

2016

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Citation of this paper:

Huvila, Isto; Anderson, Theresa Dirndorfer; Jansen, Eva; McKenzie, Pam; and Worrall, Adam, "Boundary Objects in Information Science" (2016). *FIMS Publications*. 156.
<https://ir.lib.uwo.ca/fimspub/156>

Boundary Objects in Information Science

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Abstract

Boundary objects are abstract or physical artefacts that exist in the liminal spaces between adjacent communities of people. The theory of BOs was originally introduced by Star and Griesemer in a study on information practices at the Berkeley Museum of Vertebrate Zoology but has since been adapted in a broad range of research contexts in a large number of disciplines including the various branches of information science. The aim of this review article is to present an overview of the state of the art of information science research informed by the theory of BOs, critically discuss the notion, and propose a structured overview of how the notion has been applied in the study of information.

Keywords

information science, boundary objects, boundaries

Introduction

This article takes as its subject the concept of the boundary object (BO), introduced by Star (1988) and discussed in detail by Star & Griesemer (1989). BOs are known as being abstract or physical artefacts that exist in the liminal spaces between adjacent communities of people. The communities may consist of informal groups or communities residing within organisations. BOs have the capacity to traverse perceptual and practical differences among communities and facilitate cooperation by fostering mutual understanding (Karsten et al., 2001). They negotiate meaning and help to understand and articulate connects and disconnects between communities, cultures, and information infrastructures. Extant BOs are said to help identify where these gaps and bridges can be found as well as to see how such gaps and bridges function. Over the past twenty years, we have come to think of and communicate about BOs across research paradigms, disciplines and practices. As of April 2016, Star & Griesemer's original 1989 article has been cited over 6300 times in Google Scholar and 1932 times in Web of Science (with 217 in 2014 compared to 47 in 2004), a telling indication of the influence of the concept.

In what ways does the concept of the BO offer a theoretical perspective and interpretive device that contributes to research and knowledge building across the cognate disciplines of information? Our goal is to contribute to disciplinary understanding of the limits and potential of this influential concept by describing how the concept is operationalized and understood generally, assessing the state of the art of this key theory among the cognate disciplines of information, and proposing directions for further inquiry.

Concept of Boundary Objects

Star and Griesemer (1989) described the notion of BO in their pioneering work on information practices at Berkeley's Museum of Vertebrate Zoology during the first half of the 20th century, after Star briefly introduced the concept in 1988 (Star, 1988). They described BOs as translation devices and argued that shaping and maintenance of BOs is central to developing and maintaining coherence across communities. According to Star and Griesemer (1989), BOs are a premise for communication, cooperative work, and having and reaching mutual goals. They identified four different types of BOs used at the Museum of Vertebrate Zoology: repositories of things ("ordered piles of objects"), ideal types (e.g. diagram, atlas), coincident boundaries (objects with same boundaries but different contents, e.g. the idea of the state of California and its perceived meaning) and standardized forms (e.g. fill-out forms and other devices for standardising work methods) (Star & Griesemer, 1989).

The original article describes BOs as:

- Scientific objects, which both inhabit several intersecting social worlds and satisfy the informational requirements of each of them
- Objects plastic enough to adapt to local needs and constraints of several parties employing them yet robust enough to maintain a common identity across sites
- Weakly structured in common use, becoming strongly structured in individual site use
- Abstract or concrete
- Having different meanings in different social worlds but a structure common enough to more than one world to make them recognizable, a means of translation

Star and Griesemer described BOs as translation devices between communities of people. They argued that the making and nurturing of BOs is an essential factor in initiating, advancing and maintaining coherence across communities. In a later commentary on the evolution and use of the notion of BOs in the literature, Star (2010) emphasized usefulness (at particular levels of scale) as a central premise of BOs. Objects do not function as BOs if the adjacent communities are too large and heterogeneous or too small and alike. She also extended the contextualization of BOs in the cycle of standardization (making and collapse of standardised objects and systems), emergence of residual categories (categories including “not elsewhere categorized” or “none of the above”), and the consequent surfacing of intermediary objects to facilitate cooperation.

The concept of BO has been welcomed in diverse research communities, for instance, in management (Kuhn, 2002), archival science (Yeo, 2008), development studies (Green, 2010), economics (Langenohl, 2008), education (Emad & Roth, 2009), document studies (Lund, 2009), and library and information science (Albrechtsen & Jacob, 1998), while enjoying particular popularity in information systems and computer supported cooperative work research (CSCW) (Lee, 2007; Lutters & Ackerman, 2007), among others. An equally broad variety of research artefacts from physical objects to concepts and activities have been analytically interpreted as boundary objects (for an incomplete overview of artefacts, see Table 1 and Figure 1).

<u>Artefact</u>	<u>Reference</u>
activities	(Macpherson et al., 2006)
archival standards	(Yakel, 2004)
cancer (as a conceptual artefact)	(Fujimura, 1992)
community information	(Westbrook & Finn, 2012)
concepts	(Langenohl, 2008; Ridenour, 2016)
design concepts	(Eriksson, 2008)
digital literacy	(Huvila, 2012b)
documents	(Huvila, 2012; Østerlund, 2008a)
gender	(Burnett et al., 2009)
genre	(Østerlund, 2008b)
group affiliations	(Lindberg & Czarniawska, 2006)
information services	(Huvila, 2012b)
medicine	(Frost et al., 2002)
metaphors	(Koskinen, 2005)
methods	(Olsen et al., 2012)
musical scores	(Winget, 2008)
ontologies	(Shepherd & Sampalli, 2012)
policies	(Emad & Roth, 2009)
repositories and digital libraries	(Star & Griesemer, 1989; Van House, 2003; Worrall, 2015)
room / space	(Jornet & Steier, 2015)
technical standards, geographic information systems (GIS)	(Harvey & Chrisman., 1998)
visual representations	(Henderson, 1991)
water	(Carroll, 2012)

Table 1. Types of artefacts theorized as boundary objects

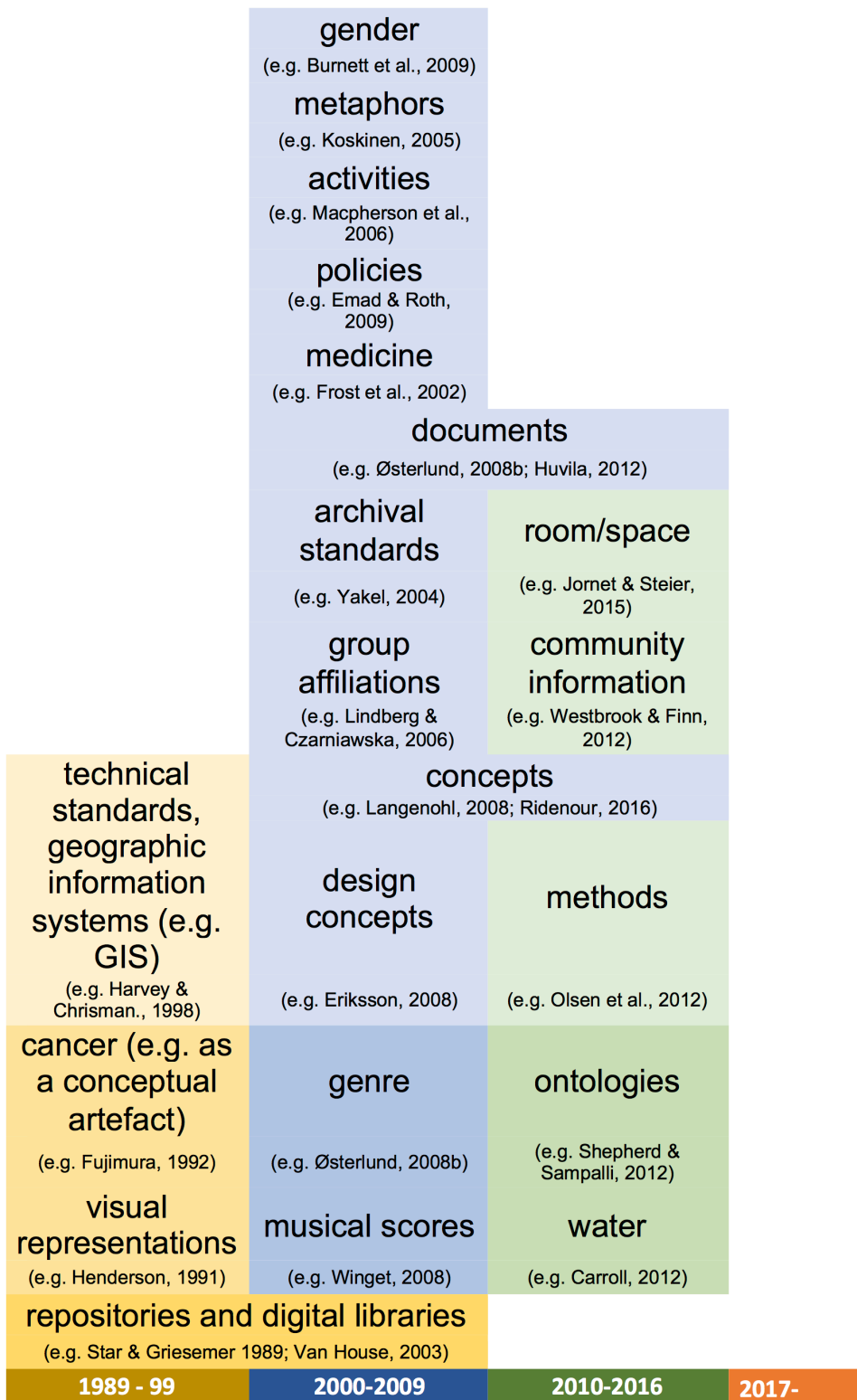


Figure 1: A selection of types of artefacts theorized as boundary objects with sample references between 1989-2016

Organized along disciplinary lines in the fields of anthropology of design, sociology of science, and organization theory, Trompette & Vinck (2009) offer a partial inventory of research topics for which the concept BO was put to use. Their review takes account of the diverse authorship and research applications of the concept and although it is not a critical review of the literature it provides a topical map. They note, importantly, that the application of the concept became somewhat autonomous from the original conceptualization. While BOs are typically described as a way to shape a liminal space between communities, other approaches show the concept can be applied to the analysis of bounding discourses (i.e. Giorgi & Redclift, 2000 and Oppermann, 2011).

Along with the four initial types of BOs proposed by Star and Griesemer (1989), researchers working in different disciplinary traditions distinguish additional kinds of BOs and boundaries, for instance:

- Visionary BOs: Institutionalised codes or 'best practices', which are conceptual and as such cannot be argued against (Briers & Chua, 2001).
- Primary and secondary BOs: Physical and abstract objects “around which all the activity is (supposed to be) focused” and secondary artefacts which facilitate collaboration around the primary artefacts (Garrety & Badham, 2000).
- Boundary-objects-in-use / designated BOs: Objects that are useful in different communities and that acquire a status as a BO; objects that are specifically promoted as boundary bridging instruments e.g. by management (Levina & Vaast, 2005).
- Classification of boundary types, BOs and their characteristics: Syntactic, semantic and pragmatic knowledge boundaries are related respectively to 1) types of BOs: repositories; standardised forms; and methods, objects, models, maps; and 2) characteristics of BOs: representing; representing and learning; representing, learning, and transforming (Carlile, 2002). Hara and Fichman (2014) propose a meta-classification of earlier identified boundary types with distinction of physical, cognitive, social and political boundaries based on reviewing the work of Carlile (2004), Hernes (2004), Wright (2009), Sturdy et al. (2009) and Werr et al. (2009).

The expanse of literature citing the concept goes beyond identifying different kinds of BOs, to a large corpus that discusses boundaries and boundary crossings using related concepts. Some of these are summarised below in Table 2.

<u>Type</u>	<u>Concept</u>	<u>References</u>
Boundary related activities	boundary breaking	(Kajamaa, 2011)
	boundary spanning	(e.g. Carlile, 2002; Levina & Vaast, 2005; Gasson, 2006)
	boundary-work	(Faraj & Yan, 2009)
	bounded activities	(Huvila, 2012)
Boundary related things	boundary concept	(Nolin, 2009)
	boundary constructs	(Holford, 2016)
	boundary negotiating artifacts	(Lee, 2007)
	boundary organizations	(Shackley & Wynne, 1996; Perkmann & Schildt, 2015)
	conscription devices	(Henderson, 1991)
Different types of boundaries	tangible, intangible; imagined and 'real' boundaries	(Huvila, 2012)
	evolutionary boundaries	(Madden, 2014)
	knowledge boundaries	(Abraham, 2015)
	three-dimensional	(Zhang & Jacob, 2013)

Table 2. Concepts theorized in relation to boundaries

We found that these new concepts seem to have a tendency to focus on elucidating boundary related activities, elaborating different types of boundaries, and explicating boundary related 'things' that, according to their proposers, are complementary to and have substantial differences with the notion of BO. A common denominator of these elaborations and extensions suggests that the notion of BO has felt too rigid, unspecific or 'thingy' to describe the particularities of the specific research cases. Although the term boundary *object* suggests a relative stability, a consideration of the relationships studied suggests that BOs are not as stable as some have considered. Gal et al. (2004) discuss the dynamic nature of BOs and their relation to social infrastructures on the basis of the work of Berger and Luckmann (1966); Mambrey and Robinson (1997) explicate the changes that can occur in the status of BOs when they cross boundaries from one community to another; and Subrahmanian et al. (2003) have shown how BOs can be obliterated by organisational changes. As Huvila (2011) has suggested, the literature suggests that objects functioning as BOs tolerate internal change within the object, but are less tolerant to changes of and in their bordering communities.

The diversification of domains and types of BOs identified and the kinds proposed suggest an emergent conceptual plurality. Researchers make claims on various aspects of what things theorized as BOs actually do in the world. These claims are of particular interest to information disciplines and the things and processes studied. These texts suggest that the concept relates not only to objects and activities of translation, even if Star and Griesemer (1989) and later Star (2010) emphasise their role in the processes of interpretation and translation. We see a spectrum of theoretical extensions emerge as the concept is operationalized. Early discussions noted that acts of translation incorporate attempts to exercise control over other communities to accept the interpretation of one community (Brown and Duguid, 1996). What seems to evolve is a shift from the explication of processes of how BOs function within communities to a focus on identifying broader societal/social relationships. Some of these processes of interpretation and translation are outlined in a chronological order in Table 3.

<u>Focus</u>	<u>Processes of interpretation and translation</u>	<u>References</u>	
	How BOs function	reflexive combination of perspective making and perspective taking	(Boland & Tenkasi, 1995)
	making and reshaping; negotiation and open recognition of power and tensions	(Boland & Tenkasi, 1995; Bowker & Star, 2000, p. 254)	
	negotiation with adjacent communities	(Fomin & Keil, 2000)	
	transforming knowledge by offering alternative views	(Carlile, 2002; Feldman et al., 2006)	
	shaping and conveying identities	(Gal et al., 2004)	
	having agency	(Fleischmann, 2006)	
	bounding entities as discourses	(Oppermann, 2011)	
	political shaping and authoring with respect to rights and liabilities	(Huvila, 2011, 2012)	
Bounding communities; Impact and influence of BOs	world-making	(Nicewonger, 2015)	

Table 3. Acts & processes performed by boundary objects in timeline

A review of the references to BOs in the literature and the plethora of new related boundary concepts demonstrates the perceived relevance of boundaries and BOs in an empirical sense but even more so as analytical concepts. A part of the popularity and variation of the theme in information science can be traced back to general analytical opportunities and limitations related to earlier conceptual apparatus. In

order to get a more comprehensive understanding of the variation, we feel that it is important to look closer to how BOs have been used as an analytical concept in empirical IS research.

Concept of Boundary Object in the Information Sciences

Information science research literature offers a surfeit of popularized and persuasive invocations of the BO concept. Our goal here is not to provide an exhaustive review of all BO related information science literature. Instead, we set out to identify relevant theoretical extensions and conceptual refinements of the concept in order that we may assess and discuss its influence on the theoretical discourse of our fields. Our overview stretches from knowledge organization (Albrechtsen & Jacob, 1998; Jansen, 2013) to information practices and work research (e.g. McKenzie & Davies, 2010; Huvila, 2013), document studies (e.g. Huvila, 2011, 2012, 2016; Lund, 2009), social and community informatics (e.g. Westbrook & Finn, 2012; Worrall, 2013; Fleischmann, 2006) and computer supported cooperative work (e.g. Roth & McGinn 1998; Light & Anderson, 2009).

Knowledge Organization

Looking back to what may now seem a nearly ‘natural fit’, early dissemination of the BO concept in LIS may be traced to a special edition of *Library Trends* edited by Bowker and Star in 1998. Having recently joined the faculty at the University of Illinois Graduate School of Library and Information Science, the editors -- with their now-famous book (Bowker & Star, 2000) in press -- were engaged in forging relationships with traditional LIS scholars. Trailblazing classification researchers Albrechtsen and Jacob (1998) were influenced by Star’s theoretical contributions to understanding collaboration in heterogeneous work (Star, 1988; Star & Griesemer, 1989). They challenged the conventional approach in classification research by staking out constructivist epistemological assumptions and interpreting research on librarians and their users with the explanatory power of the concept BO to understand the design of a children’s library catalogue. Their publications not only signaled a trend but sparked citations that led to continuing exploration and diffusion of the BO construct in LIS research.

Faced with research challenges in the ever-changing landscape of libraries and bibliographic systems, Albrechtsen and Jacob (1998) argued for the adoption of a more sociotechnical point of view. They foregrounded the role of classification scheme designers in the production of knowledge. This approach contrasted with traditional conceptualizations of classification in rationalist/empiricist paradigms. The new conception of classification took a more historical, cultural and social view of knowledge, reflecting historicist and social constructivist paradigms. Framing their study in this way afforded including users as participants. At this time, the approach was consistent with growing interest in classification research focusing on how to understand actors’ behavior in organizing knowledge (Mai, 2011, p. 115). Here, the concept of a BO exemplified a significant theoretical extension, being adapted from explicating complex relations within scientific research practices and recast among relations within a library and its public. This initial theoretical extension spurred an abundance of inquiry, proving itself a fertile concept across the literature we will go on to describe.

Further demonstration of the transferability of the concept appears in the literature where Jacob (2001) extends the concept to discuss the role of classification in work practice. While BOs do not appear to

have inspired extensive adoption of fieldwork in classification research, there is a growing body of critique that draws on the notion (Tennis, 2008). Star's theoretical sensitivity to the social, historical and cultural influences surrounding the development of classification systems (cf. Bowker & Star, 2000) has since been combined in classification research using domain analytic approaches (cf. Hjørland & Albrechtsen, 1995) to study bibliographic classifications (McTavish & Fortier, 2011; Caidi, 2004). In a departure from earlier extensions, these studies feature close reading and textual analysis focused on the term level in relation to social contexts. Here we see how additional theoretical refinements presented in Bowker and Star (2000) are extended to knowledge organization studies for analytical goals, thereby broadening their relevance. In a shift beyond bibliographic classifications, Campbell (2003) invokes the concept to explore a statistical classification of industries, taking a discursive approach similar to examinations of bibliographic organization. Eva Jansen's forthcoming study of standard occupational classification (Jansen, 2013; Howarth & Hourihan Jansen, 2014) engages ethnographic methods more frequently taken up in research described in the later sections of this paper. The extent to which the boundary object concept contributes to theoretical extension in the literature of Knowledge Organization is apparent and the limits remain an open question.

Information practices

The concept of the BO makes visible the sociotechnical contexts within which people seek, retrieve, use, share, and curate information. Using BOs as a lens therefore requires abandoning a cognitivist understanding of "information" as something residing within the head of a single individual who seeks information to meet cognitive needs or gaps (Wilson, 1997). This is consistent with the development of collectivist and constructionist approaches (Talja, Tuominen, & Savolainen, 2005) that see information seeking and use as a set of practices (Huizing & Cavanagh, 2011; Cox, 2012) that are inherently social (Savolainen, 2007) and situated within a particular context and/or community -- e.g., a community of practice, a discourse community (McKenzie & Stooke, 2007), or a community of justification (Johannisson & Sundin, 2007). Limberg (2007) argued that taking a sociocultural approach to the study of "task" could itself serve as a BO between information seeking and information system design researchers.

Several scholars have considered the collaborative information seeking or sharing practices of people who gather together over time in formal and informal groups such as departments, communities of practice, task forces, crews, and teams (for overviews, see Davenport & Cronin, 1998; Foster, 2006; Pilerot, 2012; Talja & Hansen, 2006; and Wilson, 2010). The study of BOs has been important for understanding how knowledge is shared across professional and disciplinary boundaries, both within and between organizations. This section provides an overview of some major themes in this area; many studies of BOs related to information practices also relate to documents, technologies, and systems, so there will be some overlap between this section and the related sections below.

Palmer (1996) identified several BOs operating in the work of in an interdisciplinary group of lab scientists. She showed how concrete and abstract objects (e.g., machines, literature, concepts, methods, data, results) as well as people (colleagues, students, the "big guys" of the discipline) spanned both institutional and disciplinary boundaries. Choo (2007) proposed that organizations may house multiple and colliding information cultures, epistemic contexts, and styles. He suggested that both people and objects may do boundary-spanning work in organizations by serving as intermediaries: recognizing needs and seeking, using, and translating information from one area of the organization on behalf of another.

Mueller (2012) found that project teams in an organization shared knowledge by transferring BOs, interchanging team members, and directly interacting. Veinot (2007) showed how a blue-collar worker created and used BOs to observe, interpret, and document phenomena for employees throughout the organization and to translate observations into categories that are actionable and calculable by others. Yakura (2002) and Davies and McKenzie (2004) showed that tools such as calendars and timelines may function as temporal BOs, mediating and attempting to synchronize the multiple timelines of complex work environments. Nolin (2009) proposed that the concept of “relevance” strengthens boundaries and makes them more visible. He suggested that the “boundary concept” could serve as a companion concept to the BO, showing “where the boundaries lie and ... [being] of use for manipulation of boundaries” (p. 748).

Given that they are embedded within communities, BOs do much more than merely transferring and transforming knowledge between groups. Davenport (2000) showed that national-level clinical practice guidelines served as BOs aligning the professional domains of medicine and nursing. At the same time, however, she showed that the creation and maintenance of practice guidelines is a political process because organizational actors who engage with them will seek to use them to promote their own concerns. Kimble, Grenier, and Goglio-Pimard (2010) proposed that BOs carry not only symbolic but political value and can be used to re-define or steer the direction of joint enterprise, for example by restricting the flow of information or by differentially acknowledging the importance of actors’ expertise. Godbold (2012) identified an element of the BO, its useful vagueness, to show how personal narratives on online discussion groups became recognizable and vague enough to fit in a general way with the situations of discussion group readers. Westbrook and Finn (2012) showed that this vagueness is not always helpful. They found that tensions may arise as a result of the distinct priorities and perspectives that each member of a broad network of community partners brings to the problem of intimate partner violence (IPV). These tensions may mean that the boundaries between agencies, governing policies, and legislation fail to intersect effectively, leading to the potential for direct and serious impacts on the lives of IPV survivors.

This illustrates also in more general terms the principal strength of BOs in the context of information practices and behavior research. BOs can be identified in diverse ‘informational’ situation within which their vagueness turns to an asset. The line between being vague enough and too indefinite is fine and as, for instance, the example of Westbrook and Finn (2012) shows, BOs can fail. Even if the BOs are fallible and in a constant process of (re-)making, the review shows that the recent theoretical shift in information behavior research towards the notion of information practices has increased the relevance of the notion and its usefulness as an analytical lens for explicating continuities and discontinuities of collaborative information activities.

Documentation

Documents are undoubtedly the most cited type of BO in the literature. The literature on documentary BOs has its roots in CSCW and information systems science, but the approach has similarities with the documentalist tradition of LIS (Lund, 2009). Document theory has not made similarly frequent direct references to the notion of BO or vice versa, even if they both share roughly a similar understanding of documents and the significance of the role of documentary processes. Researchers like Huvila (2011) and Björk (2015) have noted, citing the latter, that “the concept of BO sits comfortably within the field of document theory” (Björk, 2015). Boell and Hoof (2015) suggested that one reason for the close affinity of

documents and BO theory is that, borrowing Heider (1926), documents are simultaneously functioning as (tangible and visible) things and (transparent, infrastructural) medium. Many of the references to documents as BOs in information science literature stem from the context of the studies of information practices (e.g. Davies & McKenzie, 2004) and, for instance, research in social informatics and CSCW (e.g. Østerlund, 2008a) discussed elsewhere in this article. Even if it is difficult to draw clear lines between the different lines of inquiry, it is possible to identify a number of studies which have contributed to the understanding of the nature of documents and/or BOs.

Firstly, several authors have discussed how documents function as BOs. This perspective is common across the spectrum of BO research and documents were highlighted as a central type of BOs already in the seminal text of Star and Griesemer. In contrast to other scholarly and scientific disciplines, the significance of documents and other informative artefacts is a central premise of information science research and the usefulness of documents as BOs is perhaps less remarkable than in some other contexts. From the document perspective, a significant implication of the notion of BOs is in how it helps to explicate how documents and other informative objects function in the context of various types of social and solitary pursuits. Frohmann (2004a) referred to BOs and their coordinative capacity as an example of non-informative uses of documents. Yeo (2008) has integrated BOs as one aspect of theorizing the notion of (archival) record. Several studies have shown how different types of documents from medical records (Zhou et al., 2011) to a blackboard (Kawatoko, 1999) can function as BOs, how their use is “deeply embedded in the activities” (Kawatoko, 1999) of their users, and permeated by meta-negotiations, negotiation and recontextualization (Lutters & Ackerman, 2007). The research has showed that the use of documentary BOs is not merely a question of reading, seeing and becoming informed but rather a complex situated activity with elaborate social and material implications and premises. Winget (2008) wrote about musical scores as “action-oriented” BOs. Björk’s (Björk, 2015) conceptualization of digital resources (i.e. documents) as BOs and the observation of how the concept helps to understand the making and use of documents, their multiple representational levels as metadata, transcription and image and their double-framing as being conditioned and conditioning technical systems used to manage them underlines the actional nature of the translational capability of BOs. Also Pilerot (2014; 2015) has written about the multi-faceted nature of documentary BOs. He showed how Star and Griesemer’s (1989) article itself functioned as both a BO and an epistemic object (Knorr Cetina, 2001) in the information sharing of a geographically dispersed network of design researchers.

Another line of research has focused on the making of documents. Here the notion of BOs has been useful in explicating the political and social aspects of the making of documents in liminal spaces between different communities. Huvila discussed from a documentalist perspective how documents are authored as documentary BOs (Huvila, 2012), how they come to incorporate political aspirations of their authors (Huvila, 2011), and why some documents do and some others do not end up becoming BOs (Huvila, 2016). Björk’s study underlines the multiple levels of representations embedded in documents and the similar multiplicity of their making (Björk, 2015). Grimes et al. (2008) conceptualized virtual worlds and their governing documents as BOs with agency and discuss the development of the documents to serve specific purposes. The process of producing documents has also been discussed in policy research and from that perspective, conceptualized as their key characteristic together with their use (Freeman & Maybin, 2011) and ‘counter-use’ as resistance to dominant constructions (Hunter, 2008). Their interest is particularly in advancing a more democratic point of view and the needs and rights of all stakeholder

groups instead of focusing on those of the developers' of the milieu. Lin's study of OpenStreetMap provides an additional perspective to the process of negotiating and making of documents in the context of a highly complex collaborative international undertaking as a process of co-production, mutual interaction, and negotiation of the meaning of the document production, data, and information needed for the document and of the document itself (Lin, 2011).

In comparison to many other types of non-documentary BOs, documents have additional explicit levels of interpretation (materiality and content) and they tend to have several, both internal and external dependencies to their stakeholders and other related objects. Similarly to all BOs (Star & Griesemer, 1989), documents do not necessarily represent a consensus (McLeod & Doolin, 2010) but rather convene personal perspectives of their different stakeholders. Martin and Wall describe contested nature of the often cited documentary BO, medical record, and note that their use in medical work tend require workarounds to compensate for the lack of common ground (Martin & Wall, 2011). From this perspective, documents differ from many other types of BOs by their meta-discursive ability to simultaneously incorporate and represent conflicting perspectives (Huvila, 2011). The multiple perspectives and contested nature of interpretations can be more explicit in a document than in, for instance, physical artefacts.

Social informatics

BOs have been used significantly in the interdisciplinary area of social informatics to examine information and communication technologies (ICTs) in sociotechnical contexts (Rosenbaum, 2009, 2014; Sawyer & Tapia, 2007) and "the complex relationships between [their] design and use ... and the character of real social life in settings where people use them" (Robbin, Lamb, King, & Berleur, 2006, p. 17). Unlike work in knowledge management that incorporates boundary concepts (e.g. Bechky, 2003; Brown & Duguid, 1998; Kimble, Grenier, & Goglio-Primard, 2010; Wenger, 1998, 2000), social informatics holds that communities cannot be "built" or deliberately "seeded," but must *emerge* from sociotechnical contexts. ICTs can help encourage this process, but there is no quick, easy fix to ensure coherence and convergence around a BO, nor is full coherence or convergence always desired (cf. the discussion of groupthink by Star, Bowker, & Neumann, 2003).

Much social informatics research conceptualizes ICTs as BOs, with their strong role being a key theme. For example, Fleischmann (2006) used a grounded theory approach to uncover human anatomy simulations as BOs emerging at the intersections between the multiple social worlds (Strauss, 1978) of designers and users. As BOs they played "an active role in reshaping the interactions and relationships among these social worlds" (Fleischmann, 2006, p. 82), acting with agency to "take such an active role in reshaping the sociotechnical landscape" (p. 84). Landry, Levin, Rowe, and Nickelson (2009) also found a strong role for ICTs; the visualized information spaces used by air traffic managers served as "boundary object displays" (p. 89) which decreased the need for coordination, improved collaboration, shifted concerns from the local to regional level, and increased desire for situational awareness. Landry et al. found BOs could improve collaboration and concluded with design implications or visual displays.

A second, related stream of research has a stronger focus on information practices. Anderson (2007) incorporated the concept of BOs into a theoretical framework of information practices in socio-material context, arguing such a framing allows for greater understanding of "the situated, embodied character of

human experience” and of the “socio-material (and increasingly socio-technical) context [that] needs to be brought more actively” into information science research (“Socio-material framings of information practices” section, paras. 2-3). Her approach did not mandate the presence of ICTs or computer-mediated practices, but is indicative of how BOs are incorporated into broader frameworks in social informatics research. Others have examined digital libraries and the communities they serve as BOs, including issues of trust (Van House, 2003), the processes of community coherence and convergence (Bowker & Star, 2000; Star, Bowker, & Neumann, 2003; Van House, 2003; Worrall, 2015), values (Fleischmann, 2007a, 2007b; Worrall, 2015), and other design and use practices surrounding these sociotechnical systems. Conceiving of ICTs as BOs allows for consideration of how they support and serve multiple, multi-faceted communities and facilitate users’ engagement in “cognitive or knowledge work” that is “situated, distributed, and social” (Van House, 2003, p. 272).

An interest in the ICTs themselves as BOs characterizes Lee (2007), but also in artefacts and practices used in designing them. In a study of collaborative design of a museum exhibit, she uncovered active and chaotic negotiation processes among designers, users, and other stakeholders to establish “shared understanding,” an element she felt was missing from BO theory (p. 313). Lee argued for “opening the box around boundary objects” to ensure “more comprehensive and richly specified models of negotiation and enactment” can be considered (p. 335), in line with the tenets of both social informatics and CSCW (discussed further below). Vines, Clarke, Wright, McCarthy, and Olivier (2013); Doolin and McLeod (2012); and Millerand and Baker (2009) provide further examples of focusing on system design artefacts as BOs. Gasson (2006) took a similar approach in considering artefacts as BOs, but also as parts of an actor-network under actor-network theory (ANT; see Latour, 2005). Unlike Lee, Gasson’s (2006) artefacts related to both system and process design; organizational responsibilities and roles and the business processes of the organization were considered BOs. Managers shaped the reality and context of the systems and processes through the “genealogical process” of information and knowledge sharing (p. 26). Gasson also uncovered tensions between localized and global views of processes and systems as BOs, echoing Star and Griesemer’s (1989) work. Both Lee (2007) and Gasson (2006, p. 39) argued BO artefacts should be “as plastic as possible” in sociotechnical design and research. Barrett and Oborn (2010) identified design specifications as a naturally emerging BO between different groups in cross-cultural software development, including study of the complex, sociotechnical, and multicultural context surrounding the BOs, a common theme in social informatics research.

A few authors have brought social informatics sensibilities to studies of other concepts serving as BOs in sociotechnical contexts, akin to Bowker and Star’s (2000) view of classifications and categorizations as BOs. These include Bannon (1997) applying BO theory to examine the use of “the very concept of the interface” in HCI (p. 357); and Burnett, Subramaniam, and Gibson (2009) exploring the role played by gender as a BO for Latina IT professionals. These studies may not conceive of ICTs as BOs, but use BO concepts and theory to explore “the complex relationships” surrounding ICTs that IT professionals design, use, and support, and “the character of real social life” for these professionals (Robbin et al., 2006, p. 17).

Computer supported cooperative work

In computer supported cooperative work (CSCW), where the focus of study is cooperative work, material artefacts are often theorized as BOs serving coordinating functions. Pennington (2010) explored how some BOs negotiate between perspectives while others specify across perspectives, making the notion a contested one. The BO concept is particularly fruitful for recognizing informative artefacts (books, documents, records, citations or other informative representations) as socio-material forms. Framing BOs within a sociomaterial perspective, research like that reported in Doolin & McLeod (2012), Light & Anderson (2009), Anderson (2007), Lutters and Ackerman (2007) and Levina & Vaast (2005) drew particular attention to the practices within which BOs are constituted. Light and Anderson (2009) discussed, for instance, how the concept can be applied to explicate the functioning of a work project in its own right (Light & Anderson, 2009).

From the perspective of BO theory, the CSCW literature highlights two aspects of the functioning of BOs. Firstly, notions of inscription and alignment are closely associated with the BO construct as it is discussed in CSCW literature. For Roth and McGinn (1998) BOs are inscriptions used across communities of practice and as such are a critical feature of their theoretical approach to embodied representations. For them, BOs serve as "...interfaces between multiple social worlds and facilitate the flow of resources (information, concepts, skills, materials) among multiple social actors (Roth & McGinn 1998, p. 42). Inscription-related activities are part of networks of social practices and shared artefacts (Paay et al, 2009). Different communities can and do inscribe different meanings on these objects, but the close association between BOs and the notion of inscription can change "...the location of representing activity from individual minds to social arenas" (Roth & McGinn 1998, p. 37). This translational activity enables the focus to turn from representation as a mental activity to inscription as a social activity.

Artefactual agency in this CSCW work is often discussed in terms of sociomaterial 'assemblages' (Suchman, 2007), in which humans and artefacts are intertwined and where agency is the capacity for action realized through their sociomaterial entanglement. Doolin and McLeod (2012) suggested that this sociomaterial awareness encourages a view of BOs as diverse and shifting assemblages, where the focus is on use (they refer to this as boundary object-in-use) and where the BO emerges from the performance of situated sociomaterial practices (p. 582). They offer five concepts to support this view of BOs for information systems development (practice, temporal emergence, sociomaterial agency, performativity and multiplicity) which they propose to provide a theoretical vocabulary with which to explain how and why BOs function the way they do.

Foregrounding this sociomateriality makes BOs vital pieces of craftwork that serve to make things visible. As representational devices they are central actors in the structuring of practices and technologies as alignments of both material and discursive practice. Recognizing this artefactual agency alerts the designer to the relationship between *who* one designs for and *what* one designs. Lutters and Ackerman (2007) discussed a process of BO crystallization that is a dynamic process of reinterpretation in light of meta-negotiation. Recognizing that BOs are wrapped up in institutional processes and negotiations and often inextricable from surrounding artifacts, they contend, is critical for both the production of a BO and its application. The three theoretical extensions to boundary objects they offer (loose routinization, punctuated crystallization, and meta-negotiation streams) alert us to the boundary making processes and practices central to BO becoming.

The CSCW literature highlights also the aspect of boundary spanning related to BOs. The interpretive flexibility (Star, 2010) of the BOs makes the reconstructing of a decontextualized BO an essential practice for the reuse of information in any community. The inscription and translation work attributed to the BO makes it a bridge from one community/context into another. This boundary spanning function is very evident in the early BO account in Bødker and Christiansen (1997) where scenarios are springboards for the participatory design work in and across communities.

The articulation work of interest in CSCW is happening at the boundaries between communities and contexts. Sitting within this framework of design and work practice, this theorizing of BOs involves studies of movement, shifts and zones. Lutters and Ackerman (2007) argued for greater flexibility for BOs in the situated context of negotiation and deviations from official process, echoing the work of Lee (2007) and further enriched in Barrett and Oborn (2010). The work of Lee, Barrett, Oborn, Lutters, and Ackerman showed the *social* must be considered alongside the *technical* (Meyer, 2014) and *material* (Suchman, 2007), and that BOs, their use, and their interpretation should be flexible, to ensure that team dynamics, power, and authority issues do not hamper information and knowledge sharing.

Lutters and Ackerman (2007) drew particular attention to the analytical power of BOs for understanding negotiation and mediation in work practices. They believed BOs should be viewed through a temporal lens: “boundary objects existed within a history greater than themselves” (p. 366). Lee (2007) focused on this boundary work to the extent of offering more free-form boundary negotiating artefacts framed as less structured and standardized than BOs. They negotiate boundaries by serving to establish and destabilize and in the process can push beyond the existing boundaries. Following in this same vein we find boundary negotiating zones (Halpern et al, 2013) and emergent Boundary Zones (Dalsgaard, 2014), As a translational device, the BO performs critical work at organizational and intellectual boundaries. Recognizing this boundary spanning quality positions the BO as a lifeline – allowing communities to embrace plasticity, but appreciate rigidity.

Boundary objects in action

The overview of the uses of the notion of BOs in information sciences shows the variety of ways the BO concept has been used as a theoretical construct and how it has influenced research in a broad variety of fields. In spite of the variety, it is possible to identify commonalities between the approaches and to work towards a structured understanding of how BOs can inform research in the information field. We observe that the concept of BO is useful for unfolding the socio-material aspects of information-related activities on an artefactual-practical-epistemological continuum (Table 4 and Figure 2) by explicating a) informational artefacts; b) their related practices; and c) the epistemological premises of artefacts, practices and their intersections by making visible the following:

1. **The characteristics of artefacts that turn them to informative socio-material forms** in the practices of sharing, disseminating, reusing and exchanging information (e.g. theoretical understanding of their nature as in Albrechtsen & Jacob, 1998; artefacts have different levels of interpretation in Huvila, 2011); in how the vagueness of BOs can be both an advantage (Godbold, 2012) and disadvantage (Westbrook & Finn, 2012); in how the meta-discursive ability increases the flexibility of documents as BOs and informative socio-material forms (Huvila, 2011); and in

how different modes of representation (of how documents are represented) and informative configurations (ways in which users engage with documents) affect their use (Björk, 2015).

2. **The roles of physical and conceptual artefacts as informative socio-material forms** in the practices of sharing, disseminating, reusing, and exchanging information, with a specific focus on how specific artefacts can support and serve multiple, multi-faceted communities and allow users to engage in situated, distributed, and social information work. Examples include Frohmann (2004a) on the coordinative capacity of documents, Yeo (2008) on the roles of (archival) records, Van House (2003) and Worrall (2015) on the capacity of ICTs to serve multiple communities, Lutters and Ackerman (2007) on how BOs are invoked in the structuring of practices, Davenport (2000) on how clinical practice guidelines can help to align professional communities, and the informational role of BOs in the work of e.g. Doolin and McLeod (2012), Levina and Vaast (2005), Light and Anderson (2009), Kawatoko (1999), and Anderson (2007).
3. **The making of information objects/artefacts in socio-material settings** (who is designing, who one designs for, what is being designed), as in the work of Huvila (2011, 2012) on the making of documents and documentary BOs, Grimes et al. (2008) on virtual worlds and governing documents and Lin (2011) on OpenStreetMap, Lutters and Ackerman (2007) on BO crystallization, and Björk (2015) on digitization as the making of digital resources of non-digital documents.
4. **The roles of particular information-related practices** in the context of work, leisure, and everyday life, as in studies of negotiation and mediation in aircraft technical support (Lutters & Ackerman, 2007); knowledge sharing (e.g. Palmer, 1996); seeking, using and translating (Choo, 2007); observing, interpreting, and documenting (Veinot, 2007); translation and negotiation of information values between communities (Worrall, 2015); and synchronizing multiple timelines of complex work environments (Davies & McKenzie, 2004).
5. **The epistemological premises of information science concepts** (e.g. classification, abstract understanding of information vs. situated and practiced information; non-informative capacities of informational artefacts like documents in the work of Frohmann, 2004a) and **critiques and redefinitions of them** (e.g. in the work of Albrechtsen and Jacob 1998; Jacob, 2001; and Yeo, 2008).

<u>Level of interpretation</u>	<u>BOs are used to make visible the</u>	<u>Focus</u>
Artefactual	Characteristics of artefacts	Objects
Artefactual	Role of artefacts	Objects in relation to practices
Epistemological	Epistemological premises of information science concepts	Conceptualizations of objects, practices and interactions of objects and practices
Practices	Making of artefacts	Objects as outcomes of practices
Practices	Role of information-related practices	Practices in relation to objects

Table 4: Foci and levels of interpretation in the references to BOs in information science research.

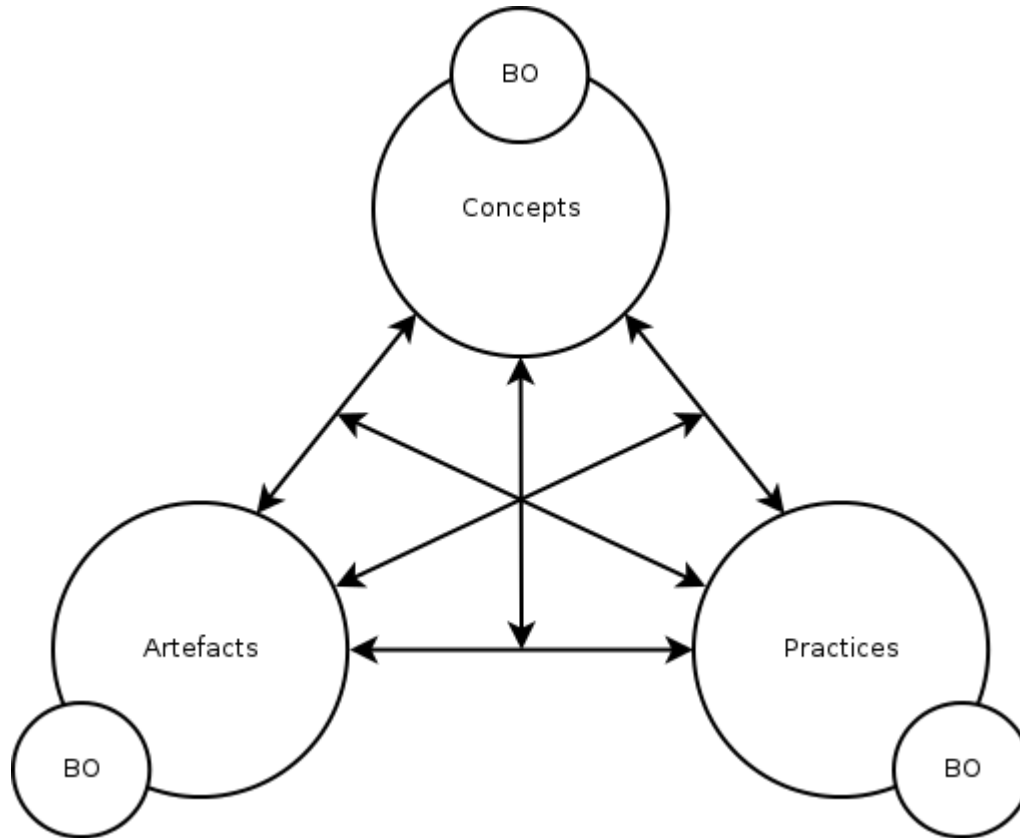


Figure 2: Schematic illustration of some of the uses of artefacts, practices, and concepts as boundary objects to explicate relations and influences. As indicated by the arrows in the diagram, boundary objects relate to the influences between these phenomena and to their relations to each other within an artefactual-practical-epistemological (conceptual) continuum in information science research.

Our review demonstrates that in specific areas of information science research there is a propensity to focus on particular aspects of BOs. Technology-oriented social informatics, CSCW and documentation studies research emphasizes explicating the role of artefacts, whereas studies of information practices conceptualize BOs in relation to information related activities and knowledge organization research focuses on epistemological questions. In the areas of information science research with fewer BO-oriented studies the preferences can be traced back to the interests of individual authors, but it is apparent that the use and perceived usefulness of the concept is also indicative of the central questions of the sub-fields.

Discussion

This synthesis of the literature on BOs in information science research reveals the flexibility and explanatory power of the notion in highly differentiated contexts. In contrast to other types of analytical notions, the inbetweenness of the concept of BO makes it a valuable analytical device for examining

ensembles of people, information, and technology that are ever-shifting and multi-sited. Shared work will inevitably lead to the generation of shared artefacts.

Even if there seems to be a tendency that the typical references to BO follow the conventional lines of inquiry in the sub-fields of information science research, a meta-level review demonstrates opportunities to extend the obvious research questions and conceptualizations of the sub-field. BOs help to bring attention to the other-than-informative functions of documents (Frohmann, 2004) and informative things, and even more so to the interplay of their information-related and information-unrelated aspects. There is much more in the functioning of information than merely getting informed or informing others. Information interactions are entangled as a part of the texture of the multitude of human pursuits. The review also shows that many central concepts and tools discussed in information science research -- from classification systems to documents and information systems -- function as BOs, and much of information science research relates to boundaries, boundary crossings, and collaboration or the lack of it. Thinking about BOs can make us more sensitive to how individuals, communities, and things interact, and how these interactions have implications for their respective positions in mutual context. Further, the recognition of the consequences of boundaries and the authority and agency that are designed into processes and materials (e.g. Light & Anderson, 2009; Kimble et al., 2010) extends the theory into critical authoring and making of systems, artefacts, documents, concepts and other objects.

As Star (2010) reminds, however, not everything is a BO. Even if she explicitly refuses to provide a tight definition of a BO, the BO-ness of any given thing depends on how it functions in a situation. Star herself suggests that scale and scope can be useful in determining whether a thing functions as a BO in a given situation; conceiving of a word as a BO, for example, would not lead to much insight in most cases. Star also recommended focusing on one BO in any particular study, and—based on our review—we agree with this recommendation in most cases. Studying the sociotechnical infrastructure (Edwards et al., 2009; Ribes et al., 2012) and sociomaterial assemblage (Suchman, 2007), however, means considering the roles of many different objects within a sociotechnical or sociomaterial system. Most studies will have a main BO of interest and focus—a system, artefact, document, classification, or other object—but there will be additional BOs of potential interest that should not be discarded from further analysis. To do so would place artificial restrictions on the potential objects that can serve as BOs, if perhaps in more secondary roles. We should remain pluralistic and flexible in how we consider the scale and scope of BOs.

Star (2010) also mentioned a need for further research on the types of BOs that are found in communities and other social settings, a need that our review finds agreement with. Star suggested further research on the interfacing roles that are played by BOs would be particularly useful, which could include focusing on their degrees of translation, coherence, and convergence, or particular individual- or group-level phenomena that they support the negotiation, translation, and sharing of information and meaning. People can also serve as boundary spanners or gatekeepers (Levina & Vaast, 2005). In considering the types of boundary spanning that both people and objects can engage in, Hara and Fichman's (2014) review and synthesized framework -- including physical, cognitive, social, and political boundary types -- allows for considering different types of BOs and the roles those objects can play, albeit their framework does not directly address boundary *objects* per se. Further research to—as Star (2010) called for—catalog the types of BOs and categorize the roles these types may play in interfacing with communities would be a welcome addition to the literature. Such work should continue to build on the work of the many authors

cited above and in Hara and Fichman's (2014) chapter as part of their synthesized framework. The work of Burnett, Subramaniam, and Gibson (2009) and Worrall (2015) has begun to address this need, but we believe that further theoretical and practical research on the types of BOs that are of interest is necessary.

Another useful line of future research relates to the explication of the current patchwork of various boundary concepts and their relations. As we noted earlier in this article, in many cases the emergence of new concepts can be traced back to an experience that something is missing from the original theory or that BOs are too 'thingy' for a perspective that focuses on processes rather than their constituents. Even if it is apparent that a single concept is hardly capable of covering all boundary related conceptions, we feel that some of the earlier research may have been too hasty to abandon the concept after a needlessly literal reading of BOs as nearly physical objects. A closer look at Star and Griesemer's (1989) article and, for instance, Star's (2010) later discussion of the concept would have nuanced the picture and showed that the BO concept, theory, and literature is incorporating much of the flexibility demanded by its critics.

In spite of its usefulness, the notion of BO and its uses in the literature warrants critique. Even if it has proven to be flexible in use, the notion is based on specific epistemological assumptions and an understanding of social dynamics between communities based on the work of Latour and Callon. At the same time, the vagueness of how the notion has been defined using examples and the metaphorical rather than constitutive nature of references has invited a non-critical and sloppy use of the concept. Instead of acknowledging that BO is a theoretical concept, it is not uncommon to refer to BOs as nearly physical entities in highly essentialist terms (cf. Adams et al., 2013). It is critical to make a distinction between real entities and their conceptual characterizations. Even if the BO-ness of a thing would be an authored aspect of an entity, it cannot be made and deployed like an artefact. Further, even if Star (2010) emphasizes the contrary, the comfortability of the notion seems also to have made it too easy to claim that almost everything is a BO without any further consideration of whether the claim holds or has any analytical validity, relevance, or implications. Claiming that something is a BO is not an extremely useful observation if this particular framing of a specific thing does not help to understand its nature or function. Finally, the diversity of the use of the BO concept makes it deeply problematic. Even if the conceptual plurality has brought new insights into boundaries, boundary related artefacts and activities, a never-ending conceptual profusion by the introduction of new BOs and boundary concepts and a lack of critique and theoretical consolidation can eventually become counter-productive. Instead of taking BO theory too lightly, a deep theoretical and analytical rigor is necessary to maintain its usefulness in future research.

In pursuing analytical rigor, we feel that it is important to consider how BO theory relates to other theoretical constructs. Many grounding theories and frameworks can fit alongside and add to the power of BO theory for a study of informational artefacts, information, infrastructures and technical systems and their relationships with individuals, groups, communities, and organizations. These include but are not limited to literature on Strauss's social worlds perspective (Strauss, 1978), Burnett and Jaeger's theory of information worlds (Jaeger & Burnett, 2010), gatekeepers and boundary spanners (Levina & Vaast, 2005), hegemony and discourse (Laclau & Mouffe, 2001), Pickering's mangle of practice (Pickering, 1995), document theory (Lund, 2009), Fisher's information grounds (Fisher, Durrance, & Hinton, 2004), Savolainen's (1995) everyday life information seeking, and social network perspectives (Garton et al., 1997). BO theory also shares its intellectual beginnings with actor-network theory (ANT; Latour, 2005), and many studies using BO concepts and theory are further grounded in ANT (e.g. Fleischmann, 2006;

Gasson, 2006); translation, in particular, is a common phenomena of interest to both sets of literature. We are unaware, however, of any significant reviews of the connections with BO theory in ANT literature; Díaz Andrade and Urquhart's (2010) paper contains a short review (p. 356), but a briefer one than is deserved.

Whether used one at a time or in syntheses, a view to research that is sensitive to boundaries and BOs and incorporates solid, strong grounding in existing theory should lead to greater insights and implications for information science. This awareness of existing theories and frameworks should extend to the awareness of how we and other researchers are using and invoking the concept of BO as being useful. We should ask whether it is merely useful as a signal or metaphor, or whether the strength of the concept should be drawn from the explanatory power exemplified among studies of, for instance, historical, political, ethical, cultural, spatial and sociotechnical relationships of informational things. On a meta-disciplinary level, interdisciplinary and transdisciplinary work studying BOs can be helpful in framing the perspective and specific role of information science in various contexts of study, including those reviewed in this paper.

Conclusions

This review of the literature on BOs in information science research demonstrates the flexibility and explanatory potential of the notion in various contexts of information science research. Many central concepts and tools discussed in information science research from knowledge organization and information systems to documents can be fruitfully conceptualized as BOs. It is also apparent that much of information science research relates to boundaries, boundary crossings, and collaboration or the lack of it. Thinking about the concept can make us more sensitive to how individuals, communities, and things interact on the levels of artefacts, practices, and their epistemic premises, and how these interactions have implications for their respective positions in mutual context. A better understanding of the characteristics and various roles played by different types of things conceptualized as BOs and identified in information science research and of the processes of how physical and conceptual things are made to become BOs can give us further insights into the central concepts and tools of information science research.

Writing about fluid concepts runs the risk of making concrete certain formulations of boundaries, boundary objects, and their relationships as we have come to see them in information science research. To contradict this point our collective review has presented the many ways we interpret the notion of a boundary object in the empirical research of our field. The value of this contribution lies in offering a starting point for reflecting on our processes of meaning making in research and knowledge production. Doubtless, there are different starting points and trajectories; several of these are drawn together well through a commemorative collected volume that, in ecological spirit, includes Star's seminal texts and her own reflections among them (Bowker, Timmermans, Clarke, & Balka, 2015). Our suggestion is that beyond this point we should continue to consider ecologically our intellectual histories, passionate engagements, and research trajectories as they are woven together with the conceptual foundations gathered here.

We believe that if done critically and by acknowledging the limitations of the approach, the power of incorporating BO concepts and sensitivities into information science research is great, and can help further research in many areas within the field. Our collective interest suggests further analysis may

produce fruitful inquiry into the BO concept and its dissemination. Research that “crosses the streams” between disciplines, areas, and literatures—and researchers who are willing to participate in such crossing—will provide deeper, richer, more insightful findings about information, technology, artefacts, and practices. Mutual familiarity with the lessons that can be learned from research on documents, classification, technologies, systems, and practices, combined with bridging and spanning of boundaries, will help connect what are sometimes disparate research literatures together. Researchers must juggle, bridge, and adapt to multiple communities to encourage successful long-term research on boundaries and their implications to their adjacent communities, concepts, artefacts, and practices. As we have presented here a boundary-sensitive view already crosses many areas of information science and with other disciplines, but we believe that there is much more to be done and drawn from this particular line of research.

Acknowledgements

We would like to thank Lynn Westbrook for participating in the early stages of the work that led to this article at the panel on “Boundary objects in information science research : An approach for explicating connections between collections, cultures and communities” held at ASIS&T 2014 Annual Meeting in Seattle. We would also like to thank anonymous reviewers for constructive and helpful feedback and all who have contributed to discussions and reflections on boundary objects with us and the field. We would like to thank Geoffrey Bowker for generously sharing his recollections of Leigh’s early connections with LIS scholars. Finally, we acknowledge a debt of gratitude to Leigh Star, who as the central star in the constellation of boundary objects, continues to serve as a guiding light for much of the work discussed herein.

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