Antecedents and Outcomes of Boundary Objects in Knowledge Interaction in the Context of Software Systems Analysis

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Abstract

Much of knowledge management research has focused on knowledge generation, translation and storage during interactions among knowledge workers, which has led to project success; however, less effort has been made to examine the effects of artifacts or boundary objects that such interactions yield. Thus, the study aimed to help fill this research gap by investigating, not only the categories and characteristics of boundary objects, but also the possible antecedents, taking into consideration the link between outcome and type of boundary object. In the information system field, system design and implementation is a continuous process of interactions between system analysts and end-users, with most interactions occurring in the stage of defining system requirements. Thus, this stage offers an appropriate context to study knowledge interaction. Based on data collected and codified from 82 records of knowledge interaction, the results showed that project performance could be highly enhanced by making use of syntactic, semantic, pragmatic and metaphoric boundary objects. In addition, higher atmosphere leads to a higher frequency of the occurrence of semantic boundary objects. Although the results may be inevitably linked to the context being investigated, the importance of the expected findings will trigger like studies in other contexts.

1. Introduction

Over the past years, the broad concept of knowledge management has progressed and being enriched. Quite a few research topics have branched out from the field of knowledge management (Vorakulpipat & Rezgui, [1]), and a growing number of organizations have included knowledge management into their competitive strategies (Earl, [2]; Nonaka & Takeuchi, [3]; Mcadam & Mccreedy, [4]; Schultz & Leidner, [5]). As the essence of knowledge management becomes better understood, the keyword “interaction” is gaining its attention in this field. For example, Smoliar [6] believed that the next step in the field of knowledge management is interaction management, which involves the interactions among people, technologies and techniques (Bhatt, [7]). Since most innovation takes place at the boundaries between specializations (Leonard-Barton, [8]), spotlight should still be focused on people, especially those in different specific domains. These people are knowledge workers who use techniques and technologies to accomplish their tasks. In other words, the process of knowledge transfer across knowledge boundaries and the process of knowledge generation are conducted by knowledge workers. These processes involve interactions, including social interactions, which are critical to the quality of knowledge creation (Chua, [9]). Thus, organizations need to establish an environment that allows for sufficient opportunity for efficient interactions among knowledge workers and across knowledge boundaries (Nickson & Zenger, [10]), if efficient ways of producing knowledge or capabilities are desired.

In the field of knowledge management, the unit of analysis had often been knowledge workers instead of knowledge itself. Huang & Huang [11] is one exception. They switched the focus to knowledge itself and pointed out that knowledge interaction, in which the resource involved is actually knowledge, occurs when knowledge workers among different domains communicate with each other. The outcome of knowledge interaction, such as project collaboration across different domains, could be investigated in a concrete way inside or between organizations by observing the interaction between knowledge workers. Although there are many ways to achieve the objective of projects or knowledge interactions, boundary objects make possible an efficient way to assess knowledge, achieve mutual understanding and facilitate knowledge interaction (Star & Griesemer, [12]). Thus, boundary objects play an important role in leading to project success.

Knowledge interaction takes place everywhere and every moment within and between organizations. For
example, in the information system (IS) field, system design and implementation is a continuous process of knowledge interaction. During the development of an IS, system designers interact with end-users to identify relevant system requirements, trying their best to comprehend end-users’ tasks and procedures which are relating to the information system in organization. This effort produces the statement of feasible solutions. Since system analysts and end-user’s knowledge is somewhat confined within different domains, creating knowledge boundaries (Carlile, [13]; Carlile, [14]), relevant IS requirements would be obtained through the interaction or integration between these boundaries. Thus, the process of IS requirements identification provides an appropriate context to study knowledge interaction.

Franz and Robey [15] stated that end-users influence the different stages of system development: in the first stage, they explain and clarify their information needs; in the second, they describe their input and output requirements; in the third, they help in the formulation of system needs and objectives; and in the last stage, they ask questions and provide answers. Systems analysts need to make use of different strategies to elicit information from end-users, including using various types of boundary objects and developing interview skills, in the different stages. The study contends that most knowledge interaction between systems analysts and end-users occurs in defining the system requirements.

Regardless of the method used for system implementation, such as the system development life cycle (SDLC), prototype development, rapid application development (RAD), object-oriented analysis and design, component-based development (CBD), computer aided software engineering (CASE), joint application development (JAD) or agile methodologies, system requirements are the foundation of system implementation. Therefore, the study focused on the system requirements rather than the system coding stage.

System requirements that match end-user needs lead to successful information systems (Ives & Olson, [16]; Tait & Vessey, [17]). To obtain system requirements more efficiently, systems analysts should consider the use of boundary objects during knowledge interactions, and organizations should pay more attention to knowledge management initiatives on specific intermediate performance outcomes (Zack, Mckeen & Singh, [18]), including various types of boundary objects. This study argued that different types of boundary objects lead to different levels of project performance, and that the antecedents of boundary objects, including atmosphere, influence the frequency of occurrence of these objects. Hence, this study intended to answer the following questions:

What is the relationship between the frequencies of occurrences of different types of boundary objects and project performance? What is the relationship between atmosphere and the frequencies of occurrences of different types of boundary objects?

This study emphasized on both antecedents and outcomes of different types of boundary objects rather than merely the direct impacts of boundary objects, trying to understand what affect the occurrence of various types of boundary objects. The research result would not only augment the theorization of knowledge management but also offer insights into the causal chain involving boundary objects.

2. Literature review

Much of the knowledge management research has focused on the knowledge generation, translation and storage as a result of interactions among knowledge workers, which has led to project success; however, less effort has been made to examine the effects of artifacts or boundary objects that such interactions yield. Yet the link between project outcome and type of boundary object mandates the central role of boundary objects in the understanding of knowledge management. Hence, in this study, we investigated not only the categories and characteristics of boundary objects, whether explicit or tacit, but also the possible antecedents.

2.1. Boundary objects

The concept of boundary objects was first proposed by Star and Griesemer [12] and has been investigated in a number of studies (Briers & Chua, [19]; Carlile, [13]; Nosek, [20]; Carlile, [14]; Koskinen, [21]; Huang & Huang, [11]). By means of boundary objects, people in different domains who share a common goal can communicate, or translate, their viewpoints to build a common understanding across boundaries. Because these objects mean different things in different contexts, people must reconcile the different meanings to collaborate successfully. Huang and Huang [11] stated that boundary objects, whether explicit or tacit, can enhance mutual understanding and improve communication among people from multiple domains. Without boundary objects, however, the opportunity to achieve successful interaction is limited. Therefore, organizations should try to understand the nature of existing boundary objects to take more effective action to overcome existing barriers (Koskinen, [21]).

Various categories of boundary objects have been proposed in the literature. Star and Griesemer [12]
divided boundary objects into four categories: repositories, ideal types, coincident boundaries and standardized forms. Reframing Star and Griesemer’s list of boundary objects, Carlile ([13], [14]) argued that people can manage knowledge effectively across knowledge boundaries through the use of syntactic, semantic and pragmatic boundary objects. In addition, Koskinen [21] contended that vocabulary-based, or metaphorical, boundary objects, which include figurative language and symbolism, could enhance and support knowledge sharing within and between organizations in innovation processes. Expanding Carlile’s categorization scheme, Huang and Huang [11] proposed a new category, metaphorical boundary objects, which include nonverbal expressions (Nosek, [20]), figurative language and symbolism (Koskinen, [21]), visionary objects (Briers & Chua, [19]) and genres (Cook & Brown, [22]), and argued that identifying and facilitating useful boundary objects is the key to achieving better project outcomes. The present study extends Huang and Huang’s work, proposing that the different types of boundary objects lead to different levels of project performance. Based on this argument, the following hypothesis is proposed.  

**Hypothesis 1:** The frequency of occurrence of boundary objects is positively related to project performance.  

Based on Huang and Huang’s categorization scheme, the foregoing hypothesis is expanded as follows.  

**Hypothesis 1a:** The frequency of occurrence of syntactic boundary objects is positively related to project performance.  

**Hypothesis 1b:** The frequency of occurrence of semantic boundary objects is positively related to project performance.  

**Hypothesis 1c:** The frequency of occurrence of pragmatic boundary objects is positively related to project performance.  

**Hypothesis 1d:** The frequency of occurrence of metaphorical boundary objects is positively related to project performance.  

### 2.2. Atmosphere  

Communication climate is generally viewed as a subset of the organizational or work climate (Guzley, [23]; Trombetta & Rogers, [24]; Welsch & Lavan, [25]; Pritchard & Karasick, [26]; Abbey & Dickson, [27]). The organizational climate consists of a set of attributes perceived about a particular organization, and is based on the interactions among organizational members (Hellriegel & Slocum, Jr., [28]; Downey, Hellriegel & Slocum, Jr., [29]), whereas the communication climate refers to the accepted communication behavior of an organization (Putnam & Cheney, [30]). Dillard, Wigand and Boster [31] stated that the communication climate includes only the communicative phenomena in an organization, such as those perceptions directly involving the climate in which communication occurs. Thus, the communication climate represents a separate construct from the organizational climate, while sharing some common dimensions with it.  

Smidts, Pruyn and van Riel [32] measured communication climate and contended that a positive communication climate increases the level of identification of the individual with the organization. Van den Hooff and de Ridder [33] stated that the communication climate can range from supportive to defensive, and that a supportive communication climate is characterized by an overall culture of knowledge sharing, cooperative interaction and open information exchange.  

A number of studies have examined possible links between organizational climate and organizational effectiveness (Schneider, [34]; Schneider & Hall, [35]), treating climate as an independent variable. Communication climate, as a subset of organizational climate, has not been studied at length as to its relationship with organizational effectiveness. However a few relationships between the proxies of communication climate and those of organizational effectiveness were proven. Snyder [36] found that the quality of communication and information exchange were strongly related to critical revenue and overall organizational performance, while O’Reilly [37], O’Reilly and Roberts [38] showed that individual and group performance were directly affected by the ability to obtain information. Ali, Pascoe and Warne [39] stated that the communication climate affected the generation, existence and distribution of organizational knowledge. Also, Van den Hooff and de Ridder [33] found that a constructive communication climate significantly and positively influences knowledge sharing, including knowledge donating and collecting. With the belief that boundary objects are the mediating constructs of these relationships, the proposed study adopts communication climate as an antecedent of boundary objects and attempts to investigate its effect on project performance through boundary objects. In advance, based on the studies of Trombette and Rogers [24] and Guzley [23], the proposed study argues that some indicators of communication climate, termed atmosphere, will be indirectly associated with better performance, and that a more positive atmosphere will increase the level of a given member’s identification
with an organization. The authors intend to measure the atmosphere, an antecedent of boundary objects in knowledge interaction, referencing the communication climate constructs of interest to this study. The above review of literature suggests a general hypothesis of the relationship between the atmosphere and boundary objects:

**Hypothesis 2**: The atmosphere perceived by a systems analyst is positively related to the frequency of occurrence of boundary objects.

As the study framework includes four types of boundary objects, namely, syntactic, semantic, pragmatic and metaphoric, the foregoing hypothesis was expanded as follows.

**Hypothesis 2a**: The atmosphere perceived by a systems analyst is positively related to the frequency of occurrence of syntactic boundary objects.

**Hypothesis 2b**: The atmosphere perceived by a systems analyst is positively related to the frequency of occurrence of semantic boundary objects.

**Hypothesis 2c**: The atmosphere perceived by a systems analyst is positively related to the frequency of occurrence of pragmatic boundary objects.

**Hypothesis 2d**: The atmosphere perceived by a systems analyst is positively related to the frequency of occurrence of metaphoric boundary objects.

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### 3. Research method

#### 3.1. Subjects

82 college seniors majored in IS from two sections of the same IS project course were recruited. As a major part of the course requirement, student analysts defined information system requirements of various real business cases. These student analysts were reasonable proxies of practical world system analysts, because they were in graduation class and ready for job market. Each class was taught by the same instructor in the same semester, using the same teaching materials and under the same learning conditions. This course has been offered for the past eight consecutive years.

#### 3.2. Procedure

To investigate knowledge interaction in terms of collaboration between, and performance of, two actors in different domains, questionnaires were administered to 82 student system analysts and 82 end-users. Student analysts were aware that they are involved in a project in which performance will be measured, but blinded to the research hypotheses.

Each knowledge interaction was observed for actors from different organizations. Each student analyst was assigned a real business case, and during the semester the student analysts communicated with a user from the business firm to acquire the system requirements. The main task was website design. For example, one student helped a baker to develop an information system plan for a Web site to promote the bakery, or helped a pet shop or print shop owner with such a plan for a Web site to market the shop’s products and services.

Final project reports comprised of the system requirements for the companies. Students also had to record their working hours per week on the project, including their attendance at organizational meetings and interviews. After the projects had been completed, an expert interviewed student analysts to assess their perception of the atmosphere in the knowledge interaction. Besides, the expert also codified the frequency of occurrence of boundary objects and graded project performance according to final reports and the recordings of interviews, respectively. The research model shown in Figure 1 was tested using the codified data of atmosphere, boundary objects and project performance.

#### 3.3. Measurement

The independent variable in this study was perceived atmosphere. It was codified by an expert and described below. The frequency of occurrence of boundary objects were codified by an expert according
to the classification table that follows. The dependent variable was each student’s project performance, which was graded by the same expert based on the student’s IT implementation report. The measurement of each construct was described as follows.

**Boundary objects.** The frequency of occurrence of boundary objects were codified according to the following classification table, which was modified from that of Carlile ([13], [14]), by an expert who reviewed the interview data.

**Atmosphere.** Appropriate items were chosen from the 35-item organizational communication scale (Roberts & O’Reilly, [40]) to evaluate the atmosphere perceived by the students who play the role of systems analysts. Those items were mainly focused on measuring the degree of willing cooperation, which was based on mutual sincerity. Then, referencing those items, an expert interviewed each student analyst and codified the atmosphere of each knowledge interaction from the statement as a 5-points scale.

**Project performance.** Project performance was measured based on the final project reports. Each report included a detailed description of the work done during the semester and the final IT implementation suggestions made to the company.

4. Results

4.1. Data analysis

The proposed model was assessed with maximum likelihood estimation using AMOS. All calculations were based on the covariance matrix of the variables. Five common model-fit measures were used to assess the model’s overall goodness of fit: the ratio of $\chi^2$ to degrees of freedom (d.f.), goodness-of-fit (GFI), adjusted goodness-of-fit index (AGFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA).

Table 2 shows the Pearson correlations for the study variables. With relation to the proposed variables, the atmosphere was not significantly related to syntactic boundary objects, pragmatic boundary objects, metaphoric boundary objects and project performance ($r=-.034$, $r=-.096$; $r=-.006$; $p>.05$), while four types of boundary objects were all significantly related to project performance. In addition, metaphoric boundary objects were also significantly related to other types of boundary objects, including syntactic, semantic and pragmatic boundary objects.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Syntactic</td>
<td>Ordered &quot;piles&quot; of objects that are indexed in a standardized fashion. (Star &amp; Griesemer, 1989)</td>
</tr>
<tr>
<td>Semantic</td>
<td>Standardized forms and methods such as objects devised as methods of common communication across dispersed work groups. (Star &amp; Griesemer, 1989)</td>
</tr>
<tr>
<td>Pragmatic</td>
<td>Objects, models and maps that have the same boundaries but different internal content. (Star &amp; Griesemer, 1989)</td>
</tr>
<tr>
<td>Metaphoric</td>
<td>Objects such as a diagram, an atlas or other descriptive element that does not in fact accurately give the details of any one locality or thing. (Star &amp; Griesemer, 1989)</td>
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<tr>
<th>Table 1. Type and description of boundary objects</th>
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<th>Table 2. Correlations among variables</th>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Syntactic B. O.</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Semantic B. O.</td>
<td>.252*</td>
<td>1</td>
<td>.138</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Pragmatic B. O.</td>
<td>.310**</td>
<td>.245*</td>
<td>.282*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Metaphoric B. O.</td>
<td>-.034</td>
<td>.248*</td>
<td>-.096</td>
<td>-.006</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5. Atmosphere</td>
<td>.512**</td>
<td>.456**</td>
<td>.551**</td>
<td>.537**</td>
<td>.107</td>
<td>1</td>
</tr>
<tr>
<td>6. Project Performance</td>
<td>.246**</td>
<td>1</td>
<td></td>
<td></td>
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</table>

Note. *p< .05  **p<.01  ***p<.001
**Figure 2. Standardized path coefficients of the proposed model (Model 1)**
(Note: The dotted lines indicated not statistical significant)

**Figure 3. Standardized path coefficients of the final model (Model 2)**
(Note: *p< .05. **p<.01 ***p<.001)
4.2. Structure model

Because we made no prediction as to whether or not the relationships in the model would be significant in advance, we tested two competing models: a proposed model (model 1; shown in figure 2) and a final model, which is appended and had several paths deleted (model 2, shown in figure 3). The difference between these two models is described as follows. First, while model 1 has three more direct paths than model 2, namely paths from atmosphere to syntactic, pragmatic and metaphoric boundary objects respectively, shown in Figure 2, these direct links were not statistically significant (β = -.034, β = -.096, β = .006, p > .05), disconfirming hypotheses 2a, 2c and 2d. Thus, these paths are deleted in model 2. Second, according to the path suggestions made by AMOS 7.0, two direct links are appended to model 2. While the first link between metaphoric boundary objects and semantic boundary objects was significant, the second link between syntactic boundary objects and semantic boundary objects was not (β = .19, p > .05).

We then compared model 1 and model 2 that include the paths running from Syntactic boundary objects and Metaphoric boundary objects to Semantic boundary objects, respectively. The results indicated that the final model ($\chi^2$ (5, N = 82) = 2.742; GFI = .989, AGFI = .954, CFI = 1, RMSEA = .000) had a much better fit ($\Delta \chi^2 = 30.911$, p < .01) than the proposed model ($\chi^2$ (7, N = 82) = 33.653; GFI = .861, AGFI = .582, CFI = .729, RMSEA = .217). Therefore, we preserved the better fit model (Figure 3, model 2) as the final model and used it to examine our hypotheses.

All standardized path coefficients of semantic boundary objects, shown in Figure 3, were statistically significant except for the path running from syntactic boundary objects to semantic boundary objects, thereby offering support for hypotheses 1a, 1b, 1c, 1d and 2b. In addition, each type of boundary object was significantly related to project performance, and the R2 indicates that 59.7% of the variance in the project performance was explained by four types of boundary objects in the model.

5. Conclusion

This research empirically examined how different types of boundary objects affect project performance. The effects of an antecedent variable were confirmed; this was atmosphere. The results showed that knowledge interactions in which four types of boundary objects are applied are better in achieving project performance. Additionally, atmosphere positively influences the frequency of the occurrence of semantic boundary objects, which is also proved to be positively affected by the frequency of the occurrence of metaphoric boundary objects.

In the context of system analysis, a very important practical implication is the possibility of increasing project performance by promoting the frequency of the occurrence of four types of boundary objects, especially the metaphoric boundary objects. As Koskinen [17] stated, metaphoric boundary objects could be diffused rapidly throughout organizations. This is a more effective way to enhance the outcome performance of knowledge interaction by asserting metaphoric boundary objects which could result in semantic boundary objects. In other words, organizations should pay more attention to making use of those boundary objects, if better outcome of knowledge interaction is wanted. In addition, while it is very difficult to judge the degree of influence of the antecedent factors of boundary objects, sensible organization should consider taking actions to enhance the atmosphere of knowledge interaction.

In conclusion, the findings of this study contribute to the theory building concerning the effect of boundary objects on knowledge management. By identifying the possible antecedent of four types of boundary objects and answering the how and why aspects of the relationship between boundary objects and project performance, the results significantly contribute to the development of the theory.

5.1. Limitation and future research

A few limitations of this study should be noted. First, the research results may be linked to the context being investigated. Therefore, to confirm the applicability of the findings to other contexts, the research model will need to be tested in various settings. When further research has been conducted and the contexts have been categorized, a general conclusion can be drawn with greater confidence.

Second, the frequency of occurrence of four types of boundary objects, project performance and atmosphere could be assessed by two or more independent raters, who are experts and blinded to the research hypotheses, rather than just one rater in the study, if a more objective evaluation is required. Third, the study focused on the relationships between all types of boundary objects and project performance, but the relationships between different types of boundary objects should be investigated to fill the gap in the literature.

Finally, although atmosphere was only showed significant results in semantic boundary objects, it may be due to the definition of atmosphere in the study. Future research may refine or expand the construct of atmosphere. After all, atmosphere could be the tipping point.
point of a series of future studies in identifying antecedents of boundary objects.

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