An Integrative Concept for Artifacts and Boundary Effects in Innovation Activities

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The presented research focuses on inter-organizational innovation activities, where information systems (IS) enable the knowledge exchange between involved actors. The resulting interactions can be described with help of the boundary object concept. Boundary objects are generally studied as single information technology artifacts. Offering the view of boundary objects as elements of a boundary infrastructure, the integrative concept of "composite boundary objects" is developed, which comprises a portfolio of artifacts. A qualitative study has provided evidence that this new concept is able to extend the explanatory power of the boundary object idea in explaining coordinative effects.

Keywords: Boundary Objects, Composite Boundary Objects, Inter-Organizational Innovation, New Product Development

1. Introduction

Organizations are recognized today as part of business ecosystems that conduct activities with business partners in a cooperative fashion 18. The role of information systems (IS) in inter-organizational cooperation, and in cooperative innovation activities in particular, is significant 13.

Information systems enable and constrain the sharing of knowledge within teams of experts, or communities of practice, that come together across organizational and functional boundaries for a particular innovation project 6,9,52. Rarely are the systems used isolated pieces of software; they are more often parts of a larger portfolio of systems employed to accomplish cooperative activities 1. It is vital to understand, manage, design, and use these IS resources by establishing appropriate management processes 30, 36, 44. A large body of literature exists that emphasizes the significance of IS in cooperations, addressing issues such as appropriation 49, adaptation 34, or adaptive structuration 19. Yet the *coordinative effects* IS can trigger, provide a largely unaddressed problem in this area. Coordinative effects can occur as changes in the cooperative behavior of actors, in their decision-making, in their uses of artifacts, or in other alterations of work arrangements that influence the overall cooperation process. They influence the efficiency and effectiveness and hence, the success, of cooperation processes, and thus play a vital role for the management of inter-organizational cooperations.

The concept of boundary objects is well established in literature on knowledge sharing and re-use 11, 47. Boundary objects are used to understand interactions between actors with varying information and knowledge needs. Boundary objects emerge within such scenarios, allowing information and knowledge to flow between actors often without requiring prior consensus on rules for interactions – and to be interpreted in individual contexts, "reframed in the context of a wider collective activity" 3,28. While this vital role of boundary objects has been recognized in IS literature, less attention has been paid to the process of emergence of boundary objects and infrastructures of boundary objects (or "boundary infrastructures" 7, 46). For most of the contributions to research, boundary objects are studied in their manifestations as single information technology (IT) artifacts such as a database or spreadsheet (e.g. 22). This article offers the view of boundary objects as elements of a boundary infrastructure, comprising a portfolio of separate artifacts, which is referred to as "composite boundary objects"43.

The research presented here calls for a shift of focus in IS research on boundary management and on IS support of knowledge management, moving away from considering isolated artifacts, towards clusters or environments of communication. In the following, a conceptualization of composite boundary objects as well as an approach to explain their emergence and their significance in the context of inter-organizational innovation activities are provided.

2. Literature Review

Managing Knowledge in Inter-organizational Innovation Projects

An important source for a firm's competitive advantage lies in its network of external relationships 18. In order to benefit from those relationships, besides the capability to manage an organization's internal knowledge 2, 21, 45, acquiring and integrating knowledge from outside the firm is vital 14. One possibility to gain access to external knowledge is to form partnerships for knowledge generation and co-creation 17. A considerable amount of literature exists on the cooperative, "open" flow of ideas and knowledge, as well as on knowledge exploration and exploitation 14, 38, that is related to the management of knowledge in inter-organizational partnerships. Surprisingly, relatively less attention has been paid to *collaborative knowledge creation*, and the processes, practices, and tools that support generation and elaboration of new knowledge 24.

Such processes are particularly important in inter-organizational innovation project teams in the early phases of the New Product Development (NPD) process, which target at disruptive innovation. Primary characteristics of this context are the novelty of created knowledge and the novelty of resulting tasks to be carried out 15. The particular importance of tacit knowledge and specific expertise in these phases makes it difficult to introduce highly formalized processes 25, 42. This creates uncertainty regarding the process and outcome of knowledge exchange, and generates high requirements for the management of such activities 16, 50. While providing access to external resources is vital to the development process 27, the management of inter-organizational communication can prove complex. In general, this context defines a set of unique boundary conditions in terms of managing resources 20 and puts high demands on the dynamic capabilities of organizations 21,48,53. Particular attention must be paid on *how to coordinate* teams that

collaboratively create knowledge, considering in particular the appropriate IS support as a critical enabler. Eventually, IS support for team coordination needs to be dynamically altered with the progressing innovation process 34, 35, 49.

Often, interactions that occur between actors during the early phases of innovation involve informal processes of networking and information sharing 8,37. Various integration mechanisms such as access to communication channels or coordination through social norms may motivate or inhibit cooperation 23. In an optimal scenario, team members recognize each other's competences and "accomplish tasks by acting as a coordinated unit" 26. In such phases, structuration processes are taking place, which allow for knowledge exploration, creation, sharing and transformation between involved actors 19. A theoretical construct that describes such processes are "boundary objects" as discussed next.

3. Boundary Objects

The concept of boundary objects was introduced by Star and Griesemer 47 as a way to explain coordination between actors with different knowledge backgrounds or viewpoints. Boundary objects establish a shared point of reference for individuals to represent their knowledge during interactions 11. Boundary objects can be concrete objects like a spreadsheet or prototype, or abstract concepts like a symbol or shared experience, which however possess some "interpretative flexibility" 5,41. Star 46 emphasizes that boundary objects are at once temporal (existing temporally, and eventually changing), based in action, i.e., part of a process of understanding, and subject to reflection and local tailoring.

Carlile 11 points out that for boundary objects to be effective, they need to (i) "[establish] a shared syntax or language for individuals to represent their knowledge", (ii) "provide a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary", and (iii) "[facilitate] a process where individuals can jointly transform their knowledge". He refers to the mentioned three aspects as syntactic, semantic and pragmatic. They are illustrated in Table 1.

Syntactic knowledge boundaries arise due to inconsistencies in the terminology used, or due to lacking availability of facts and data that need to be shared between actors. Establishing a shared and stable syntax solves the information processing, or transfer, problems of such a boundary. Repositories such as databases provide a common reference point of data, measures, or labels across functional areas that establish shared definitions and (data) values for problem solving.

Semantic knowledge boundaries arise when, despite a common syntax, interpretations differ, maybe because of differing contexts 51, causing communication problems. This can be considered as a problem of knowledge communication between the actors. Nonaka and Takeuchi 37 suggest making tacit knowledge or implicit interpretations explicit. Techniques include verbal approaches such as story-telling 10, or codifying knowledge in standardized forms and methods, such as establishing best practices 17. Utilizing such means in order to translate knowledge between actors is intending to overcome this boundary.

Pragmatic knowledge boundaries arise when knowledge needs to be transformed between actors in order to reach a shared understanding. This involves the notions of knowledge creation and alteration by each actor. Hence pragmatic boundaries are not limited to representing one's knowledge for the purpose of communication, which

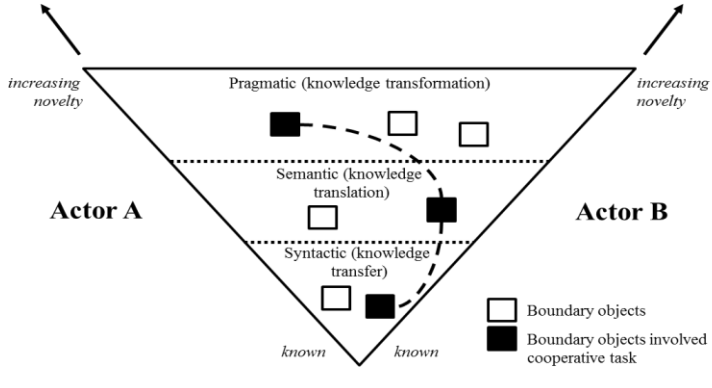
includes syntactic and semantic differences, but includes an individual development process. Thus, pragmatic knowledge boundaries shape boundary objects that are dynamic and enable collaborative sense-making. In terms of IT artifacts, this can comprise models or maps which are exchanged and collaboratively altered by the actors. Pragmatic boundary objects encapsulate all three characteristics outlined in Table 1.

Table 1. *Types of Knowledge Boundaries, Boundary Objects, and their Characteristics Based on Carlile* 11

Type of Knowledge Boundary	Category of Boundary Object	Characteristics of Boundary Objects
Syntactic	Repositories, databases	Representing (enabling a shared, common point of reference)
Semantic	Standardized forms and methods	Representing and learning (enabling knowledge transfer due to shared reference)
Pragmatic	Objects, models, and maps	Representing, learning and transforming (enabling a process where individuals can jointly transform their knowledge)

Carlile 12 formulates suggestions for managing knowledge across boundaries, with respect to the three types of boundaries outlined, which he views as levels. The resultant framework is depicted in Figure 1. This framework illustrates in particular the role of boundary objects with respect to cooperative tasks two actors need to accomplish. The pyramid shape in Figure 1 opens up a spectrum, or "continuum" 46 of tasks between well-known ("known") and novel tasks ("increasing novelty"). Actors A and B interact within this spectrum with correspondence to boundary objects that exist on the three levels.

Figure 1. *Framework for Managing Knowledge across Boundaries Based on Carlile* 12



The role of IS in spanning syntactic and semantic boundaries has been studied extensively in IS literature (e.g. 32,33,39,6). Relatively less attention has been paid to the role of IS in supporting boundary objects that span pragmatic boundaries.

And, no research could be identified by the author of this paper that studies the interplay in between boundary objects that exist on different levels.

Carlile 11 states that in New Product Development (NPD) the concept of pragmatic boundary objects "*provides an infrastructure or process where current and more novel forms of knowledge can be jointly transformed, producing more shared knowledge or syntax at the boundary*." This process however requires a knowledge base with objects on the semantic and syntactic layers. As a result, this insight stimulates the adoption of boundary objects *at all levels* for the context of the study presented here.

In general, the boundary object concept explains well the knowledge exchange between actors, and the principle occurrence of coordinated interaction, but it does not account for changes in the decision-making or the cooperative behavior of actors with respect to coordination. It is likely that, to achieve different objectives, interactions between actors and artifacts occur at different times and levels, eventually involving a mix of boundary objects. This consideration motivates an extension of the notion of boundary objects as outlined in the following paragraphs.

4. Integrative Concept for Artifacts and Boundary Effects in Innovation Activities

Adopting a boundary perspective, the management of innovation activities in the context of inter-organizational cooperation might profit from better understanding and considering the interplay between involved actors and artifacts. This interplay can include IT and physical artifacts, work arrangements, processes and uses, such as cooperation methods, or management routines as boundary objects on the one hand, as well as individual and team sense-making, or coordination processes of actors as "boundary effects" on the other hand. In this work context, usually various different IT artifacts are used in parallel. Those groups of artifacts may comprise the description of a product idea in a document, data on materials or simulations in a data base or technical files, a virtual prototype, a web-based cooperation platform, a work flow-based application software and others. In particular cases, a *single* artifact, e.g. a certain structure for describing a product, might be sufficient to coordinate between actors, forming a boundary object (as outlined e.g. in 4). In other cases however, this might not suffice, and a coordinative effect is established only by the interplay of *several* artifacts, arrangements etc.

Building on this idea, an extended conception of boundary objects can be conceived, which is in particular directed towards analyzing boundary effects in cooperations. In a case study of an innovation network of small and medium sized enterprises the researcher team has collected empiric evidence suggesting that *several artifacts together* can provide for boundary effects. On basis of episodic interviews, incidents—or events—have been identified which triggered coordinative effects. In such cases, the interplay and configuration of several artifacts together influenced the involved actors in their cooperative behavior or decision-making. Such incidents were for instance the achievement of a project milestone, or the introduction of a new collaboration tool in the team. This interplay of artifacts from different types of knowledge boundaries is highlighted in Figure 1, as boundary objects involved into a cooperative task.

While the concept of boundary objects has been applied in the context of IS in order to trace the occurrence of coordination, the idea of explicating their role in providing for coordinative effects—that occur due to the interaction of multiple artifacts— has not been considered in literature. Hence, a *composite boundary object* can be conceived of as a *portfolio of artifacts, work arrangements, processes and uses that enable representation, learning, and/or transformation of knowledge between actors cooperating across boundaries*.

It is reasonable to assume that during the lifetime of a composite boundary object, its composition may change, and with it its significance towards boundary effects, such as coordination. The emergence of composite boundary objects ought to be studied with respect to the particular set of conditions regarding the cooperation context, the actors, the artifacts, and the tasks involved.

5. Conclusion

The research question underlying the outlined study was, to what extent boundary objects as reference points of knowledge exchange are significant for coordination. In order to characterize the emerging landscape of boundary objects, a framework developed by Carlile 11,12is used. With help of this framework boundary objects can be grouped according to three knowledge boundaries. Other authors report that boundary objects themselves can provide for coordination (e.g. 3, 4, 31, 32, 28, 29, 40). Results of the study outlined here suggest that in the context of certain incidents, artifacts, work arrangements, processes and uses can form alliances. In such incidents, these alliances (portfolios, sets, compositions)—or *composite boundary objects*—have significance for the coordination of actors.

The coordinative effects IS can trigger provide a largely unaddressed problem in the area of inter-organizational cooperative innovation. The author believes that the concept of composite boundary objects as abstract auxiliary concept is able to extend the explanatory power of the boundary object idea in explaining these coordinative effects.

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