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ELICITING AND CONNECTING INFORMATION REQUIREMENTS: A STUDY OF BROKERING SITUATIONS IN DATA WAREHOUSE DEVELOPMENT

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Abstract

Information management and logistics rely on underlying data warehouse (DWH) systems. The development of DWHs brings together different communities of practice. In this paper, we concentrate on the role of DWH professionals as a brokering community in DWH development projects. We argue that each time they engage in brokering activities towards neighboring communities of practice, representatives from these communities take brokering roles as well. As a result, a so-called brokering situation resides within the social structure, which builds a brokering community. To closer observe the roles of DWH professionals within these brokering situations, we conducted in-depth interviews with experienced DWH professionals. Based on the analysis, we argue that the selection of the community's representatives with experience in neighboring communities can improve brokering situations. Objects exchanged between communities of practice during brokering situations can have either positive or negative effects, depending on their capacity and the type of complexity on the boundary.

Keywords: Data Warehouse, Requirements Engineering, Boundary Spanning, Boundary Objects.

1 INTRODUCTION

Today's analytical applications, in practice often described as "business intelligence" (BI), allow users to access data in support of decision-making (Watson & Wixom 2007). These applications fundamentally rely on an underlying data warehouse (DWH). DWHs are the data-foundation for information management (Krcmar 1997) and information logistics (Behme 1996, Winter 2008), the company-wide processes for planning, implementing, and controlling cross-unit data flows.

The development of a DWH, which requires huge capital spending and also consumes a good deal of development time, has a very high possibility of failure (Hwang et al. 2004). Fundamentally, most DHW development projects are large-scale IT projects with a significant and complex software component. Such information system (IS) development projects are inherently complex (Xia & Lee 2005, p. 46), caused by the broad scope, the large size, the heterogeneous IT infrastructure, and a multitude of different participants from different communities of practice (e. g., DWH experts, operational source system specialists, business experts, or managers and decision-makers). However, next to the acquisition and integration of information from a wide range of sources and stakeholders, the clear challenge, specific to the development of DWHs, lies in the determination and application of information that enables the identification and use of organizational competencies needed for reaching the competitive advantage on the market (March & Hevner 2007, p. 1034). In other words, DWH needs to support BI, that "is a process, not just a software product" (Miller et al. 2006, p. 8) and the key to successful processes are DWH professionals: developers who are informed of the process and can follow its dynamics. Therefore DWH professionals need to span over the boundaries of their community in order to receive necessary information from other participating *communities of practice* (1998). Consequently, developing a DWH is a complex team activity, bringing together a variety of heterogeneous communities of practices, "much more than in the realm of traditional transactional systems" (Horakh et al. 2008, p. 2). Each communities of practice owns specific knowledge (e. g., IT-specific knowledge or experience-based organizational knowledge) that needs to be integrated in the DWH specification (March & Hevner 2007, p. 1035). This gets very evident in more complicated or inter-organizational settings, for example, in information logistics projects for supply chain controlling (Holten & Dreiling 2003, Holten & Laumann 2004). The fact that DWH development occurs at the boundary between these specialized communities of practice domains (Winter & Strauch 2003) suggests that effectively managing knowledge across the communities boundaries in a DWH development project is what determines its success and what ultimately drives competitive advantage.

In BI practitioner literature (Miller et al. 2006, Zeid 2006) the concept of a BI competency center (BICC) was introduced as a recommendation how individuals with certain skills should be formally organized to support the development and operation of BI across different communities of practices within a company. Nevertheless, despite growing research in the fields of BICC (Horakh et al. 2008, Unger et al. 2008, Chasalow 2009), DWH project management (Vassiliadis et al. 2001, Winter & Strauch 2003, Winter & Strauch 2004), or success factors of DWH development projects (Chen et al. 2000, Wixom & Watson 2001, Shin 2003, Hwang & Xu 2008) we still lack a thorough understanding of how interaction between the participating communities of practice and their members, outside the realm of formal, organized structures such as a BICC, influences the DWH development process per se.

Previous research has identified necessary states, transitions, and participant-based enablers/inhibitors for successful requirements elicitation (Chakraborty et al. 2010). This had led to the recognition of necessary skills of participants from the perspectives of knowledge transfer, collaboration, and trust. Given the complex nature of requirement elicitation, however, other lenses are important as well for understanding this process. For example, requirements specification documents, data and process models, diagrams, or program code examples, which are instances of the "design boundary objects" discussed in the IS development literature, are all important in requirement elicitation. A design boundary object is "any representational artefact that enables knowledge about a designed system, its design process, or its environment to be transferred between social worlds and that simultaneously facilitates the alignment of stakeholder interests populating these social worlds by reducing design knowledge gaps" (Bergman et al., p. 551). As a result, we concentrate on the following research question: "How significant is the selection of the communities' participants (or 'representatives') in comparison to the use of (design) boundary objects for improving requirements elicitation in the DWH development process?"

The remainder of the paper is structured as follows. Section 2 discusses general and DWH-specific challenges of the requirements elicitation phase in IS development. We also discuss the role of communities of practice, boundary spanning, and boundary objects with regard to these challenges. Section 3 then presents our research approach and Section 4 the findings of our analysis. We argue that the existence of brokers and adequate boundary objects accelerates the process of requirements elicitation by allowing better creation of shared, common understanding. We discuss our results in Section 5. In Section 6, we summarize our findings, indicate the/its limitations, and conclude with an outlook on further research.

2 RELATED WORK

2.1 Requirements Elicitation in DWH Development

Several studies have revealed the importance of determining information requirements in DWH development (Wixom & Watson 2001, Watson et al. 2004, Winter & Strauch 2004) and translating those requirements into specifications based on a common vocabulary between IT experts and decision-makers (Rizzi et al. 2006). The resulting "shared" (Hirschheim & Klein 1989), "mutual" (Tan 1994), or "common understanding" (Tiwana & McLean 2003) has been repeatedly identified as a key determinant of quality of elicited user's requirements leading to IS development success (Siau et al. 2010). According to recent study results, so-called "limits of individual cognition" in requirements elicitation mostly stem from the inability of relevant stakeholders to articulate their needs concisely due to differing perspectives (Hansen & Lyytinen 2010). Moreover, the problematic relationship between business and IT as separate communities provides an outstanding challenge: "It has repeatedly been observed that business and IT professionals 'speak different languages' and apply differential yardsticks for desired outcomes" (Hansen & Lyytinen 2010, p. 4). We use the label "community" because it captures the sense of independent groups of individuals sharing the knowledge about a practice.

In support of this argument, recent studies (Ko et al. 2005, Chakraborty et al. 2010) argue that one decision appears to be highly relevant with respect to overcoming the aforementioned challenges: which members of the different communities to assign to a project. For example, user domain experts who not only have an intricate knowledge of the business processes, but also previous experience with technical aspects of development, appear to be important. The same holds for developers who have business knowledge and familiarity with the thinking of business people. This is also in line with Ancona and Caldwell's (1998, p. 27) view of project team composition. Applied to the context of knowledge sharing across communities of practice involved in DWH development, Ancona and Caldwell's (1998, p. 27) findings imply that there should be individuals with experience in bordering communities among the DWH developers who can respond to the diversity of the practices of external communities.

DWH developers or DWH professionals respectively thus form an important community in DWH development. Other involved communities are mainly operational source system specialists (OSPs) and, as the intended users of most analytical applications, business experts in decision-making fields (BEDFs). DWH professionals are in charge of eliciting all necessary information requirements from BEDFs and then, in collaboration with OSPs, try to identify source data in order to fulfill these requirements. OSPs usually have strong technical knowledge; however, they typically lack business domain knowledge. In contrast, BEDFs have strong business but not deep technical knowledge and usually do not engage directly or deeply with technical components or artifacts. All three communities are internally and informally bound by what they do on a daily basis and by what they have learned through their mutual engagement in these activities. Therefore OSPs, BEDFs, and DWH professionals differ from simple "communities of interest" because they imply a shared practice as well as a joint enterprise and a shared communication repertoire. Wenger (1998) defines communities with such characteristics as "communities of practice".

Communities of practice are usually considered to be voluntary groups that emerge from common work practice (Storck & Hill 2000, p. 65). For example, the practice of OSPs is in charge of designing, managing, and maintaining operational source systems, whereas the practice of BEDFs develops, and implements business strategies or makes informed decisions. We therefore assume each OSP community and BEDF community to be a separate community of practice. In case of DWH development, a multitude of different OSP and BEDF communities as well as DWH professionals can be found. Due to the fact that DWH development usually lasts for a longer period of time, we argue that DWH professionals also may form a community of practice over time.

2.2 Brokering and Boundary Objects in Requirements Elicitation

On the one hand, eliciting BEDF requirements in DWH development means for DWH professionals to meet and discuss with BEDFs. In these meetings, for example, definitions of sample reports can be used as examples of required information. Only through interaction of DWH professionals with BDEFs, who participated in the process of defining these reports, can a full understanding of the requirements be reached. On the other hand, in interaction with OSPs, DWH professionals concentrate on the technical design of extraction, transformation, and loading (ETL) processes (Kimball & Caserta 2004). Only in close cooperation with knowledgeable representatives from the OSP community can DWH professionals extract and interpret operational data so that it matches the BEDFs' requirements. Therefore we expect DWH professionals to engage in "brokering" (Pawlowski et al. 2000, p. 335), namely to manage coordination, knowledge transfer, and political maneuvering needed for information sharing across the borders of their community of practice.

However, brokering is not carried out only by DWH professionals. Instead, representatives from BEDF and OSP communities of practice may take brokering roles as well during the interaction. Therefore we define the concept of a *brokering situation* as a knowledge exchange situation with at least two boundary brokers from different communities of practice. During these situations all involved community representatives, not only DWH Professionals, can take brokering roles that facilitate knowledge transfer on the border towards neighboring communities of practice. Furthermore, we argue that the objects exchanged during these brokering situations (e. g., report print-outs, data models, and so forth) may as well play a significant role in mediating knowledge transfer between communities of practice.

Star and Griesemer (1989, p. 393) define the objects exchanged on boundaries between different communities of practice as "boundary objects" (BOs). In order to support negotiation and alignment in IS development, BOs need to represent, transform, mobilize, and legitimize heterogeneous design knowledge between all participating stakeholders. Bergman et al. (2007) define objects embodying these features as "design boundary objects" (DBOs). However, depending on the type of complexity the boundary faces, BOs with different capacities are required. Carlile (2004) scaled the relative complexity of the circumstances at the boundary using Shanon and Weaver's (1949) three levels of communication complexity: syntactic, semantic, and pragmatic. He argues that in case of mismatch between boundary faced and BO used, effectively sharing and assessing each other's domain-specific knowledge can be handicapped. To overcome this situation, good brokers help to introduce the reified objects from their community of practice to the others, when such translation is needed (Pawlowski et al. 2000, p. 335).

To sum up, we argue that brokers use BOs and DBOs within a brokering situation in the requirements elicitation phase to mediate knowledge transfer between participants from different communities of practice, thereby helping to align their different perspectives. The social structure concentrated around each brokering situation represents a *brokering community*. In many important aspects, our concept of a brokering community does not differ from the traditional perception of a project team. However, as discussed in (Vranesic & Rosenkranz 2010), we propose that successful brokering communities develop over time into a community of practice of its own. This community could later take on the formal role of a "BI competence center" (Miller et al. 2006, Zeid 2006). We argue that it is insufficient to focus on project teams in the traditional sense because most of the teams in an organization cease to exist after accomplishing their goal (Storck & Hill 2000). The analysis of brokering communities may also allow us the evaluation of effects lasting longer than the DWH development project itself.

3 RESEARCH APPROACH AND DESIGN

We conducted an exploratory study in order to address our research question. We collected data by expert interviews with 20 experienced DWH professionals that have been working on various projects in different industries, either in-house or as consultants (see Table 1). We conducted the interviews in two interconnected phases. The interviews lasted from 30 to 120 minutes. All interviews were recorded and transcribed. The interviewees averaged 7 years of experience in DWH development. All interviewees have a master's degree in computer science or related areas. The number of participants in the reported projects ranged from 4 to 70, with an average of 15. The durations of these projects were from 6 months to 6 years.

	Years in IS	Years in DWH	Reported projects	Industries	Phase I	Phase II
1	6	2.5	L, M	Banking/Telecomm.	X	X
2	8	8	Ω, E	Banking/ Energy	X	X
3	8	8	U, V	Telecom/Pub. Health Ins.	X	
4	12	2	Z	Higher education	X	
5	8	8	W	Higher education	X	
6	9	7	C, D, X	Banking/Insurance/Trading	X	X
7	10	7	Π	Telecom.	X	
8	10	10	A, Y	Banking/ Energy	X	
9	5	5	F	Trading		X
10	15	10	N	Telecom.		X
11	11	8	P, O	Trading/Metal Industry		X
12	4	3	H, I	Banking		X
13	6	4	J, K	Banking		X
14	6	6	G	Banking		X
15	3	3	R	Telecom.		X
16	8	8	E, S, T	Energy		X
17	5	4	Q	Telecom.		X
18	12	10	A, B	Banking/Tobacco Industry		X
19	11	11	A, B	Banking/Tobacco Industry		X
20	3	2	C	Banking		X

Table 1. Overview of Interview Subjects and reported projects from Phase I and Phase II

Phase I covered 8 open interviews. We applied a variant of the critical incident technique (Flanagan 1954). During phase I, subjects were asked: (a) to identify and discuss brokering activities and BOs within early phases of DWH projects; (b) for their impressions of the goals of BEDFs, of OSPs, and of their own goal for the project; (c) to describe the activities of DWH developers. Each of these open questions was followed by extemporaneous, probing ones. The findings from phase I were used to form the topic guideline for a series of semi-structured interviews in phase II that covered 15 semi-structured interviews in total. Phase II focused on exploring brokering situations in more detail. Related work implies that brokering roles are not only delegated to DWH professionals (cf. Section 2). We therefore tried to direct our questions towards revealing all possible factors that enable DWH professionals to successfully elicit requirements and what factors prompt OSP and BEDF participants to successfully share their knowledge with DWH professionals. We asked interviewees to be as inclusive as possible in their descriptions of: (a) the team's skills and the team's familiarity with the project's business domain; (b) individuals from the OSP and BEDF community, including their familiarity with the business domain as well as both the business and IT background of the data delivered by source systems; (c) all exchanged BOs/DBOs.

The interviews in phase I and phase II were coded by two researchers using MAXqda and open coding (Miles & Huberman 1994). Our categories for constructs emerged from the analysis of the interviews. We additionally analyzed the transcripts of each of the 15 interviewees in phase II using causal mapping (Fahey & Narayanan 1989, Nelson et al. 2000). As specific cause-effect pairs began to surface in the coding process, clarifying discussions were conducted with the same informants via instant messaging and/or e-mail in order to clarify open issues. Both coders iteratively revised the cause-effects pairs until they determined that all relevant themes were reflected (Eisenhardt 1989).

Figure 1 provides an example of the analysis table for the interviews for project C. It lists cause-effect pairs followed by the substantiating passages of the interview transcript. In the end, this process delivered a set of elemental cause-effect pairs that served as basis for the causal mapping. We consolidated all cause-effects pairs for each project separately. Next, we transformed each resulting analysis table into a consolidated causal map. For example, Figure 2 shows the consolidated map for project C. The causal relationships are presented in form of numbered arrows; the numbers referring to the codes from the first column in Figure 1. Positive or a negative influence of a variable is emphasized by including signs (+, -) on the connecting arrows.

4 ANALYSIS AND RESULTS

4.1 Analysis of Brokering Situations

Participation in requirements elicitation necessitates "a clear definition of business needs"(Hwang & Xu 2008, p. 52), exposing DWH professionals to problems that could be outside the realm of their competence in the customer's business domain. However, several interviews revealed that the DWH professional community responded to this challenge by bringing in community members who were most familiar with the customer's business. For example, for the project D, one developer reported:

> "*If you have experience in the customer's business branch, then you partially know what customers want from you. Although they have problems expressing themselves, you can adjust their statements and produce more fitting reports.* […] *We knew roughly how the DWH model should look like so we asked the 'right' questions.*" (Interviewee 6, project D)

Further analysis also revealed that specific BEDF members had already conducted data analysis and were therefore familiar with the meaning of the source data required for further DWH development.

> *"Perhaps they have worked with similar [reporting] systems before or they have managed to get the same functionality they later received with the new system by using, e.g., Excel. The goal is the understanding of data, and you generally have to do that on your own. Sometimes such people unexpectedly help you."* (Interviewee 1, project M)

We found similar examples of "knowledgeable BEDF brokers" in project C (Figure 1, code 3). These individuals as well possessed the necessary business domain knowledge in fields where DWH professionals were inexperienced (Figure 1, code 2). The BEDF and DWH brokers, however, did not possess a general overview of source data (Figure 1, codes 1, 3). This implies that they had insufficient IT domain knowledge. The involvement of a representative from the OSP community familiar with in-house built source system was therefore also necessary (Figure 1, code 5). However, in case the number of source systems is more than one, the reported episode for project A reveals that these members of the OSP community, who have a general overview of all data sources, play an important role in aligning the understanding of all relevant concepts and terms right from the start of the project:

> *"That system is very complex, only their ERP. They had people who were in charge of certain segments. We actually never talked to anyone who would be the architect of the entire system. …They did seem like islands over there.… I remember that there were problems... You know, a lady goes on maternity leave and now, the application works, but it's hard to catch someone who knows how to work with it."* (Interviewee 19, project A)

1	Has no source data general overview (DWH broker) & Has no experience with analysis of source data (DWH Broker) & Has experience with DWH development (DWH broker)
	DWH brokers were outsourced. Therefore they were not familiar with the source systems, nor with the analysis of the data coming from those systems. From the interview's introduction: DWH brokers had 7 years of experience in average working on DWH projects.
2	Has no experience with the customer's business (DWH Broker)
	Q: You have said, you had no experience working (developing DWHs) for this branch of business? **A**: Well, I didn't, definitively I didn't.
3	Has no general overview of the source data (BEDF broker) & Has experience with analysis of source data (BEDF broker) & Has experience with the customer's business (BEDF broker)
	Q: Those people, those two guys [BEDF brokers], what was their profession? How long have they been working for the company? **A**: They were economists working over 5-6 years for the company. **Q**: Were they very familiar with the business they were doing for the company? **A**: Yes **Q**: And they were familiar with reporting/working with reports? **A**: Well yes, they created reports. Although they were only economists, they worked with the data too: knew how the data was structured [on the business level] and their business as well
4	Has no experience with DWH development (BEDF broker)
	BEDF brokers were business users; no reference has been introduced in the interview to their possible knowledge of DWH development.
5	Has experience with analysis of source data (OSP broker) & Has experience with the customer's business (OSP broker) & Has source data general overview (OSP broker) & no reference in the interview to their possible knowledge of DWH development
	Q: Did you understand each other well with that department? Did you understand them better, if you compare it to the communication with users? **A**: IT dep. was very helpful in explaining technical side of the data. From the technical side, we understood each other great. The source system was only one and it was in-house developed.
6	DBO reviewing (confronting with the pragmatical boundary object) -> **Develop shared understanding**
	A: Have you ever referred to the document [fun. specification]? **Q**: Yes. The analysis document has approximately defined the scope and how the system will look like, what was actually the point of this document, but it wasn't a very accurate one. By having the scope defined, we were able to say "no" to postponed user's wishes. They would just start with: "We would like to have such and such security", "Sorry, it was defined differently." Reports definitions in the document were much more roughly described. We were lucky to have those milestones, during which we have figured out what we had done wrong.
7	Milestone meetings = Prototype reviewing (confronting with the pragmatical boundary object) -> **Develop shared understanding**
	We were lucky to have the milestone meetings while we were developing. We were presenting them the results of our development, allowing them just-in-time corrections. The end result was of a very good quality and they were very satisfied with the final product as well… Those milestones, during which they continuously corrected our work, saved us literally. They were able to express what they thought made sense and what didn't. ... The analysis phase of the project was very good and we succeded to cover users' wishes 80-90%. In the end of the project even 90%. The missing 10% were some differences we faced due to the fact that the users expressed themselves incorrectly... and only when they saw the [finished] system, they figured out that they had expressed themselves inaccurately/incorrectly.
8	Has no experience with the customer's business (DWH broker) & Has experience with the customer's business (BEDF broker) & Has experience with analysis of source data (BEDF broker) -> **Develop shared understanding**
	A: We talked to the four main users. With two of them we cooperated very intensively. We meet very often. **Q**: You had only one business area in this project? **A**: We had only one business area and we had meetings with those two main users weekly... When you don't know [the business], you need someone who does and who will always direct you in the right direction.
9	Defining functional specification using syntactical BO Has no experience with the customer's business (DWH broker) & Has experience with analysis of source data (BEDF broker) & Has experience with the customer's business (BEDF broker) ->**Did not develop shared understanding over time** **Change of BO (Prototype reviewing) -> Develop shared understanding**
	Q: In the beginning of the project they gave you an excel table with calculation? **A**: That is right. They gave us … a table with some calculations that defined: How some data is to be calculated… **Q**: So, it was all clear to you, in the analysis phase? Have you made mistakes during development that were connected with the wrong interpretation of the table? **A**: Well, one of the biggest mistakes, I wouldn't call them mistakes but misunderstanding, happened due to the fact that we understood something differently [from what they had in mind]. We have literally implemented according to their definitions in that table. When they saw an example in our prototype, they responded: "well, we don't want this in this way, but in the other way" …Second problem was that they have changed the table with calculations 4-5 times. When they said, for example, in one of the milestone meetings,… only after we put the developed prototype into production, they have realized that they've made a mistake [in definitions]. So they changed the table. **Q:** And without those milestones…they wouldn't be able…? **A:** No, they wouldn't be able to [get what they really wanted in the first place]…We would work, work, …and finished and then when they would be using the system, only then, they would figure out, that that was not what they wanted in the first place.

Figure 1. Excerpt from interview analysis for project C - codes and resulting cause-effect pairs followed by relevant passages from interview transcripts

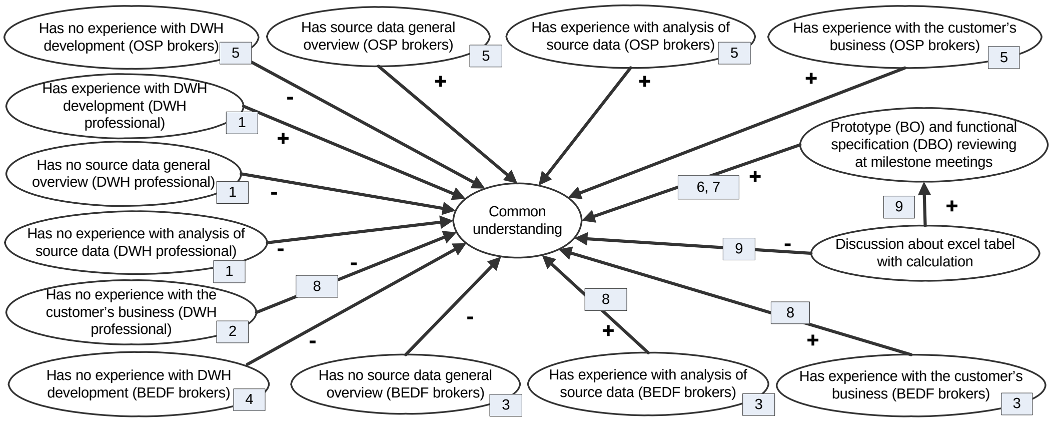

Figure 2. Sample consolidated causal map for project C

Furthermore, due to the fact that DWH technology already exists for several years, some companies already have running DWH implementations. Our findings imply that work experience with previous versions of such a DWH can influence the development of shared understanding between participants.

> *"… for a long number of years, actually, the company did have a warehouse of data and a reporting system based on those parts, however..for Sales, only for Sales, but some of the people were already familiar with it, part of the IT [OSP]...They worked on the ERP system and the warehouse. So, they managed well with the user needs. They know what the users could ask from them. They can manage in the whole story and they have some inside information on how all of it works."* (Interviewee 18, project B)

To sum up, our first major finding based on the iteratively revised codes from phase I and phase II (e. g., for project C, Figure 1, codes 1-5) is that *different types of previous experience influences brokers' overall competence*. We argue that all four factors - (1) experience with user's business, (2) experience with analysis of source data, (3) general source data overview, as well as (4) experience with (previously implemented) DWH development - play a significant role in the successful transfer of knowledge during requirements elicitation in DWH development projects (e. g. see Table 2).

Experiences in project C	DWH prof.	BEDF brokers (banking)	OSP brokers
DWH development	+	-	-
analysis of source data	-	+	+
customer's business	-	+ (general)	+ (familiar)
source data general overview	-	-	+

Table 2. Sample summary of brokers' experiences in project C (has = '+', has no = '-')

Chakraborty et al. (2010, p. 235) have already discussed similar types of developer-based (e. g., prior experience working with user's business, technical knowledge) and user-based factors (e. g., organizational knowledge) acting as enabler/inhibitors of the requirements elicitation process (cf. Section 2). However, previous research has grouped these factors according to participants' roles in the project. In contrast, our findings (especially from phase I) show that the line between those participants who possess necessary knowledge due to previous experience and those who do not was dynamically moving in the course of different projects.

For example, in case of an in-house DWH project W, the community of DWH professionals consisted mostly of members from the company (no external consultants), implying therefore that DWHs had a good understanding of the customer's business, as well as general overview of source data. For project E, one interviewee reported a situation where a member of the BEDF community was not only familiar with the source data, but had apparently participated in its development. This "power BEDF broker" was able to define his requirements by directly referring to the sources. In addition, he helped to define the ETL, hence exhibiting membership to both BEDF and OSP communities (Table 3).

> *"We've worked with quite an advanced user that had a degree in math, worked at first in the production department, afterwards in the IT department and de facto developed their information system, and now works in the department of strategic planning. He understands both IT and the company's business process, being able to sketch examples of reports he expected. We pretty much understood it all."* (Interview 2, project E)

Experiences in project E	DWH prof.	BEDF brokers (production)	OSP brokers
DWH development	+	-	-
analysis of source data	-	+	+
customer's business	-	+ (general)	+ (familiar)
source data general overview	-	+	+

Table 3. Sample summary of brokers' experiences in project E (has = '+', has no = '-')

Subsequent probing in phase II confirmed that the four aforementioned factors varied for each participating community from project to project. For example, the already reported episode from the project B, where DWH technology already exists for several years, shows that OSP members as well can become familiar with DWH development techniques (see Interviewee 18, project B). An episode from in-house Project F demonstrates that only few business departments (BEDFs in Table 4.) had experience with data analysis of source data due to the nature of their job. As a result, only two departments (D1, D2) had brokers who could articulate future system requirements and thereby help DWH professionals to better elicit requirements than the other departments (D3, D4, D5, D6):

> *"Most of them [users from D1, D2] knew exactly what they wanted and what they could get from the information system. They didn't have unrealistic requirements because they knew the system's limits (restrictions) and such things … they had that somehow in their heads. Most of the users who work with reports understand neither the DWH nor what is going on in the background [in D3 through D6], whereas they [users from D1, D2] had a good idea about it. There [in D3 through D6] were mainly business clients who knew how to define very good reports, but communication with someone, who has background in informatics [as in D1, D2], was much easier…"* (Interviewee 9, project F)

Our analysis also reveals that, in the absence of BEDF brokers (as for departments D3, D 4, D5, D6), OSPs who were familiar with those BEDF communities' business were able to compensate for ambiguous statements in users' requirement definitions:

> *"There were cases when users had a request that we could not understand. Then we explained them what they could get and what could not. Finally we have adjusted their requirements. Some of us were part of the department of informatics [OSP] and we were supposed to know the business side of the data very well. We could explain to the user what can be produced and what couldn't since we knew what data were available."* (Interviewee 9, project F)

Experiences in project F	DWH prof.	BEDF broker (D1, D2)	BEDF broker (D3, D4, D5, D6)	OSP brokers
DWH development	+	-	-	-
analysis of source data	+	+	-	+
customer's business	+ (familiar)	+ (general)	+ (general)	+ (familiar)
source data general overview	+	-	-	+

Table 4. Sample summary of brokers' experiences in project F (has = '+', has no = '-')

To sum up, our second major finding is that *a participant's knowledge is not necessarily role-related*. Each individual from one community of practice can become familiar with domain knowledge of another community and compensate for their missing or inaccurate semantic interpretations during brokering situation (e. g, cause-effect pair, project C, Figure 1, code 8). S/he may even become a member of a different community of practice based on experience and learning, as in the reported episode for project E.

Further analysis of our interviews revealed changes of community's representatives (projects J; R) as well as their early departure from the project (projects O). For example, an episode from Project J reports on positive influence after the switch of BEDF participants:

> *"Q: You told me, you were talking to three different people while you were collecting user requirements. The first one quickly went on maternity leave and then you were mostly working with the other two. What interested me ... You said that you thought this third person was the best and you had the best types of discussions with her.*
> *"A: Yes. The third had a better feeling for what can and what cannot be done, than the second one. And she was… we were able to get more information from her, when we were missing something, when we didn't know something, she would dig out more information, understand it better and explain it to us - all to a much greater extent than the second one."* (Interviewee 13, project J)

In contrast, our findings from the Project O show that the departure of the OSP broker even led to the project standstill.

> *"A: When the new owners arrived, they brought a man with them whom they appointed as IT director at the forge... However, all the others, his new IT department, who knew their old Cobol database – they would pull out certain data from there, print it out, but they had serious issues with Excel, something unheard of for us. You have an IT specialist who can't find his way around Excel, let alone doing something in more modern databases.*
>
> *Q: So who did you do the analysis with, with this manager (IT leader)?*
>
> *A: More or less, with him, since he had the technical skills and has been troubling himself with these people, dragging the information out of them, making them… that project did not end very well, since... I think there is now a Data Warehouse, being filled as we speak, but that man has given up in the meantime, he is through with quarreling with the IT-locals there. Now the whole thing is hanging in the air."*(Interviewee 11, project O)

To recap, we summarize our findings so far in the following propositions:

(H1) If DWH professionals lack a general overview of source data needed for DWH development or lack experience in working with users' business, brokers from other communities of practice can compensate for their missing or inaccurate semantic interpretations during brokering situations.

(H2) If BEDF brokers lack experience in analysis of the source data, brokers from other communities of practice can compensate for their missing or inaccurate semantic interpretations during brokering situations.

(H3) If OSP brokers lack a general overview of source data needed for DWH development, brokers from other communities of practice can compensate for their missing or inaccurate semantic interpretations during brokering situations.

(H4) Change of the brokering communities' members can influence the result of brokering situations.

4.2 Boundary Objects as a Nexus of Analysis in Brokering situations

Informants from all projects mentioned a wide range of BOs within the process of requirements elicitation (e. g., prototypes, functional and technical specifications, database documentation). Our analysis confirms Carlile's (2004, p. 560) classification of the relative complexity of the circumstances at the boundary. According to Carlile, if the communication border between two communities of practice is positioned on the syntactic level, a common lexicon suffices to specify the differences and dependencies of consequences at the boundary. In this situation, syntactic BOs can be used to support communication (Carlile 2004, p. 558).

For project C, for example, statements refer to the use of Excel spreadsheets with examples of required calculations in reports (Figure 1, code 9). During the first few brokering situations (e. g., pilot meetings) in project C, representatives from the BEDF community are reported to have shared requirements definitions with DWH professionals in form of old reports that were defined in Excel spreadsheets. The problem that the DWH professionals did not foresee was that although they possessed what Black et al. (2004) coined "operational knowledge", namely knowledge of how to create a DWH and to build a set of reports, they lacked "diagnostic knowledge". Our analysis indicates that the DWH professionals were not able to interpret the BEDFs' requirements in the form of old reports definitions (cause-effect pairs, Figure 1, code 9) given to them by BEDFs. They were also unable to look at an existing report and understand why it was set up the way it was. In other words, although the DWH professionals had experience of working in businesses similar to the one of the BEDF community, they were not equally proficient as members of BEDF community in terms of general knowledge about the business (Table 2). Their relative deficit of general BEDFs' business domain knowledge is reported to have hampered their ability to interpret the implicit knowledge embodied in exchanged BOs (old reports). The DWH professionals tried to guess the meaning of concepts or to use their "own" semantics to transfer knowledge, but they actually first needed to transform and align with representatives from the BEDF community the concepts' meanings semantically. This knowledge imbalance created a pragmatic boundary across which knowledge not only had to be transferred, but also had to be transformed into a "common lexicon" that DWH professionals could interpret.

In such situations, a DWH professional may think that s/he has understood what s/he has been told, even though s/he has not. DWH professionals might believe that they have reached a shared understanding with the BEDFs, whereas in fact they only experience an "illusion of evidence" (Bromme et al. 2005). For example, in project C, by the time DWH professionals and BEDFs jointly reviewed the first prototype, the DWH professionals realized their misinterpretations of the BEDFs' requirements based on the old reports. Thus, only after the switch to BOs that had adequate capacity (prototype) for discussions about the (semantic) meaning of the calculations, the DWH professionals were able to create a shared understanding with the BEDFs (cause-effect pairs, Figure 1, codes 6, 7).

Further, our analysis of in-house Project F reveals that in absence of BEDF brokers (as for departments D3, D4, D5, D6 in Table 4), OSPs who were familiar with those BEDF communities' business were able to compensate for ambiguous statements in users' requirement definitions. In other words, if OSP brokers were not involved in the brokering situation, the border between DWH and BEDF would have been pragmatic. In that case, developers would have to switch from the document with requirement definitions (syntactic BO) to BOs that have adequate capacity. However, due to the OSPs' involvement, exchanged BO between BEDFs and DWH Professionals was adequate.

We conclude that BOs and DBOs that do have adequate capacity are highly instrumental in enabling the fine-tuning of behavioral control. They enable higher-order knowledge to be shared between participants, particularly in cases where significant gaps in understanding were apparent. We argue that (a) BOs and DBOs in general form a nexus of analysis for brokering situations and based on the previous discussion, we formulate the following proposition:

(H5) If boundary objects with sufficient capacity are used during brokering situations, common understanding between the participants is developed with less difficulty.

5 DISCUSSION

Brokering situation are knowledge exchange situations with at least two boundary brokers from different communities of practice that use BOs and DBOs to mediate knowledge exchange. Previous research has already explored and conceptualized the process of requirements elicitation, with a specific focus on the dynamics of the interaction between the different project participants. This has let to a process model of the requirements elicitation phase (Chakraborty et al. 2010). Our analysis fits with this process model in that participants' previous knowledge influences the shared understanding between participants. However, we also found that a participant's knowledge is not necessarily role-related, as previous research has suggested. Furthermore, next to the people/participant-based enablers and inhibitors for successful requirements elicitation, BOs and DBOs play a significant role for knowledge transfer in brokering situations.

We argue that our analysis of brokering situations in DWH development projects, coupled with the "boundary object lens" we employed in Section 4.2, offers an important extension of Chakraborty et al.'s (2010) process model. Our findings refer to the first three states (scoping, sense-making and dissension) during which DWH professionals need to elicit and internalize broad knowledge about the system requirements from the BEDF representatives. Following from our findings and propositions, we suggest that requirements elicitation in IS development in general and DWH development in particular can be understood as *a chain of successive brokering situations*. We argue that during brokering situations the participants process not only the input combinations of participants' experiences into their changed outputs, but also different BOs and DBOs, ending either in the state of common understanding between all involved parties, or in failure leading to the unsuccessful termination of the project. We therefore argue that each brokering situation in DWH development projects is unique combination of participants' experiences and DBOs/BOs. Consequently, we suggest that brokering situations present a unique occasion both for changes in participants' experiences and for change of brokers and BOs/DBOs themselves as well. Overall, this conceptualization has four major implications:

(1) DWH professionals acquire knowledge of involved communities of practice in brokering situations via interaction with external community brokers by forming a brokering community.

(2) It is beneficial to choose the "right" representatives from involved communities of practice, that is, BEDFs and OSPs with experience in DWH development, analysis of source data, customer's business, and with general overview of source data.

(3) DBOs/BOs do not only have a positive effect on creating common understanding in brokering situations; if mismatched, they can also have a negative impact and their capacity is insufficient.

(4) In case a brokering situations ends in misunderstanding, change of BO/DBO or brokers can be beneficial.

Figure 3 summarizes our results in a conceptual research model. We group BOs into a category: "boundary objects with sufficient capacity" if a boundary-BO pair matches levels. We also aggregate all "has experience" variables (used in analysis tables and causal maps) in a single category "experience".

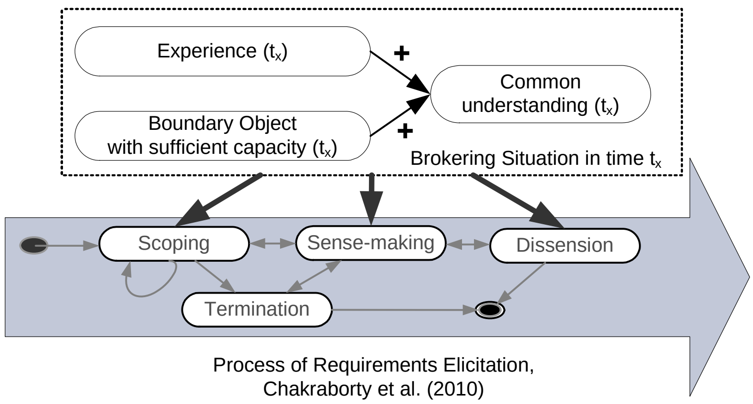

Figure 3. Consolidated model of brokering in requirements elicitation in DWH development

6 CONCLUSION AND OUTLOOK

In this paper, we reported on results from our study that investigates the role of brokering situations in contemporary DWH development projects. To closer observe the process of requirements elicitation, we conducted interviews with experienced DWH developers in two interconnected phases. The first analysis of our results indicates that brokering roles within brokering situations are not only delegated to DWH professionals; knowledge representatives from BEDF and OSP communities can take brokering roles as well. In regard to our research question, we showed that the selection of those community representatives with experience in boundary communities can improve brokering situations. Our analysis further showed that those communities' representatives can compensate for missing or inaccurate semantic interpretations of other participants within the brokering community. Therefore not only the selected individuals, but the resulting brokering community as a whole, can compensate for limits of individual cognition and challenges based on interpersonal processes. This improves the DWH development process per se. Moreover, our analysis revealed that BOs cannot only have a positive effect on creating common understanding in brokering situations, but that they may also have a negative impact if they are mismatched and their capacity is found insufficient for handling the complexity on the border between communities of practice. Finally, the results from our analysis revealed that in case a brokering situations ends in misunderstanding, change of BO/DBO or brokers can be beneficial.

Our study has limitations with regard to the data. For example, we conducted only exploratory expert interviews, however we are convinced that the reported projects introduce enough diversity for generalization. Moreover, the study itself, although illustrative, does not in any way test the findings being discovered. In order to alleviate these issues and confirm the consolidated model of brokering in DWH projects, we plan to conduct detailed case studies and surveys where we also want to explore the effect of different DBOs and IS development methodologies on brokering situations.

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