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Gloria H. W. Liu
National Central University, glorialiu2007@gmail.com

Cecil Chua
University of Auckland, aeh.chua@auckland.ac.nz

Eric T.G Wang
National Central University, ewang@mgt.ncu.edu.tw

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Spanning Knowledge Holes In IS Projects

Gloria H.W. Liu
National Central University
glorialiu2007@gmail.com

Cecil E.H. Chua
The University of Auckland
aeh.chua@auckland.ac.nz

Eric T.G. Wang
National Central University
ewang@mgt.ncu.edu.tw

ABSTRACT

Prior studies have demonstrated the importance of bridging structural holes across functional groups in IS projects. In this study, we argue that bridging structural holes is necessary but insufficient for ensuring project success. An additional requirement is that knowledge holes across functional groups need to be bridged to enable effective problem-solving across functional groups. We propose and empirically study the concept of knowledge holes in a case study of an ERP upgrade. Our findings suggest that complementary to the concept of structural holes, the concept of knowledge holes is useful for explaining different project outcomes. Our findings also demonstrate methods for bridging knowledge holes. Contributions of this study are manifold.

Keywords

Knowledge holes, structural holes, boundary spanner, IS projects.

INTRODUCTION

The proliferation of knowledge communities and the need for their integration result in the emergence of flexible organizational forms, such as cross-functional projects (e.g., ERP implementations). During cross-functional projects, people representing different communities coordinate to achieve organizational goals. However, there is no guarantee that by assigning people to projects, knowledge will be transmitted/created for achieving goals.

This paper introduces the idea of knowledge holes. The literature has documented the important role of boundary spanners who use weak ties to bridge structural holes across organizations' functional boundaries (Hargadon and Sutton, 1997). The boundary spanner literature has generally focused on their relationship structures and how they help bridge structural holes. We show that boundary spanners must also bridge knowledge holes (Pawlowski and Robey, 2004). Each function contains within it specialized knowledge. When boundary spanners perform their role, some knowledge is transmitted across the boundary. We show such knowledge does not translate successfully unless boundary spanners understand the knowledge within the transmitting boundary. Thus, boundary spanners must span not only the structural hole, but the knowledge hole.

We demonstrate our claim through a cross-case analysis of two departments participating in an ERP upgrade project. In one case, boundary spanners between IT and the function understood knowledge across the functional boundary, including syntax/meanings/consequences. Thus, solutions were localized around problems faced in the department, and jointly implemented. In the other, this knowledge was poorly understood resulting in incomplete solutions and unresolved problems. Our contribution is a more nuanced theorization for analyzing events and actions within and across IS project boundaries. Our findings further suggest a shift of focus from boundary spanners' appropriating boundary objects for bridging knowledge holes (Carlile, 2002, 2004) to their practices and interaction for creating common narratives about those events and actions.

KNOWLEDGE SPACES OF AN IT PROJECT

Cross-functional IT projects involve designing/implementing IT artifacts where at least two organizational departments are involved (Simon and Newell, 1971). In most such projects, one cross-boundary problem occurs where the project team (i.e., internal IT members and/or consultants) must understand the non-IT problem (i.e., the problem space) and construct IT solutions to the problem (i.e., the design space) (Purao, Rossi and Bush, 2002).

The problem space is a metaphorical space containing the team's interpretation of user requirements in the face of a task environment (Purao et al., 2002). It includes a mental model of "a subset of the real world with which a computer system is concerned" (Guindon, 1990: 317). To construct the problem space, there must be an understanding of the task/requirements, and a conceptual match between information about the task/requirements and IT technologies' capacities/advantages/limitations/impact (Bassellier, Reich and Benbasat, 2001). Conceptual mismatch can cause major difficulty in constructing the problem space.

The design space, also known as the implementation domain (Blum, 1989), is a metaphorical space that contains mental representations of the team's solutions to the problem, based on which the team creates formal models/specifications for building systems (Purao et al., 2002). The team can explore diverse solutions based on current IS methods/techniques (Oxman, 1997). For example, information systems can be developed in-house, outsourced, or customized from application packages. Or an IT project can follow open source or agile development. Different solutions can generate distinct consequences. The project team and departments involved share the consequences of a solution (Carlile, 2002, 2004).

The knowledge domains in the problem and design space are often different (Iivari, Hirschheim and Klein, 2004). The knowledge domain of the problem space (i.e., application domain knowledge) is often associated with the departments/functions. For example, in an accounting-based IT project, lots of the necessary problem-space knowledge will be associated with accounting. The literature has emphasized the importance of application domain knowledge for solving problems in the real world. High application domain knowledge is found to prompt IT teams to engage in strategies contingent upon the nature of a problem: a focused search for solving simple problems, and an exploratory search for complex, ill-defined problems; in contrast, teams with low application domain knowledge tend to be distracted by simple problems' surface features (e.g., the order of prompts in a problem description), and cannot meaningfully code information for solving complex problems (Khatri and Vessey, 2016).

In contrast, the knowledge domain of the design space is often technical/IT related (i.e., IS domain knowledge). Algorithms, hardware configurations, programming languages, design languages and databases are often associated with the design space. Technical complexity can be a barrier for departments to understand IT's language/meanings, and to envision consequences associated with solutions. The literature has documented the way IT projects and their impacts is communicated to departments is consequential (Lapointe and Rivard, 2005). Further, departments' knowledge for designing workarounds and understanding of costs/benefits/risks associated with operating an IS can impact their choices about how to engage with the system, leading to organization-wide consequences (e.g., errors/inefficiencies/shadow systems) (Alter, 2014). Given the two kinds of knowledge are possessed by different departments, it is often necessary to have individuals perform boundary spanning to bridge departments.

BOUNDARY SPANNING

Boundary spanning refers to activities, occurring at functional boundaries (Pawlowski and Robey, 2004). It is about creating/maintaining linkages to "monitor, exchange with, or represent" (Mange and Eisenberg, 1987: 313) a group to its environment. Boundary-spanning can be responses to the environment, or proactive moves for managing interdependencies (Cross, Yan and Louis, 2000).

It involves a two-step process: searching out relevant information on one side, and disseminating it on the other (Tushman and Scanlan, 1981). Each department only knows things under its purview, so departments need information from others to adapt/coordinate goals and activities to meet organizational/environmental demands. However, searching without disseminating creates internal silos (Roberts and O'Reilly, 1979). Thus, successful boundary spanning must also fulfill the external representation function to important outsiders, such as customers/suppliers/the board of directors for obtaining their support/resources (Ancona and Caldwell, 1988). Boundary spanning can only be accomplished by those who are well connected externally/internally. Specific boundary spanning activities include environmental scanning, contractual negotiation, task coordination (Choi, 2002), building relationships (Druskat and Wheeler, 2003), representing projects to stakeholders (Marrone, 2010), and routinizing information searching/acquiring/storing activities (Hargadon and Sutton, 1997).

The boundary spanning literature principally employs network structure as a proxy for information flow and assumes connections lead to information processing across boundaries (Granovetter, 1973, 1983; Hargadon and Sutton, 1997; Podolny and Baron, 1997; Xiao and Tsui, 2007). How the substance of the network structure is moved/combined/transformed across structural holes is rarely studied. An exception is the work of Pawlowski and Robey (2004) who argue that boundary spanners need to reframe/translate information from one group in terms of the perspective of another, deliberately ask why to challenge current processes, and build cases to generate support for their proposals.

KNOWLEDGE HOLE

Structural hole theory highlights the information and control benefits boundary spanners can create in an ill-connected network (Burt, 1992, 2005). Boundary spanners are often the main channel to access knowledge and to negotiate solutions across boundaries. Their network position exposes them to information that reveals conditions/opportunities otherwise invisible to those within boundaries. That information can possibly inform strategies to negotiate solutions. A structural view of boundary spanning thus must be augmented by considering the knowledge understood by boundary spanners in the network. Other research finds while knowledge diversity is correlated with network structure, there is considerable variance unexplainable by network structure (Rodan and Galunic, 2004). We therefore argue just having individuals perform boundary spanning is insufficient to bridge the problem space/design space gap. We introduce the concept of knowledge holes, arguing that knowledge holes should be spanned so that knowledge can be applied on both sides of the hole to solve shared problems. Knowledge holes refer to the absence of shared syntaxes/interpretations/consequences that impedes problem-solving across boundaries. They can be considered as a complement to “structural holes” which are missing relations that inhibit information flow between people (Burt, 1992).

Based on Carlile (2002; 2004), we argue knowledge across boundaries comprises three elements: shared syntax/interpretations/consequences. First, a shared syntax is a medium for representing/storing/retrieving knowledge with fixed meaning (Boland and Tenkasi, 1995; Vilhena et al., 2014). It is vocabulary specific to situations (Khatri, Vessey, Ramesh, Clay and Park, 2006). For example, the ER model’s symbols (e.g., rectangles/diamonds) are the syntax to represent objects, abstract concepts and their relationships in a system. While shared syntax is always necessary to analyze problems, it is insufficient to represent semantic differences and dependencies, particularly when novel conditions emerge (Boland and Tenkasi, 1995; Carlile, 2002). Even under stable conditions, the same concept can have different connotations for different people. For example, the concept of production cost means different things for the accounting and manufacturing departments. For accounting, production cost involves calculating the accurate actual cost with consideration of equipment/machinery depreciation. For manufacturing, production cost emphasizes the variance analysis between predefined and actual cost for monitoring/intervention.

Second, shared interpretation means there is consensus of meaning (Boland and Tenkasi, 1995; Carlile, 2002). Shared interpretation is situated in the context and contains a group’s systems of meaning and cognitive repertoires, i.e., what they know and how they know it. It cannot be easily transferred across boundaries, and requires translation into another group’s perspective (Carlile, 2004). Shared interpretation can only be reached by understanding the nuances/details of actual practice (Brown and Duguid, 1991), learning from different interpretive communities (Fish, 1980), or enhancing mental models by using cognitive support tools (Vitharana, Zahedi and Jain, 2016). Shared interpretation recognizes even if shared syntax exists, interpretations can be different and evolve over time/space (Carlile, 2002). For example, through interacting with users, a team discovers “data availability” not only means data available “at users’ request” but “the liberty” to retrieve/update data when needed.

Third, shared consequences recognizes the purposive nature of knowledge as people create/apply knowledge to solve problems (Carlile, 2002). Shared consequences involve developing common interests and making trade-offs between actors (Brown and Duguid, 1991). Common interests motivate joint problem-solving, whereas when interests are in conflict (i.e., solving a problem does good for one, but does harm for the other), one of the parties may be unwilling to make changes; likewise, projected positive consequences of a solution motivate people to adopt the solution, whereas negative ones imply the need to alter the solution or create a new one, and validate it (Carlile, 2002, 2004). Thus, shared consequences can be achieved by identifying actors involved, convincing them they have common problems, and persuading them to accept responsibilities and outcomes associated with the solution (e.g., learning or transforming skills/knowledge) (Callon, 1986).

Constructing the problem space/design space requires shared syntax/interpretations/consequences, so that common issues and potential solutions can be identified/debated/understood. Problems not represented, translated and resolved can prove consequential over time. For example, many ERP workarounds are performed because the problem being worked around is not represented in the system. Likewise, solutions not understood, negotiated and valued will not receive attention and support needed to implement them. For example, users who are not well trained may ignore an ERP system's querying facilities in favor of doing their own analysis in MS Excel.

As we move from shared syntax, to shared interpretations, and to shared consequences, complexity increases. Shared consequences require the existence of shared syntaxes and interpretations (Carlile, 2004). However, it is also likely that given shared syntaxes and interpretations, actors are unwilling to make trade-offs and negotiate solutions/responsibilities, because transforming or learning new skills can be costly.

Table 1 presents our preliminary conception of the intersection between the problem/design space and knowledge holes (Liu, Chua and Wang, 2016). A hypothetical knowledge failure in any of the quadrants could lead to difficulties implementing IT projects.

	Problem Space	Design Space
Syntactical hole	Definition: IT's failure to comprehend terms/labels that describe the problem a department faces in their task environment. Example: IT is not clear about what the consolidated financial statement is composed of, such as which companies are subsidiaries or associates, which accounting items are included, which currencies are used etc.	Definition: departments' failure to comprehend terms/labels that describe IT solutions. Example: Accounting thinks of data storage as a group of Excel spreadsheets and does not appreciate the additional complexity of querying a database. They thus neglect to specify important data cubes they need
Interpretation hole	Definition: IT's failure to adjust their interpretation of the problem a department faces in related contexts. Example: IT fails to understand that "price" is negotiated between buyer and seller and assumes everything has a fixed price under all conditions.	Definition: departments' failure to evaluate potential IT solutions and their implications. Example: Purchasing is not aware that input is required from them for IT to develop solutions to effectively integrate with suppliers.
Consequence hole	Definition: IT's failure to envision how a problem influences the departments involved and agree on the scope of the problem. Example: IT understands a requirement, but thinks of the requirement as of low priority to be delayed to the next implementation cycle. They don't understand not implementing this violates accounting principles.	Definition: departments' failure to envision how the adopted IT solution impacts the departments and accept ensuing responsibilities and outcomes. Example: Marketing thinks of an IT implementation as a new physical device used by data-entry people. They don't understand the new system will impact those who aren't using the system (e.g., by impacting commission calculations).

Table 1. Syntactical/interpretation/consequence holes in the problem/design space

METHODOLOGY

We conducted a cross-case analysis of a 10-month long ERP upgrade project in two functions of a Taiwanese manufacturer (ElectroCom) (Yin, 2003). An upgrade is the replacement of an installed version with a new one from the software vendor (Khoo and Robey, 2007). It varies in terms of scope (technical and/or functional upgrade) and version (minor or major) (Ng, 2001). The project involved a major version and functional upgrade of a highly customized system. Hence, bringing together diverse knowledge was needed to decide what the upgraded system would look like. We compared how knowledge domains (i.e., application/IS domains) understood by representative users (i.e., boundary spanners) in the two functions affected the construction of the problem/design space, and ultimately the IT project outcome for the departments concerned.

Research site

ElectroCom is a Taiwanese manufacturer, with headquarters in Taiwan, factories in Taiwan and China, and sales offices across Pacific Asia/Europe/the US. At the time of study, it employed over 2,500 employees worldwide.

An ERP system had been used across ElectroCom in Taiwan and China since its first implementation in 1999. The upgrade project was expected to affect offices and factories in Taiwan and China. This project was in response to the local Taiwanese government's adoption of International Financial Reporting Standards (IFRS) two years later (i.e., in 2013). It upgraded the database (from Oracle 9i to 11g) and ERP version (R11.5.10 to R12.1.3) from Oracle EBS. The upgrade was scheduled for 10 months. However, because of problems encountered, the upgrade for the marketing division was delayed by 3 months. Three modules (finance, sales and distribution, and production) were upgraded across 4 divisions (SCM, marketing, general administration, and manufacturing).

The upgrade project was the largest IT project in ElectroCom at the time, involving 6 internal IT members and 4 consultants. The internal IT members were highly skilled (an average company tenure about 10 years), with the most junior one having work experience with the Oracle ERP system for about 5 years. The consultants were hired principally to facilitate training. The ERP upgrade cost approximately 150 thousand US dollars, including an annual fee for the maintenance/support from Oracle, and the training fee paid to Taiwanese consultants. The amount excludes new hardware, internal IT personnel costs, and the opportunity costs of users participating in the project.

Data collection

The first researcher accessed the site about 1 year after project completion to collect retrospective data. We collected data from multiple sources (management/non-management/consultants) and used multiple methods. Data collection methods include (1) interviews, (2) documentation, and (3) on-site observation (Table 2). The documentation, especially, helped combat the retrospective nature of data collection as document contents do not change over time.

Documents		
Project proposal		
Minutes of meetings including the kickoff and review meetings		
Project schedule		
Project-related training materials		
On-site observation		
Interviews		
Stakeholders	**# of interviews**	**# of distinct interviewees**
Top management (including CIO)	4	2
SCM representatives	3	2
Marketing representatives	2	2
IT	7	5
Consultants (project manager)	1	1
Total	**17**	**12**

Table 2. Breakdown of data sources

We first queried two knowledgeable IT members (IT project manager-CIO and project coordinator) about divisions affected by the implementation. Two departments (marketing/supply chain management) had the strongest differences in outcomes. Specifically, the implementation in the marketing department was described as "*a total disaster*" and "*appalling*" (IT project manager), whereas the supply chain management (SCM) department described the new ERP as "*richer*" and the project helped "*connect more dots*" (SCM user). The first author thus focused data collection on those two departments to observe contrasting implementation processes. As data collection proceeded, we serendipitously discovered representative users' (i.e., boundary spanners) understanding of the IT domain knowledge affected the construction/implementation of IT solutions (i.e., bridged vs. unbridged knowledge holes).

During data collection, the first author was assigned a meeting room in ElectroCom's Taiwan premises to conduct interviews. Interviews with two former employees and one consultant who were key project participants were conducted outside of the company premises.

We developed an interview protocol and adapted it to reflect interviewees' positions and issues as the research progressed. Interview questions focused on issues related to project management (e.g., planning/execution/control and coordination/problem-solving/evaluation). We asked interviewees (1) their roles in the organization/project, (2) tasks they involved, and (3) their experiences/perceptions in the project.

Data analysis

Within each case, we asked initial interviewees to identify potential boundary spanners who had more interaction across departments. Representative users (i.e., key users) from both functions were nominated as boundary spanners. They were required to acquire knowledge about user needs, relay knowledge to IT, and help implement IT solutions. Based on preliminary definitions of knowledge holes in Table 1, we then focused on coding the three types of knowledge holes in the problem space/design space. Table 3 has sample quotes. New concepts were also allowed to emerge, and were categorized. These new codes captured contextual factors associated with knowledge holes, causal mechanisms explaining bridged/unbridged holes, and project outcomes. The analysis followed the constant comparison logic (Eisenhardt, 1989; Yin, 2003).

	Code definition & Quote
Syntactical hole	(**problem space**) Syntactical holes existed (1) if there were no common terms/labels to describe problems/concerns departments faced, or (2) if IT failed to understand terms/labels departments used to describe their problems/concerns; syntactical holes were bridged if IT shared and understood terms/labels that departments used to describe problems they faced. *Many obsolete data [suppliers who they stopped trading with] were still around… They were becoming a burden to the system.* (Consultant) [hole bridged because both IT and department described data of suppliers who they stopped trading with as the major problem]
	(***design space***) Syntactical holes existed (1) if there were no common terms/labels to describe IT solutions, or (2) if departments failed to understand terms/labels IT used to describe solutions; syntactical holes were bridged if departments shared and understood terms/labels IT used to describe IT solutions. *IT told us the changed data structure a bit…we didn't discuss much about the structure…[we're] thinking that this would be just another minor upgrade…* (Marketing key user) [holes not bridged because the department did not grasp the connotation of a changed data structure]
Interpretation hole	(**problem space**) Interpretation holes existed, if IT failed to adjust their interpretation of the problem a department faced in different settings; interpretation holes were bridged when IT had a mental extension or an awareness of contingencies that could change the interpretation of the problem. *…each of [the users] dealt with distinct suppliers. Some were in charge of purchasing raw materials, and some in charge of purchasing tools or equipment…They were exclusive contacts for distinct suppliers.* (IT, manufacturing module) [hole bridged because IT understood contingencies, i.e., data ownership, that might require alteration of IT solutions]
	(**design space**) Interpretation holes existed, if departments could not evaluate potential IT solutions and their implications according to their local situations; interpretation holes were bridged when departments had a mental extension or an awareness of contingencies that could possible change the meaning of potential IT solutions. *Users complained about why IT couldn't just migrate the data and save them efforts and time. I explained even if IT could do so, the changed data structure meant we had to check the data [manually]…*(SCM key user) [hole bridged because the department could evaluate alternative IT solutions according to local situations and their implications]
Consequence hole	(**problem space**) consequence holes existed, if IT failed (1) to understand how a problem or project task influenced the department, or (2) to reach an agreement on the problem/task scope; consequence holes were bridged, when IT (1) understood the impact of a problem/project task to departments, and (2) reached an agreement on the problem/task scope. **…***We helped migrate data of clients and orders…[users] filled extra fields manually…it's just garbage in, garbage out.* (IT, distribution module) [hole not bridged because IT was only willing to map out part of the problem scope and offered a partial solution]
	(**design space**) consequence holes existed, if departments failed (1) to understand how adopted solutions impacted the departments and (2) to accept ensuing responsibilities and outcomes; consequence holes were bridged, when departments (1) understood the impact of adopted IT

	solutions, and (2) accepted ensuing responsibilities/outcomes. *…To enter that amount of data…I kind of underestimated efforts required…also some sales orders were to be re-entered and checked…torrential workload in the last week…*(Marketing key user) [hole not bridged because the department underestimated their responsibilities associated with adopted IT solutions]

Table 3. Representative quotes grouped according to codes

Due to space constraints, we present only one problem that provided us with rich insights (i.e., data management problem). The problem in the SCM division is counterbalanced by a similar problem in the marketing division. This contrast demonstrates how knowledge holes were (not) bridged. For each case, we highlight the knowledge holes in the problem/design space.

FINDINGS

When the project began, key users from all departments attended training sessions about the new ERP. They were introduced to the ERP's new features and the new financial regulations. Initially, they thought the project was mainly to "*help the finance people out*" (Marketing key user) and knew "*some effortful participation*" (SCM key user) was required from them.

The SCM and marketing key user had worked with IT on other projects before. They were trusted by the department head and empowered to make decisions associated with the project.

Master data quality

Master data is a single source of common data shared across systems/applications/processes. It describes attributes of business entities (e.g., products/sites/clients/suppliers), and is rarely changed. Different business domains thus can use master data for their own functional needs. Managing master data to enable the use of accurate, timely and relevant data across systems/applications is essential (Spruit and Pietzka, 2015).

ElectroCom had accumulated a large amount of master data in the ERP over time, and protected it from unauthorized changes. The common narrative was the master data constituted "*the foundation*" (SCM key user) and "*a critical point of control*" (SCM user) for many IT applications/systems. However, the new ERP's data structure was more complex. It had more fields to fill, and was presented differently (HTML pages vs. a Windows-based form).

Vignette: supplier master data

Bridging knowledge holes in the problem space: After the kick-off, IT informed the SCM key user about the task of managing the master data (e.g., cleansing/updating/enriching). The key user then expressed her concern about users' unwillingness to do the task, especially if users could not foresee its benefits. After the discussion, the key user and IT agreed the major problem with the supplier master data lay in its obsolescence which could cause inefficiencies in daily routines and slow down the system. "*Obsolescence*" became the buzzword used by the SCM and IT divisions to describe the problem.

Many obsolete data [suppliers who they stopped trading with] were still around… They were becoming a burden to the system. (Consultant)

The key user further probed to identify areas in supply chain the new data could possibly improve. She discussed with IT/consultants during training and informally. IT thus understood the key user anticipated the new data would be applied to enhance supply chain's analytical capability.

… [the SCM key user] asked consultants lots of questions…how those new data could possibly be useful…how to use those data to streamline their process…improve their analysis…we communicated a lot informally via phone or in person… (Project coordinator)

Because of the conversations, the team realized the data-entry interface might compromise data quality, which would then reduce data analysis quality. The key user identified specific problems, including the lack of user familiarity with the interface and the language barrier (i.e., Taiwanese users using an English interface). IT thus could realistically imagine the specific difficulties users would face, and understood that users "*needed some process to ensure its quality"* (IT, manufacturing module).

The key user also elaborated how users coordinated daily tasks in the SCM division. She made explicit her concern that specific users would be overwhelmed by additional data-entry tasks. Also, she highlighted unless something was done, these data-entry users would be unable to obtain other SCM users' support. The key user thus lobbied IT to allow users to directly modify certain master data elements rather than seeking changes through the organizational bureaucracy.

The key user explained to me that users deal with distinct suppliers…They are exclusive contacts for distinct suppliers. (IT, manufacturing module)

Bridging knowledge holes in the design space: IT and users shared assumptions about the master data, including that it was "*the foundation*" (SCM key user) and "*a critical point of control*" (SCM user). IT initially confined the master data task to the key user. However, the key user formed a team to sell the project across the division and roll out training for managing master data to users.

…explained to [3 relatively junior users] what I saw in this project…we four acted like a gang, demonstrating what to do to other users… (SCM key user)

Only [the key user] and I attended the training session [for managing master data]. We then came up with our individual versions of SOP [standard operating procedures]. Each of us then taught another user one-on-one, asking the user to follow the SOP to input data of two suppliers…and wrote up their own SOPs…after this, these two users showed their SOPs to other two users and taught them…the teaching and learning snowballed from two to four, to six, to all users… (SCM user)

Due to the training/guidance users received, they understood the data structure and access methods. IT agreed to extend SCM users' access to the master data. Seven SCM users participated. IT proposed two routes for solving the problem: (1) IT would migrate data to the new ERP, and users would update/correct data; or (2) users would compile data in Excel spreadsheets and then copy/paste the data to the new system. The key user realized the first option would create more risk. The key user and IT used the metaphor of house renovation vs. house building to explain the options to users.

…I explained even if IT could do so [migrated data on users' behalf], the changed data structure meant we had to check the data [manually].…it's like building a new house vs. renovating one in very bad condition…we agreed with the "house building" solution. (SCM key user)

The key user was mindful the increased workload could be a point of resistance with users. She identified users with more critical jobs, and decreased their responsibilities.

To achieve desired data quality, the key user helped develop procedures (e.g., feedback loops) and solicited management support to remove distractions.

…spending one whole week…in a meeting room without disruption…users formed 2-person groups…both entered data of their suppliers, and had the other check the accuracy… (SCM key user)

Consequently, SCM users accomplished the master data task on time and with high quality, and solved a "*recurrent problem with converting PR [purchase requests] into PO [purchase orders]*" (SCM user).

Counter-vignette: Client master data

Knowledge holes in the problem space: In the beginning of the project, IT informed the marketing key user about managing client master data. IT warned the key user about the changed data structure and attendant risks (e.g., mismatched data). Because the marketing key user perceived the system would provide minimal enhanced functionality to marketing, she considered the upgrade as "*another minor upgrade*" and the master data issue purely as a data-entry task for solving no specific problems. She did not further probe why new data would be needed, how it could be useful, and how historical data could be better managed.

Users didn't see many improved system functionalities...didn't fully grasp associated changes underneath… (IT, distribution module)

Instead, because of the tremendous amount of client data, the marketing key user was more concerned if they could finish this task within an assigned deadline and in a consistent format. The issue of data quality was considered a luxury hard to achieve. In retrospect, the IT project manager described this as "*a huge cognitive gap*" between IT and marketing.

…new fields to be filled…in a consistent format…three persons would render three different formats…very limited time to verify data… (Marketing key user)

The marketing key user was the only person from the division to make decisions. To contain the project's impact, she hoarded project information and assigned a junior administrative assistant to manage the data-entry task on her behalf.

The marketing key user worked in her silo. She did not consult those affected by the data-entry task. She did not communicate expectations/concerns of the new system with others. IT thus did not know activities users were involved in and underestimated the impact of the data-entry task on their routines.

…We told them about this early, hoping they could coordinate their efforts…we didn't find the efforts were seriously underestimated until very late…kind of too late to react at the end… (IT, distribution module)

Knowledge holes in the design space: IT saw the project as "*a reimplementation of a new ERP*" (IT project coordinator) in which master data should be reviewed/maintained. However, the marketing key user expected the upgrade to maintain status quo, and was satisfied "*as long as data didn't cause processes to stop.*" Therefore, training was not taken seriously, and knowledge not mapped to daily practices.

IT would tell us to note down something…some terms I didn't even understand at that time… (Marketing key user)

In addition, the key user considered users as a threat to data consistency, and wanted to minimize their participation. IT thus suggested automatic migration of client master data to the new ERP, and one designated user to manage the data. The key user sent the junior administrative assistant to enter and verify the data. However, the assistant received limited training prior to starting the task. She did not understand the importance of the master data, and had little knowledge about on-the-ground processes.

…I mainly learnt the data structure on-the-job…Later, another admin assistant was assigned to join the task…she didn't know much about information systems. (Marketing administrative assistant)

The marketing key user adopted the IT solution as is without considering its impact on the assistant and the support the assistant needed. Due to the lack of other users' support/cooperation, the assistant could only perform the task perfunctorily. IT described this situation as *"garbage in, garbage out"* (IT, distribution module)

…we sent checklists to sales assistants to ask for their help to verify data…not many of them replied... (Marketing administrative assistant)

Thus, the task was delayed and quality was below par. The junior assistant and several sales assistants were forced to work during national holidays and experienced tremendous stress.

Table 4 summarizes knowledge holes and boundary spanning activities associated with the data management problem.

	Problem space	Boundary spanning	Design space
SCM division			
Syntactical hole (bridged)	•IT and key user described supplier data as obsolete	•Key user discussed with IT about operation anomalies (e.g., recurrent problems, slow systems) •Key user probed future usage/benefits of new data •Key user explained work procedures and discussed with IT contingency factors in their task environment (e.g., distributed data, non-participants' lack of support)	•Key user shared with IT the discourse about master data (e.g., a critical point of control) •Key user shared with IT the metaphors to describe IT solutions (i.e., house building vs. renovation) •Key user shared IT's data quality concern given the system environment (i.e., interface and language)
Interpretation hole (bridged)	•IT understood users' expectation for better analytics in the future	•Key user was walked through data-entry processes to visualize difficulties users would face	•Key user understood potential IT solutions and attendant risks

	•IT understood users' need for extensive data access	(e.g., unfamiliar system environment, work overload, tedious task)	
Consequence hole (bridged)	•IT understood the impact of the data-entry task to users	•Key user formed a team to sell the project and mobilize users	•Key user was aware of the importance of training and guidance for users to assure data quality
Marketing division			
Syntactical hole	•IT was concerned with data quality, but the key user was concerned with the deadline and format	•Key user did not probe to understand implications of the changed data structure (e.g., potentials, risks)	•Key user described the project as "another minor upgrade" (vs. "a reimplementation" by IT)
Interpretation hole	•IT lacked knowledge about activities user were involved	•Key user was overwhelmed and distracted by the amount of data •Key user maintained the status quo	•Key user accepted the proposed IT solution as is without questioning it or adding her perspective
Consequence hole	•IT underestimated the impact of the data-entry task on users	•Key user worked in her silo (e.g., barring users' participation and feedback)	•Key user ignored training/support/cooperation required for data-entry tasks

Table 4. Knowledge holes and associated boundary spanning activities

DISCUSSION AND IMPLICATIONS

Our study of an ERP upgrade project across two divisions in a large manufacturer reveals the importance of bridging knowledge holes for cross-functional IT projects. Within the ERP upgrade project, key users and IT (i.e., IT representatives for individual modules) brought in diverse knowledge, and served the role as boundary spanners. Research on structural holes shows boundary spanners are exposed to alternative ways of thinking, and are important for combining/synthesizing information across boundaries (Burt, 2005). The SCM division case particularly reveals how boundary spanners (the key user & IT representative) jointly synthesized information to develop common narratives in the problem/design space to guide or regulate their actions. The narratives were built on common syntax with intricacies of actual work practices (e.g., exclusive data ownership) and considerations of mutual interests (concerns of data quality/user workload). In contrast, the marketing key user and IT representative failed to integrate/interpret the information. They were overwhelmed by information and could not filter irrelevant information and identify important information for actions. Therefore, either wrong/incomplete problems were identified or wrong/incomplete solutions were imposed.

Our findings suggest bridging knowledge holes in the problem/design space is required for positive project outcomes. First, syntactical holes need to be bridged by common words/language in the problem/design space. The SCM key user and IT both recognized the problem was "obsolete data." Because the two were able to exchange information successfully, they could grasp the implications of this from the SCM users and develop plans to manage contingencies. Specifically, they realized to make this work would mean opening up data so SCM users could self-query, and that SCM users would need to be coached to understand how updated master data would benefit them.

Being able to visualize these consequences, in turn required both the SCM key user and IT appreciated how the changes would affect the SCM department. This in turn meant they had to understand the words the other used, translate words when needed to communicate consequences, and use the right words to persuade SCM users to take attendant responsibilities (e.g., acquiring skills for managing data).

In contrast, when the same scenario played in the marketing department, IT did not appreciate how the data-entry task would affect marketing users. Similarly, the marketing key user did not appreciate the changed data structure's implications. Therefore, simple solutions with damaging consequences (e.g., assigning untrained assistants to enter/verify data) were implemented. The failure of both IT and marketing to appreciate the on-the-ground situation and consequences of their actions similarly stemmed from different language and understanding of each other.

Our findings thus confirm the importance of spanning syntax, interpretation, and consequence holes. Our findings also suggest ways to bridge said holes.

Our findings suggest one way of bridging the syntax hole is via using common words/labels to build common narratives. Common narratives connect characters with a sequence of events that have shared meanings (Cunliffe and Coupland, 2012). Within organization studies, narratives are found to be a means of making sense of (Boje, 1995) or giving sense to (Currie and Brown, 2003) a situation. In the SCM department, the key user and IT used common words (obsolete data, a critical point of control, house building) to construct narratives to describe the problem/design space. They thus could make sense of and give sense to the difficulties users faced (e.g., concerns of other users' commitment) and IT solutions.

Second, at the interpretation level, more particularistic/local clues need to be integrated to the common narratives about the problem/design space. Through probing contingency factors and processes (discussed/walked through users' data-entry procedures), the SCM key user and IT gained insight into users' task environment, including direct, indirect, distal and near causes (e.g., system interface, task coordination, distractions) of some failure situations (e.g., data quality concern, perceived stress). IT thus could refine IT solutions accordingly (e.g., extensive data access for users).

Finally, consequence holes can be bridged by creating venues for stakeholders to negotiate problem scopes and learn new knowledge/skills. Because the SCM key user and IT routinely shared information, sought opinions from each other, and helped each other, a community of practice was formed beyond functional boundaries. The SCM key user also articulated her vision to users, arranged venues for their learning/working together, and consulted their opinions about decisions that would affect them. IT and SCM department thus could see mutual benefits in the project, collectively learn skills and knowledge, and value their new competence.

Our contributions build on a conceptualization of knowledge holes that is empirically studied in a real-life IS project. We demonstrate knowledge holes cannot be bridged before the syntactical, interpretation, and consequence holes in the problem/design space are bridged. Based upon Carlile (2002, 2004), our conceptualization provides a more nuanced theorization for analyzing events and actions within and across IS project boundaries. Our findings further suggest a shift of focus to boundary spanners' active practices and interaction for creating common narratives about those events and actions.

Our findings concur with the foundational role of shared syntax in bridging knowledge holes (Carlile, 2004). Shared syntax can not only be used to transfer information accurately, but help develop common narratives with local details and considerations of mutual interests to regulate one's thought/action.

Practically, this study explains how boundary spanners in big IS projects (e.g., key users/IT) may act to bridge knowledge holes. Our findings demonstrate boundary spanners bridge knowledge holes via building common narratives in the problem/design space. That is, boundary spanners use common labels/words/language to construct common narratives; integrate local clues from users' work context to said narratives; and create venues for negotiating problems and learning new knowledge.

CONCLUSION

The proliferation of specialized knowledge communities highlights the importance of boundary spanning. In this study, we propose and empirically study the concept of knowledge holes in a case study of an ERP upgrade. Our findings suggest bridging knowledge holes is a necessary condition for positive project outcomes. The concept of knowledge holes thus complements the concept of structural holes for explaining distinct project outcomes. Conditions for bridging the knowledge holes is to bridge syntactical, interpretation and consequence holes separating functional groups in large IS projects.

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