from a longer period of observation. Finally, as with any qualitative study, the generalizability of the results needs to be established with a follow-up quantitative study.

Suggestions for Future Research Future research should quantitatively validate the proposed optimal knowledge-sharing designs to test the generalizability of the findings. A survey and profile deviation analysis [37] could be conducted for this purpose. The combinations of context (i.e., knowledge boundary, spatial dispersion, and knowledge commonality) and knowledge-sharing design (i.e., knowledge-sharing process, media, and boundary objects) shown in Table VIII constitute ideal knowledge-sharing profiles which were found in this study to be consistently successful. The first step of a profile deviation analysis is to quantify the qualitative descriptions of each ideal profile. This can be achieved by involving some experts in the research. (See [37] as an example.) The next step is to survey the boundary spanners and find out how they facilitate knowledge sharing. The deviation indices of their knowledge-sharing profiles from each of the ideal profiles shown in Table VIII are then to be computed. Consequently, the lower the deviation index is from any of the ideal profiles, the higher is the success rate of the knowledge sharing. Moreover, future research could also extend this study by collecting and analyzing a longer period of knowledge-sharing interactions via a boundary spanner. Selecting other companies rather than financial companies as the contexts of studies may also be interesting for future research to test the generalizability of the findings of our study.

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