Boundary Objects and the Technical Culture Divide: Successful Practices for Voluntary Innovation Teams Crossing Scientific and Professional Fields

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This paper was supported by the European Commission (30-CE-0066163/00-39) and DG Information Society. It has benefitted from the insightful comments of editor Pablo Martin de Holan and the anonymous reviewers, and advice from many colleagues, including Andrew Abbott, Karin Knorr Cetina, James Evans, Raghu Garud, Bill Harley, Terry Amburgey, David Obsfeldt, Yuval Millo, Taylor Spears and many others, along with copyediting by Emma Nichols and Joel Barnes.

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Abstract

This paper examines the creation and stabilization of early-stage boundary objects by voluntary teams spanning divergent professional and scientific fields. Cross-disciplinary collaborators can share similar goals, yet nonetheless face frictions from differences in professional expertise, practices and technical systems. Yet if boundary objects help to span disciplinary divides, the same challenges are likely to hinder initial boundary object development. Comparative ethnography of three projects adapting Grid computing technology to fields of science highlights challenges for boundary object creation, including a "mindset shift" before the technology could stabilize. Enriching our knowledge of boundary object beginnings, we find successful stabilization requires both appropriate localization and further resources, which enable the simultaneously global-local nature of boundary objects. This essential feature is understudied in management research. Developing the boundary object concept on its own terms enhances empirical and theoretical application, particularly when researchers prefer one main theory of objects, rather than a "pluralist" approach.

Keywords: Boundary object creation and stabilization, expertise, technical practices, professional and scientific fields, cross-disciplinary collaboration

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Introduction

How do experts span technical and disciplinary divides seen in innovative projects with mutual goals but conflicting disciplinary expertise and expectations? Boundary objects (Star, 2010; Star & Griesemer, 1989) offer the promise of spanning different social worlds where there is cooperation but not consensus. Defined as “those objects that both inhabit several communities of practice *and* satisfy the informational requirements of each of them” (Bowker & Star, 1999, p. 16), boundary objects are able to travel across borders while maintaining a common identity, and can be tailored to the needs of a particular community while retaining this common identity (Bowker & Star, 1999; Bowker, Timmermans, Clarke & Balka, 2015; Star, 2010; Star & Griesemer, 1989). These properties make boundary objects ideal in spanning diverse technical and scientific fields, an important contribution given the disparate knowledge, tools and practices that characterize expert communities (Abbott, 1988, 2001; Knorr Cetina, 1999), particularly because they only require work when these worlds meet (Star, 2010; Star & Griesemer, 1989).

Originally developed to conceptualize spanning scientific fields and distributed research sites (Star, 2015 [1989]; Star & Griesemer, 1989), the boundary object concept has been widely applied in management and elsewhere, particularly in cross-disciplinary contexts (e.g. Carlile, 2002, 2004; Dibenigno & Kellogg, 2014; Kellogg, Orlikowski & Yates, 2006; Nicolini, Mengis & Swan, 2012). This includes various empirical settings, from hospitals to architectural firms (Ewenstein & Whyte, 2009; Lindberg & Walter, 2013), and boundary object examples including standardized protocols, platforms, classifications, etc. (Bowker & Star, 1999; Griesemer, 2015). With such diverse uses, one major critique is that the boundary object concept has been applied too widely (Nicolini et al., 2012). Moreover, if anything can, in theory, become a boundary object (Griesemer, 2015), the divergent practices, expectations and knowledge that make boundary objects so useful in spanning across different technical and disciplinary contexts would likely make it difficult for boundary objects to successfully become established. Hence, we examine two key research questions: (1) How are boundary objects created? (2) How do boundary objects achieve stability?

We thus seek to understand how highly technical boundary objects can initially become established in a way that will suit multiple communities of expertise, but retain their "plastic" yet "robust" quality (Star, 2015 [1989]). While existing work has focused on how boundary objects can become more durable infrastructure (e.g. Bowker & Star, 1999; Star, 2010; Star & Ruhleder, 1996), we know less about their beginnings. In organization theory, research initially focused on boundary management (Carlile, 2004), rather than the "essence of the objects themselves" (Ewenstein & Whyte, 2009, p. 8). Current research, particularly from practice-focused researchers, has tended to use what Nicolini et al. (2012) call a "pluralist" approach, employing additional object-based theories to, for example, specify when objects function as boundary objects vs. epistemic objects (e.g. Ewenstein & Whyte, 2009; Lindberg & Walter, 2013; Scarbrough, Panourgias & Nandhakumar, 2015). In contrast, we argue that deeper engagement with the words of Star and her collaborators could enrich the boundary object concept on its own terms. As the concept of boundary object creation is implied in core works, we believe further empirical examination of the difficult creation processes is fruitful, particularly when requiring active collaboration between disparate groups from the beginning.

Our specific context is Grid computing, a technology used to harness multiple computers and networks to form a "virtual supercomputer." A precursor to cloud computing, Grid computing promised to revolutionize fields of science and engineering with distributed, collaborative, and efficient features, plus larger dataset capabilities (Atkins et al., 2003). It is also an appropriate context for our research questions. At the time of study (2004–2009), Grid computing packages were still evolving, requiring major adaptation to target fields. In boundary object terms, this enabled a focus on the early stages of co-construction, given disciplinary scientists' rejection of standard Grid templates, allowing insight into the processes leading to successful stabilization. We used comparative ethnographic methods to examine cross-disciplinary projects in three fields of science: astrophysics, behavioral neuroscience and agent-based modelling. We adopted a "follow the object" method (e.g. Czarniawska, 2004, 2007), following the early-stage Grid projects, challenges encountered and resolutions developed.

The findings allow us to contribute three insights. First, we articulate stages of boundary object development, which in this case required a "mindset shift" for co-creation to successfully occur in the three projects, marking the beginning of stabilization, i.e. development of the noted properties of flexible durability, sharing and recognizability. Second, we identify the human and technical resources facilitating stabilization, such as "strengthening people" who help mediate and translate the stabilizing boundary object. Finally, we contribute to organization and management theory by delving into a fundamental property of boundary objects, but one underused in management: the simultaneously global-local nature of boundary objects. We argue this enhances the methodological utility of the concept for management research in the internet age, with growing cross-organizational and globally distributed work. These findings have important implications for management theory and practice for cross-disciplinary collaboration, both across and within organizations, as discussed in the concluding section.

Boundary Objects to Bridge Technical Culture Divides

We are particularly interested in the creation of boundary objects bridging expert communities, and indeed, transcending competing disciplinary practices, languages and goals motivated Susan Leigh Star's foundational work on boundary objects as a method of reconciliation across different social worlds (Bowker & Star, 1999; Star, 2015 [1989]; Star & Griesemer, 1989). When working together across a disciplinary divide, differences between fields can engender frictions from competing knowledge, expertise, practices, devices and motivations (Abbott, 1988, 2001; Carlile, 2002; Galison, 1997), all of which can hinder organizational work. As Knorr Cetina (1999) shows in her ethnographic comparison of high-energy physics and molecular biology, the culture of a field pervades numerous aspects of work. Cross-disciplinary and role differences are known to be challenging for technology projects within firms (Bechky, 2003; Ewenstein & Whyte, 2009; Lindberg & Walter, 2013), and across firms (Kellogg et al., 2006). But disciplinary conflicts are likely amplified when project participants voluntarily work across organizational boundaries, given different organizational incentives, but fewer management tools. Moreover, working across fields entails reshaping practices, processes and expectations, challenging unquestioned assumptions about how and when to do things (Knorr Cetina, 1999). Thus, even if different groups of experts want to work together to further an innovative project, various differences are likely to hinder these efforts.

Boundary objects are one means of surmounting these problems. As objects inhabiting intersecting social worlds, they are able to meet the informational requirements of each, even if elements differ between worlds (Star & Griesemer, 1989). While such objects may be "abstract or concrete," they are common enough to be recognizable, such that their creation and maintenance helps to develop and maintain coherence across intersecting worlds (p. 393). The boundary object concept is thus useful as a heuristic and ecological unit of analysis (Star, 2015 [1989]), allowing us to see the world in productive ways, since "the world around us does not come prepackaged in objects, properties, events, processes, or activities" (Griesemer, 2015, p. 209). There are a wide variety of possible boundary objects: specimens, metadata, repositories, standard methods, design documents, etc. (Bowker & Star, 1999; Griesemer, 2015; Scarbrough et al., 2015; Star, 2015 [1989]). At least in theory, almost anything could serve as a boundary object (Griesemer, 2015, p. 206). This expansiveness also informs a key critique of the concept, namely, its indiscriminate use, which can be exacerbated by a lack of analysis (Nicolini et al., 2012). Yet the specific object chosen has to have utility for the given community. As Star notes, "there are different types of boundary objects depending on the characteristics of the heterogeneous information being joined to create them" (Star, 2015 [1989], p. 251). This might suggest a need for further conceptual development, as the boundary object under study must also be suitable "both *to the subjects* engaging the object as well as… *for the STS researchers* studying those subjects" (Griesemer, 2015, p. 206).

We next dig deeper into the essential properties of established boundary objects, those characterizing the fully-realized form. We begin with Star's definition:

> Boundary objects are objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites… weakly structured in common use, and become strongly structured in individual site use (Star, 2015 [1989], p. 251).

Boundary objects have been described as "relatively stable" (Ewenstein & Whyte, 2009), "recognizable" (Bowker & Star, 1999; Nicolini et al., 2012), "durable" (Griesemer, 2015), and "shared and shareable" (Carlile, 2002).

We thus seem to have a paradox, in that boundary objects are used to bridge disparate social worlds, but spring from nowhere. Yet the creation process seems to exist in the primary writings of Star and collaborators, speaking to our first research question. Star notes how she "found four types of boundary objects *created* by the participants," repositories, ideal types, terrains, and forms and labels (Star, 2015 [1989], p. 206-207, emph. added). Elaborated in another way: "systems of actors *create* common objects that inhabit different nodes in different fashions, and are thus locally complete but still common" (p. 207, emph. added). This indicates a process to develop stable boundary objects. For example, boundary objects arise when a working compromise becomes "an ongoing, stable relationship between different social worlds [with] shared objects… built across community boundaries" (Bowker & Star, 1999, p. 292). As these writings do not explicitly identify creation mechanisms, this seems an area for further research.

Complicating our examination of boundary object creation is the need for boundary objects to fit the local context. Star (2015 [1989]) mentions the property of decentralization creating a need for mutual agreement, given the lack of a central authority that could mediate conflicts in how to work together. Despite examples of successful coordination in scientific communities without a central authority (Star, 2015 [1989]), Star does not fully elaborate how this happens, suggesting an area for further research, particularly since much of the management research in this area examines cross-disciplinary collaboration in a single organization (cf. Kellogg et al., 2006). But unlike projects located within a single firm, it can be difficult to establish guiding principles unless voluntary participants agree. Further, in serving various communities of practice, boundary objects must satisfy each community's informational requirements (Bowker & Star, 1999), indicating needs for local adaptation and fitting. Griesemer emphasizes this plastic yet durable nature: "the object can be plastic as it moves among social worlds but can be custom-fit into local practice within each participating world…" (2015, p. 206-207). Without this, there can be problems. For example, boundary objects may fail to take hold in practice if agents do not see the local usefulness (Levina & Vaast, 2005). The process of custom-fitting at the local level is thus an essential part of boundary object creation, but in voluntary work across disciplinary divides, a likely source of frictions.

This leads us to an important property of boundary objects, the simultaneous quality of being both global and local, or “well structured” and “ill structured” simultaneously:

> They are weakly structured in common use, and become strongly structured in individual site use… They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation (Star & Griesemer, 1989, p. 393).

This dual nature is a clear accomplishment in serving multiple scientific communities or social worlds. As explained in Griesemer’s (2015, p. 202) account of their work together: “Leigh always talked about tacking back and forth through the boundary space as an important mechanism by which daily use of a boundary object could be well structured on both sides of the boundary space yet ill structured within it.” As this fundamental property has been less used in management research, in Table 1 we map the noted features of boundary objects onto the global or local context to further this distinction.

[TABLE 1 ABOUT HERE]

We next turn to our second research question: how boundary objects become stabilized. For this, we assume the boundary object has a relatively stable structure, is recognizable and is able to satisfy informational requirements, at least at the local level. But we might ask where and when this structuring takes place? Let us return to Star’s concern with “tacking back and forth.” First, if the boundary object connects disciplinary communities to establish a shared context that “sits in the middle” of a group of actors with different viewpoints (Carlile, 2002; Star & Griesemer, 1989), tacking back and forth comprises essential work to create this middle space. In terms of progress indicators, then, the ability to use boundary objects without too much friction would mark a degree of stabilization in the local context, as would local recognition. But stable may not mean fully settled; boundary objects are a product of resolved conflicts, seen in the "traces of multiple viewpoints, translations and incomplete battles" or "inscriptions" (Star & Griesemer, 1989, p. 413).

We seek to develop the boundary object concept on its own terms, but as the works of Star and collaborators were somewhat less forthcoming about stabilization processes, here we incorporate newer work on object stabilization. For example, stabilization may require additional support, both actors who can help translate between communities at crucial points, or technical accommodations, as translation at multiple levels may be required to align the disparate knowledge, tools and practices and create shared language and concepts (Callon, 1986; Carlile, 2004; Galison, 1997). We argue that "marginal people," people who inhabit more than one social world (Star & Griesemer, 1989, p. 411), play an important role in the successful stabilization of boundary objects. Work might go more smoothly with internal consultants to coordinate (Power, 2015), and collaboration and work can be enhanced when individuals can draw upon a shared identity (Dibenigno & Kellogg, 2014). For example, museum conservators are key actors in the physical stabilization of art objects, but importantly, conservators "who can collaborate and work across conservation boundaries and varied artistic mediums are better positioned in the field than those traditionally trained in one medium" (Dominguez Rubio & Silva, 2013, p. 170). This suggests divergence from single, traditional fields as a characteristic of successful marginal people. Similarly, in Power's work on accounting objects, field-level abstractions must be integrated into organizational-level practices, which may require organizational members to help translate accounting objects into organizational practices (Power, 2015), which also reminds us not to neglect additional technologies and practices for stabilization. We next use an empirical case to examine how boundary objects are created and then "stabilized."

Research Context: Grid Computing Projects in Diverse Scientific Fields

Originating in the late 1990s from national laboratories and universities, Grid computing coupled network protocols with high-performance computing to enable Internet-based, distributed computing infrastructure. This provides an apt context, because examination of successful collaborations that span highly divergent technical fields is likely to uncover both challenges and creative solutions for boundary object creation and stabilization. Successful implementations were relatively inexpensive, yet more flexible, contrasting with alternatives at the time, including clustering and supercomputing, which were both expensive and confined to single physical locations. Early Grid developments also resulted in additional functionality, while the ability to handle large amounts of distributed data gained Grid developers acceptance within their own community, a field of computer science called high-performance computing.

Grid computing included various efforts to disseminate this technology, linking universities, government agencies, and large players, e.g. HP, with initiatives targeted at scientific and commercial fields (for example, see Wikipedia's "List of distributed computing projects", n.d.). Narrowing the focus to government-funded efforts, we selected scientific Grid computing projects with teams of computer scientists working together with scientists in other disciplines. In reaching outside of computer science into other disciplines, Grid developers hoped to catalyze other areas of research by going beyond isolated scientific silos with a flagship technology. To advance this self-proclaimed revolutionary agenda, Grid developers worked to identify and connect with scientists from different fields. These engagement efforts turned many developers into road-warriors. Their schedules were packed with talks, tutorials and demonstrations given at diverse conferences, professional meetings, laboratories and university departments. As an assistant to a leading developer noted: “He was on the road every week… giving talks, giving tutorials, putting Grids on the map, arguing where it was necessary. Every kind of conference, he was there.” That is, going beyond his home field of computer science, he regularly reached out to individuals from disciplines that did not use these technologies, in service of “putting Grids on the map” (Interviewee #19).

Outside of computer science, however, these efforts often met with lack of interest or resistance from disciplinary scientists. This is unsurprising, because scientific fields are unique cultural domains, furnishing distinct bodies of knowledge, practices, discourses, understandings of technology and structural differences (Abbott, 1988, 2001; Knorr Cetina, 1999). If Grid project members earnestly believed in the transformative capabilities of this innovation, to the vast majority of scientists in other fields the Grid was foreign; for our purposes, it was not yet a boundary object. Even for interested scientists, Grid computing was a complex, highly technical innovation. In boundary object terms, it lacked the essential property of being recognizable. Co-creation was also needed: Grid developers realized they lacked in-depth knowledge in the fields of application and were unable to demonstrate utility to disciplinary scientists. Grid developers thus needed to identify, connect to and then work with scientists to further develop the Grid computing boundary object, i.e. integrate knowledge and practices within a targeted field for co-creation. Scientists in the target fields were incentivized by funding to collaborate, in addition to personal interest and the desire to solve problems with fast computing. The result was a variety of Grid projects targeted at various scientific fields, including our chosen cases.

Research Methods and Cases

The findings compare three cross-disciplinary teams attempting to introduce Grid computing into different fields of science. Two of the projects featured collaborations between Grid developers from computer science and disciplinary scientists from target fields (astrophysics, behavioral neuroscience). The third case provides comparative nuance with a project developed in an interdisciplinary lab (agent-based modeling), a context more similar to boundary object creation in a single organization. Projects featured shared goals, but outside of grant funding, no overriding power from a supervisor or need to "get along" to keep one's job, fitting Star's (2015 [1989]) coordination without a central authority. We used comparative ethnography with "follow the object" techniques (Czarniawska, 2004, 2007; Latour, 1987), common in studies of scientific research and complex professional fields, with the benefit of the prior IT experience of Author 1. Research began with broad review of Grid technology diffusion. Preliminary ethnographic research (2004–2007) included discussions with software developers in a major Grid development project. Along with reviewing publications and project documents, these data provided contextual understanding of practices in the high-performance computing field from which Grid computing emerged. This preliminary stage also established trust needed to conduct focused ethnography with a professional association connecting Grid developers and partners from diverse scientific fields. Participant observation at three meetings in 2007 allowed observation of 32 distinct sessions on the development of Grid computing and Grid adoption experiences. Observation of a wide range of participants offered detailed yet broad understanding of Grid computing projects across different fields. Research during and after these meetings included dozens of conversations with Grid developers, and with disciplinary scientists introducing this technology into their own fields (Table 2).

[TABLE 2 ABOUT HERE]

Review of initial data enabled identification of three cross-disciplinary Grid computing projects for comparative case analysis: astronomy (Astro), behavioral neurosciences (Neuro) and agent-based modeling (Agent). In-depth data collection on the three projects included twenty-eight interviews of informants with leading roles in each of the projects (Table 3), although significant overlap should be noted: twelve out of the nineteen Grid developers interviewed took part in both Astro and Neuro. Agent provided a contrast with a lab that was already interdisciplinary, yet faced similar boundary object creation and stabilization challenges. Interview data was supplemented with written materials produced by the projects. To verify that collected data accurately represented interviewee experiences, reports on each of the three projects were sent to all interviewees for cross-checking.

[TABLE 3 ABOUT HERE]

Our findings are organized around the stages of boundary object creation and stabilization with a focus on the emergent boundary object of Grid computing. Within these stages we articulate the findings using the noted properties of boundary objects (Table 1), the necessary “mindset shift” marking the beginning of the path to stabilization, and mechanisms that allow development of the global-local qualities of boundary objects.

Findings

Encouraging and Inhibiting Factors During Boundary Object Creation

We first review the growing pains of boundary object creation, following the general properties of boundary objects: durable yet plastic, shared across boundaries, and recognizable. We set the stage by discussing the similar motivations of cross-disciplinary project members.

[TABLE 4 ABOUT HERE]

Aligned motivations for co-creation. Project members from computer science and targeted scientific fields wanted to gain funding and build their reputations, but ultimately sought to change their own fields via Grid computing. Project Astro astronomers explained how they were part of a small, growing group of scientists advocating a theoretical and practical paradigm shift: multi-wavelength astronomy. Troubled by conventional wavelength-specific regimes, in which scientists work on telescopes, data and theories for a specific wavelength, such as X-ray or infrared, they sought to combine astronomical data from different wavelengths using Grid computing. Similarly, behavioral neuroscientists in project Neuro viewed the Grid as a tool to advance a scientific agenda that combined measurements and data from different physiological instruments. Neuro scientists believed that combining data streams would lead to a broader understanding of human communication, binding scientific niches into an integrated whole. Interviewees in Agent had similar objectives. In addition to finer-grained agent-based models, they sought to demonstrate the benefits of a new “trans-disciplinary” agent-based modeling, where modelers in biology, health studies, statistics, etc. used Grid computing to contribute data and work together to produce superior agent-based models. Grid developers from computer science were similarly motivated by revolutionary goals of spanning multiple fields of engineering and science with Grid technology. They had already seen productive application in high-energy physics experiments, especially the Large Hadron Collider, one of the initial successes of scientific Grid computing. Despite shared goals, all three projects faced challenges in realizing this potential. Grid developers who had helped adapt Grid technology to physics were initially flummoxed by problems in later projects. Logically, prior experience should make future work easier. The reasons why this was not the case form a major part of our findings.

Needing durable yet plastic qualities. First, boundary objects are theorized to span disciplinary divides through a durable, yet plastic nature. Yet our findings suggest this property requires active development. For one thing, computer scientists preferred standard templates, a practice that initially hindered co-creation.[2] They had begun by developing field-specific templates, which required further customization for local use. But localization was made more difficult by prior successes in high-energy physics, where developers had worked closely with physicists, leading Grid developers to assume these solutions were a standard technical template that could generalize to other fields. Grid templates instead became the basis of discussion and negotiation. In these voluntary collaborations, no central authority or body could mandate a protocol, although Agent's interdisciplinary and self-contained lab structure did provide collaboration resources.

Similarly, interviewees repeatedly mentioned challenges in data handling and analysis, where assumptions about data impeded goals of joining multiple various data types. Grid systems were designed to process large—in some cases unprecedented—amounts of distributed data. However, from their experience with data generated by particle detectors in high-energy physics, developers incorrectly expected homogenous data. For example, Project Neuro scientists noted vexing discrepancies between the original Grid computing assumptions and practices in their field. In needing to aggregate various types of data from different physiological detectors, Neuro members faced unique data validity challenges. As compared to physics data, a scientist explained, the more ambiguous data in Neuro meant one needed to distinguish real data from artifacts (Interviewee #54), i.e. separating findings from "noise" (Latour & Woolgar, 1986

[2] Software engineering practices, especially in object-oriented programming, strongly emphasize generalization and abstraction when writing code, generating beliefs among computer scientists that the best way to "scale" a product is to build a set of highly generalized interfaces (e.g. APIs) that can be used by multiple types of different users.

[1979]). Deciding which readings to save and which to discard provided a technical and theoretical challenge for data handling and analysis using Grid computing.

Challenges related to data descriptors, or metadata, also showed the difficulties of working together. While metadata itself has been analyzed as a boundary object (Griesemer, 2015), in this case it was a significant barrier. For example, Astro interviewees noted how data related to different wavelengths, each with different properties, an issue complicated by multiple astronomical metadata formats. Astronomers knew naming conventions of celestial objects in their own wavelength, but had little knowledge beyond their specializations, meaning easily-shared generic data descriptions were distrusted. In other words, project complexity came not just from scientific domain differences, but also from within-field differences.

These technical challenges highlighted discrepancies between initial assumptions built into early Grid computing systems and the actual procedures, technologies, and habits of prospective users. In boundary object terms, Grid computing was durable, but not yet sufficiently "plastic" in ways that would allow it to fit into the three contexts. Moreover, computer science and high-energy physics assumptions about users and data interfered with local customization, particularly in Astro and Neuro. But Grid developers from computer science could not impose too much – much like Star and Griesemer's "allies," the disciplinary scientists were voluntary participants. We next review additional factors blocking the ability to share Grid computing.

Factors inhibiting sharing across. Another essential characteristic of boundary objects is that they are shared and shareable across boundaries. Yet in the early days of using Grid computing in the three projects, the need for particular technical skills proved a barrier. For example, early Grid platforms required scripting language abilities and featured cumbersome interfaces. Agent and Neuro interviewees thought the technology was generally too complicated for potential adopters in the field. Even astronomers, who generally program and are used to working with large datasets, found this problematic:

> What's simple to them [Grid innovators] is totally opaque to astronomers, and they can't or they may not be interested in finding ways to make that more transparent… That's being part of the problem of "translation" [...] I have tried saying: "Look: you've got to make this relevant to the astronomers, make it simpler and make it simpler… get the website cleaned up, make it [a] more friendly website interface … We get the sort of: "Yeah, yeah. We've heard this for the last four years" (Interviewee #53, Astro scientist).

Communication challenges added to the difficulties, inhibiting initial boundary object creation when, for example, project members were unable to adequately communicate key goals for an interface. This was especially prevalent in Astro and Neuro. With divergent professional jargon, communication challenges were amplified by commonly-used words meaning different things, as seen in a developer's discussion of working with behavioral neuroscientists:

> When they first started talking about "coding-up" an experiment, that's not what I think about "coding." I'm a computer scientist. When I think about coding, I think of writing a program. Their coding is making a symbolic representation of what's happening with the gestures they're seeing, or translating verbal communication onto either paper, or into a computer program… When we think of a "schema," we tend to think of hardcore database design and they'll be talking more about a general, higher level description of things (Interviewee #7, Grid developer).

New language was bad enough, but the very same words could invoke different theoretical constructs. Other participants in Neuro confirmed severe linguistic discrepancies, and problem words such as "analysis" and "annotation". In contrast, Agent's interdisciplinary laboratory had cultivated its own language, a solution likely to be found in single-firm boundary object creation.

A further sharing issue in Neuro came from field-specific software. Grid computing required the ability to "port" scientific software from existing computing systems into a widely distributed, Grid environment. This required recompilation of existing software into the Grid, excluding many programs commonly used in the behavioral neurosciences, such as MATLAB.

These closed commercial products prevented developers from making changes necessary to port the software into a distributed Grid computing environment, while software licensing schemes were typically pay-per-computer, with no provision for distributed computing.

Motivations blocking Grid recognizability. A third property of boundary objects is that they are recognizable, allowing a shared middle ground. While the prior challenges certainly limited recognizability of the shared boundary object, we also found discrepancies between scientists' and Grid developers' agendas inhibiting co-creation, despite the many shared motivations. One issue was that Grid developers sought broad uptake of the Grid's computational principles, whereas domain scientists viewed Grid computing as an instrument for field-specific paradigm shifts. Interviews and published materials spoke to the professional culture of computer science, particularly in high-performance computing, guiding Grid developers to pursue big, fast machines and cutting-edge technologies, as funding and peer recognition required pushing the envelope. This created friction with disciplinary scientists. A Neuro interviewee described this as a "machines" vs. a "theory" orientation. Similarly, astronomers saw Grid developers in Astro as constantly searching for new computational features—"cool things" or "a sandbox to develop unique capabilities"—which became a "trade-off between creativity and discipline." Field scientists sought targeted solutions, rather than widespread adoption or general tools. These divergent objectives inhibited mutual recognition and thus boundary object creation.

To summarize the various challenges in boundary object creation, we found Grid technology failing to be durable yet plastic, shared across and recognizable. Grid developers had come into the scientific fields of interest with revolutionary goals and a template they thought would entice scientists to use Grid technology. Over-customization to high-energy physics, usability and tool problems interacted with the ability to localize, essential for wider recognizability of shared boundary objects. If boundary objects are able to inhabit multiple communities of practice while satisfying the various informational requirements (Bowker & Star, 1999), in the three projects, this essential quality was lacking.

Essential Step: The "Mindset Shift"

At the time of fieldwork, the core Grid technology was still under development, but many features had become stable in the seven years since the earliest prototypes. Grid developers had quickly realized additional accommodations were necessary, a first step toward true co-creation of Grid computing. But over time, it became clear that project success meant recognizing that some problems were not simply technological, e.g. necessitating a better template. Project success required a systematic change, which interviewees frequently characterized as a "mindset shift." Going beyond field-specific technical interfaces, Grid developers realized they needed the Grid to integrate with disciplinary scientists' usual working practices. At times, disciplinary scientists needed to press developers for contextualization and ease of use; their Grid developer collaborators would not recognize the problems otherwise. As a veteran Grid developer noted: "Different communities want different things… operate in different ways… You need different interaction mechanisms and all that" (Interviewee #16). This was not necessarily an easy shift, given the divergent goals and assumptions of developers. It required giving up a key element of the computer science orientation, the tendency towards standardization.

Interestingly, a similar mindset shift was present in Agent, where new lab members needed to let go of old assumptions to adopt the lab's agent-based modeling perspective and jargon. Similar to organizational induction processes, every scientist joining the lab had to undergo a socialization process, requiring entrants "to do away with [disciplinary] assumptions" and “get used to a new frame of mind,” as one scientist pointed out. “You pretty much have to start from scratch” (Interviewee #55). While the mindset shift began with entry into Agent’s interdisciplinary lab, which resolved communication difficulties with a shared language, in Astro and Neuro, it took time and frustration before Grid developers realized a new way of thinking was required. But in all cases, this essential mindset shift paved the way for boundary object stabilization, allowing the essential properties of boundary objects to emerge. We next review the successful resolutions for boundary object stabilization.

Factors and Attributes During Boundary Object Stabilization

After the mindset shift, we found a recognition of localization needs, particularly in Neuro and Astro. This sets the stage for boundary object stabilization, which can be seen when Grid technology begins to encompass key boundary object attributes: durable yet plastic, shared across and recognizable. We also find needs for further support and lingering frictions.

Durable yet plastic with blackboxing. With the mindset shift, the projects began to resolve a challenge repeatedly mentioned by interviewees: integrating Grid computing with core technologies in target fields. This enabled the durable yet plastic nature of boundary objects – previous designs were too rigid, overly fitted to high-energy physics, requiring modification to fit the local context. The resulting stabilization solutions hid unnecessary disciplinary complexity on both sides, with interfaces, wrappers and web portals.

First, interfaces simplified the use of Grid systems, along with application programming interfaces (APIs) and “wrappers.” APIs can be understood as libraries and applications that connect incompatible software programs and computer protocols that cannot directly interact. Wrappers translate between incompatible interfaces and data formats. Each of the studied projects developed APIs and wrappers to accommodate field-specific practices, e.g. one Astro

API was meant to serve as an interface for: “a variety of popular languages and environments for application development… providing high level object-oriented API to isolate applications for the details of the underlying framework” (Astro, internal project document).

Fixing metadata was another important issue, as this would facilitate the data sharing goals at the heart of scientists’ Grid computing agenda. For example, many Astro wrappers provided name resolution, translating celestial names into coordinates. This allowed astronomers to “open up the sky,” retrieving data by entering coordinates, rather than wavelength-specific celestial names or host computer locations. Astro interfaces also connected existing field-specific applications and computer languages with the Grid’s Java framework. Technical interfaces developed in Astro were thus used to bind diverse existing technical environments to the Grid, while masking the underlying specificity of the Grid from astronomy systems and their users.

Third, in all of the studied projects, Web-portal interfaces (“portals”) emulated field-specific practices and infrastructure, while allowing users to connect to the Grid. This was important because “barebones” command-line computer tools and native languages used in Grid systems deterred potential users. Like APIs and wrappers, portals hid the complexities of Grid technology. So when astronomers searched for multi-wavelength data, they eventually used a Web-based portal. Neuro participants pursued an almost identical approach to attract potential users in behavioral neuroscience sub-fields. Even without guidance from Grid developers, Agent also designed a Web-portal interface, one with different sections—“tentacles,” as one scientist called them—to appeal to potential users from a wide range of fields. As a system designer explained, “[it] makes the user completely oblivious to the fact that there is an underlying Grid environment. It allows the user to play with different simulations without knowledge from where he gets access” (Interviewee #46). Web portals were also a solution when “porting” scientific software into the Grid environment was not possible. For example, in Neuro, while there was still no way to port off-the-shelf products into a Grid system at the time of fieldwork, the team had identified open-source substitutes that integrated with the project's portal.

In making Grid computing durable yet plastic, the key solution was "blackboxing," i.e. tools that hid complexity in service of connection (e.g. APIs, wrappers, tentacles, web portals). These translated Grid-specific features into local, field-specific solutions, while also concealing field-specific idiosyncrasies from Grid developers. These retained a flexible character, as excessive fitting to a field would reduce the ability of the core Grid technology to evolve.

Solutions for sharing across. When it came to sharing across divides, resolutions were both technical and organizational. Technical practices were a key problem, but not the only source of friction. Project members also faced challenges in working together effectively, primarily communication and alignment of shared goals. Thus, translation was essential work for the teams to communicate effectively, such as clarifying commonly-used but discipline-specific jargon. Over time a shared set of understandings could be developed across interdisciplinary teams (Galison, 1997). A Grid developer working with astronomers and behavioral neuroscientists, plus scientists in other Grid projects, noted: "Every time I started a project there is this period of honing in to be able to understand what each side says" (Interviewee #12). Interviewees considered this a particularly long "honing in" period; it was still fresh in the memory of Neuro informants who had started over a year prior to ethnographic fieldwork. Resolution of linguistic discrepancies was thus a matter of time, requiring the better part of a year in Neuro and Astro, but very little in Agent's self-contained lab.

Another successful approach identified by respondents was to find an individual who was a trained computer scientist, yet possessed deep understanding of the field to which the Grid was being adapted, a sort of disciplinary hybrid, or “strengthening person” (Interview #47). For example, after months of challenging communication, Neuro brought in a graduate student who also had a computer science degree. “That’s a helpful tool, to have somebody that kind of understands both sides… He is a big help in kind of rounding things [out]” (Interviewee #12). This person could help in both technical work and cross-disciplinary communications.

The case of Agent adds nuance to this argument. This self-contained lab included members from the field that birthed Grid computing, who could fit Grid computing technology into agent-based modeling without additional help. But Agent did need support when reaching beyond the lab. Leaders of Agent eventually devised a parallel approach, seeking outside collaborators interested in agent-based modeling, but rooted in a field, such as economics and sociology. By working with these individuals, “We can now discuss with each other our research so that both sides can appreciate [it]” (Interviewee #6). Both of these solutions were also generic enough to apply to future work. For example, a “strengthening person” could be added to all future projects, catalyzing development.

Recognizable as global and local. The disparate motivations of Grid developers and disciplinary scientists might block initial recognition, but over time, their practical goals became more aligned, particularly after the mindset shift. But for successful boundary object stabilization, Grid technology itself also had to become more widely recognizable, particularly to peers in the scientific fields. Co-developed interfaces, wrappers and tentacles enhanced recognizability through localization, increasing the utility of these tools for peers. However, there were continuing developments at the global level; interfaces that allowed continued integration with the evolving core technology enabled the more general, global boundary object that could be commonly shared.

In service of critical complexity, we also wanted to mention several unresolved conflicts, as in Star's "cooperation without consensus," we would expect successful boundary objects to have residual issues. First, some field-specific challenges continued, including difficulties with data sharing (Neuro, Agent) and privacy (Neuro).[3] A senior neuroscientist concluded that when it came to wider Grid adoption, "Data sharing is the biggest impediment [to adoption]" (Interviewee #57). Second, in pursuing the revolutionary goals motivating Grid computing involvement, disciplinary scientists became less recognizable to peers in the same field. For example, Astro's ongoing pursuit of multi-wavelength practices distanced members from single-wavelength colleagues. The unique interdisciplinary environment of Agent also had paradoxical outcomes. Their socialization process helped to iron out communication idiosyncrasies and attune individuals to the lab's goals, while lab managers facilitated coordination, but interdisciplinary work also weakened field affiliations of member scientists. These challenges seemed likely to decrease as Grid computing gained further recognition in each of the fields. At the same time, growing standardization would require a light touch, given Star and Griesemer's (1989, p. 407) caution that participating groups ("allies"), will only conform to a central authority if protocols were adequately flexible: other communities cannot be "over disciplined."

Discussion

The findings show how boundary objects can be successfully developed in a context requiring co-creation by disparate groups working together across boundaries. Our analysis of

[3] Human subject data engendered challenging privacy issues and ethical, institutional and legal regulations, such as the U.S. Health Insurance Portability and Accountability Act (HIPAA). Data collected by behavioral neuroscientists can be used for commercial applications, e.g. drug development. Data sharing regulations were less problematic for agent-based modelers, with computer-generated data, but models were considered proprietary, inhibiting sharing.

Grid computing comprises three main insights: stages of boundary object development, additional resources facilitating stabilization and simultaneous global-local qualities.

Initial Dynamics of Boundary Object Development

The findings shed light on the early stages of boundary object creation and then stabilization, with a focus on disciplinary frictions and successful resolutions. First, we see the benefits of comparative examination of projects that cross both disciplinary and organizational boundaries (Neuro, Astro), as boundary object development was more straightforward in Agent's interdisciplinary lab. The findings show how some aspects of boundary object creation are more challenging when working across organizational borders, adding to this important area of work (e.g. Kellogg et al., 2006; Lindberg & Walter, 2013). For example, Agent's lab benefitted from existing work practices, language and support. While coordination challenges within organizations can certainly prove vexing (Dibenigno & Kellogg, 2014; Scarbrough et al., 2015)—indeed, a reason for boundary objects in the first place—this was nonetheless a beneficial starting point. In contrast, coordination resources had to be developed from scratch in the cross-organizational projects (Neuro, Astro). We also identified one downside of the interdisciplinary lab structure, given the loss of professional identity in Agent. While rigid professional identity can impede cross-cutting collaboration, for example, via occupational differences (Dibenigno & Kellogg, 2014), it is nonetheless important in scientific disciplines (Abbott, 1988, 2001; Knorr Cetina, 1999), with implications for publishing and grants.

A second important consideration was that projects were voluntary. Hence, in contrast to when, for example, accounting or educational standards bodies impose certain requirements (Power, 2015), Grid developers lacked the power to mandate adoption. Too much imposition of standard templates meant disciplinary scientist teammates were less likely to cooperate, or worse, this challenged wider dissemination goals. Unlike contexts where templates can become inscription devices with power and durability (Power, 2015), early Grid templates were rejected as not relevant for the community (Levina & Vaast, 2005), showing how the power to impose templates is an important consideration when examining cross-disciplinary work, as allies cannot be "over disciplined" (Star & Griesemer, 1989).

Given the voluntary nature of the projects, initial assumptions about users and data, together with the ease-of-use issues, posed daunting challenges to field scientists' ability to understand and use Grid technology. Projects began with standard templates, based on early successes in high-energy physics. But this meant specific assumptions were built into the material design of the innovation, assumptions that proved problematic in new contexts. Grid developers needed to realize for themselves that users in the scientific fields were not going to radically change the way they worked, but that Grid computing had to be adapted to suit existing practices. This required developers to let go of the generalizing tendency of their own discipline.

This shows why a "mindset shift" was necessary before true co-creation would happen, enabling localized forms "tailored to local use within a social world" (Star, 2010, p. 605). As Grid developers initially resisted relinquishing standard templates, despite pushing from their scientist teammates, we argue that a mindset shift is necessary for movement into the stabilization stage, complementing our understanding of early cross-disciplinary collaboration. Moreover, early success in other areas—here high-energy physics—seems to make this mindset shift more difficult, blocking the progress of co-development necessary for localization, perhaps exacerbated by the voluntary nature of the projects. While boundary objects will include prior "inscriptions" from multiple viewpoints, prior translation and conflicts (Star & Griesemer, 1989), at the early stages, it seems that overly rigid assumptions impede true co-creation. The project structure also matters, as Agent's interdisciplinary lab had an advantage over the cross-organizational projects, where the mindset shift took much longer. Overall, the fact that early boundary object development requires injections of fluidity and change is useful for understanding the trajectory to stabilization.

Stabilization Resources and Support

In service of our goal of extending the boundary object concept on its own terms, we also used an object "stabilization" lens (e.g. Dominguez Rubio & Silva, 2013; Power, 2015), noting how objects gain stability as they become translated into specific organizational practices (Power, 2015). This compatible lens enables deeper engagement with Star and her collaborators' theory, because as noted, "tacking" back and forth between the global and local form was an essential part of Star's conception of how boundary objects worked (Griesemer, 2015). In our case, this seems present in the "honing in" period mentioned by Grid developers as they began to orient themselves to the new situation, developing shared language and fitting the technology to the target discipline. But we also found that co-development was difficult for Grid developers and disciplinary scientists even after the mindset shift, perhaps because it required actively crossing the disciplinary divide, rather than merely doing work at the border, as is commonly understood with stable boundary objects (Star, 2010; Star & Griesemer, 1989).

Projects thus needed additional help for boundary object stabilization, particularly with the technical sophistication of Grid technology. First and foremost were "strengthening people," with a foot in both worlds, who could act as "marginal people" (Star & Griesemer, 1989, p. 411), to implement the localization demanded by the disciplinary scientists. With the ability to translate terms, explain objectives and write code, they allowed teammates to better understand one another. This resonates with existing research, where object stabilization may require employees who can act as de facto consultants for activity orchestration (Power, 2015). Moreover, shared social identities can help transcend occupational differences (Dibenigno & Kellogg, 2014). In contrast, external strengthening people connected Agent's interdisciplinary lab to fields of interest, which extends knowledge of boundary object dissemination once stable.

This stabilization was enhanced by the interfaces (tentacles, portals, APIs and wrappers) that helped to hide complexity, and their development starts to show the pathway to the stable boundary object. These provided enough localization for disciplinary scientists to comfortably interact with Grid technology, while gaining enhanced capabilities and data access. In theoretical terms, interfaces thus take a similar role to the visual representations (Ewenstein & Whyte, 2009) that can help to stabilize objects or evolve knowledge in other cases. While Ewenstein and Whyte were talking about evolving epistemic objects, we believe that interfaces and wrappers similarly help to build up early boundary objects to become "stable and concrete" (p. 27).

Paradoxically, the use of stabilizing people and interfaces marked a change in work practices (Power, 2015) when it came to boundary object co-creation, but this was in service of the goal of *not* requiring adopters to dramatically change their practices. In that these human and technical supports allow the durable yet plastic, shared and recognizable nature of boundary objects to come about, Grid computing becomes able to satisfy the "informational requirements" on all sides (Bowker & Star, 1999). This marks a move into a fully-established boundary object that is adequately localized to the discipline, i.e. "tailored to local use within a social world, and therefore useful for work that is NOT interdisciplinary" (Star, 2010, p. 606). This seems to be the point where the boundary object becomes clearly realized, seen in the way that it starts to fade into the background, integrated with field-specific practices, with distracting complexity hidden.

Simultaneously Global and Local

As the simultaneous global-local nature of boundary objects is less examined in management, it is productive to further discuss these qualities, particularly since our comparative design allows us to examine the developing properties of the boundary object in various contexts at the same time. For this, we link back to the identified attributes of boundary objects (Table 1), i.e., that in common use, they are “weakly structured,” and when used in a particular site they become “strongly structured” (Star, 2015 [1989], p. 251). While this point relates to stabilization, here we foreground the global-local features. Without requiring radical adjustment from either developers or users, these adjustments connected seemingly incompatible systems in ways that allowed continued parallel development of the core technology. As this dual-level work was essential for the Grid boundary object to exist, in Diagram 1 we map the essential properties of boundary objects before and after stabilization to examine how the general features change at both the global and local level. We find a gradual shift toward general properties that can be recognized in multiple social worlds (e.g. distributed data access) vs. elements specific to a local context (e.g. celestial name recognition).

[DIAGRAM 1 ABOUT HERE]

This featured technical work at both global and local levels. Blackboxing divergent technical practices allowed the Grid computing boundary object to develop simultaneously in multiple contexts and in the core technology, i.e. locally and globally. The various interfaces, tentacles and portals helped Grid computing to localize for prospective adopters in ways that still allowed development of the core technology; improvements to the underlying Grid enabled better performance at the local level. This complements existing research concerned with the coordination of parallel work in different expert groups (Kellogg et al., 2006; Scarbrough et al., 2015). Moreover, this quality helps to distinguish shared boundary objects from Knorr Cetina's (1997) unfolding epistemic objects, in that the general global and local properties can be known in advance (Figure 1). We thus can expect the development of new practices more than new knowledge, which presumably would arise *because of* the data available from Grid portals, for example, allowing us to complement pluralist research using multiple approaches to objects (e.g. Ewenstein & Whyte, 2009; Nicolini et al., 2012).

Overall, we complement the work on boundary objects by identifying key stages and the necessity of additional support to initially span disciplinary divides. If we map out our stages of development with the global and local properties of boundary object development, we get a potential roadmap for cross-disciplinary collaboration (Table 5). The original standard Grid templates failed as a boundary object, lacking the key qualities of being durable yet plastic, able to be shared across, and recognizable. With the mindset shift, these are able to be localized, while connecting back to the general developments of Grid technology at the global level. Revisiting the markers of successful boundary objects is helpful to identify the transition towards successful stabilization. The tricky part seems to be that interfaces and other accommodations had to be developed anew for each localization. When it came to their development, Star theorized that boundary objects within scientific communities would be distributed and thus jointly created within the relevant communities (Star, 2015 [1989]). We complement this and boundary object research in management by elaborating stages of development likely to be found in other cross-disciplinary contexts.

[TABLE 5 ABOUT HERE]

Management Implications and Contribution

In service of extending the boundary object concept, we have examined boundary object development in terms of creation and stabilization, adding to existing boundary object research in ways relevant to managing voluntary cross-disciplinary projects among organizations. To this end, rather than bringing in complementary theories of objects to understand boundary object creation, as seen in "pluralist" approaches (Ewenstein & Whyte, 2009; Lindberg & Walter, 2013; Nicolini et al., 2012), we revisited the work of Star and her collaborators, as boundary object creation was at least implied in the early work (Bowker & Star, 1999; Griesemer, 2015; Star, 2015 [1989]; Star & Griesemer, 1989).

We contribute three main insights to research and practice. First, we extend knowledge of boundary object creation and stabilization processes in different organizational structures with the comparative design, noting factors that are easier when crossing disciplines within an organization vs. when also crossing organizational boundaries. We posit the mindset shift as an essential step between boundary object creation and stabilization, enabling localization to go beyond superficial customization into true co-creation, though prior success in other domains can actually hinder progress. Second, we contribute further understanding to boundary object stabilization mechanisms, identifying the properties of stable boundary objects as progress indicators of stabilization, namely, durable yet plastic, able to be shared across, and reasonably recognizable in the fields. We also found the need for additional adaptations to help ensure boundary object stabilization in these early stages, over and above customization of templates. The successful adaptations—e.g. "strengthening people," web portals—while requiring time and resources, offer efficient methods of transcending disciplinary divides, particularly when projects span organizational boundaries. Our proposed mechanism is that these resources allowed participating groups to use the boundary object while remaining focused in their own fields, i.e. doing work at the border, rather than crossing a disciplinary divide (Star, 2010; Star & Griesemer, 1989). Third, we elaborate dynamics of the simultaneously global-local distinction and types of work done to produce this. While less used in management, it nonetheless represents a provocative area for future research, given the ubiquity of cloud and networked technologies in modern organizations.

Our work has important implications for management theory and practice, as the creation and use of objects is integral in all organizations, from science (Knorr Cetina, 1999) to medicine (Lindberg & Walter, 2013), to new innovations (Carlile, 2002). First, we contribute to cross-disciplinary collaboration research, where the challenge of working across technical fields both creates a need for boundary objects, but also hinders initial creation, especially if mutual development is required. Since most management studies of cross-disciplinary collaboration are within single organizations (e.g. Scarbrough et al., 2015), the comparative design extends knowledge of boundary object development in different organizational structures. The findings also enrich our understanding of the frictions faced in bridging interdisciplinary divides, particularly when there is no overarching management structure or standards body to guide the collaboration, showing how shared understanding needs to come before the development of technical solutions. We also provide further empirical evidence about which challenges of boundary object creation are more difficult when working across organizations and which elements are likely to be seen in either context. As an essential part of the boundary object concept, global-local qualities, though under-examined in management, provide suggestive ground for theory and practice.

We should also be mindful of the limitations of our case, as scientific collaborations can differ from other types of organizational work. For example, flexibility and the lack of quarterly profit incentives are a key difference between, e.g., academic computing and computer game firms (Scarbrough et al., 2015). Moreover, the simultaneous global-local features of Grid computing may be more characteristic of software than other types of boundary objects. We are also unsure whether it was helpful or unhelpful that Grid developers worked across multiple projects, suggesting another area for comparative examination.

We also see further questions for management research. One interesting question would be when to stay with the boundary object concept and when to make the jump to complementary object-focused theories, as in a pluralist approach (e.g. Lindberg & Walter, 2013), since this may complicate things but add useful nuance. For example, objects can function in different ways for different groups (Ewenstein & Whyte, 2009; Mcgivern & Dopson, 2010; Nicolini et al., 2012; Scarbrough et al., 2015). That said, there are situations where one main framework is preferable, for example when working with students or practitioners. Or work thus provides an accessible roadmap for study the evolution of objects in organizations.

References

Abbott, A. D. (1988). *The system of professions: An essay on the division of expert labor*. Chicago, IL: University of Chicago Press.

Abbott, A. D. (2001). *Chaos of disciplines*. Chicago, IL: University of Chicago Press.

Atkins, D. E., Droegemeier, K. K., Feldman, S. I., Garcia-Molina, H., Klein, M. L., Messerschmitt, D. G., Messina, P., Ostriker, J. P., & Wright, M. H. (2003). *Revolutionizing science and engineering through cyberinfrastructure: Report of the national science foundation blue-ribbon advisory panel on cyberinfrastructure*: National Science Foundation.

Bechky, B. A. (2003). Sharing meaning across occupational communities: The transformation of understanding on a production floor. *Organization Science, 14*(3), 312-330.

Bowker, G. C., & Star, S. L. (1999). *Sorting things out: Classification and its consequences*. Cambridge MA: MIT Press.

Bowker, G. C., Timmermans, S., Clarke, A. E., & Balka, E. (Eds.). (2015). *Boundary objects and beyond: Working with leigh star*. Cambridge, MA: MIT Press.

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of st. Brieuc bay. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge* (pp. 196-233). London, England: Routledge Kegan & Paul.

Carlile, P. R. (2002). A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science, 13*, 442-455.

Carlile, P. R. (2004). Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organization Science, 15*(5), 555-568.

Czarniawska, B. (2004). On time, space, and action nets. *Organization, 11*(6), 773-791.

Czarniawska, B. (2007). *Shadowing: And other techniques for doing fieldwork in modern societies*. Malmö, Sweden: Copenhagen Business School Press.

DiBenigno, J., & Kellogg, K. C. (2014). Beyond occupational differences. *Administrative Science Quarterly, 59*(3), 375-408.

Dominguez Rubio, F., & Silva, E. B. (2013). Materials in the field: Object-trajectories and object-positions in the field of contemporary art. *Cultural Sociology, 7*(2), 161-178.

Ewenstein, B., & Whyte, J. (2009). Knowledge practices in design: The role of visual representations as 'epistemic objects'. *Organization Studies, 30*(1), 07-30.

Galison, P. (1997). *Image and logic: A material culture of microphysics*. Chicago, IL: University of Chicago Press.

Griesemer, J. R. (2015). Sharing spaces, crossing boundaries. In G. C. Bowker, S. Timmermans, A. E. Clarke & E. Balka (Eds.), *Boundary objects and beyond: Working with leigh star* (pp. 201-218). Cambridge, MA: MIT Press.

Kellogg, K. C., Orlikowski, W. J., & Yates, J. (2006). Life in the trading zone: Structuring coordination across boundaries in postbureaucratic organizations. *Organization Science, 17*, 22-44.

Knorr Cetina, K. (1997). Sociality with objects: Social relations in postsocial knowledge societies. *Theory, Culture & Society, 14*(4), 1-30.

Knorr Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Cambridge, MA: Harvard University Press.

Latour, B., & Woolgar, S. (1986 [1979]). *Laboratory life: The construction of scientific facts*. Princeton, NJ: Princeton University Press.

Levina, N., & Vaast, E. (2005). The emergence of boundary spanning competence in practice: Implications for implementation and use of information systems. *MIS Quarterly, 29*(2), 335-363.

Lindberg, K., & Walter, L. (2013). Objects-in-use and organizing in action nets: A case of an infusion pump. *Journal of Management Inquiry, 22*(2), 212-227.

List of distributed computing projects. (n.d.). Retrieved 30 Aug., 2017, from https://en.wikipedia.org/wiki/List_of_distributed_computing_projects

McGivern, G., & Dopson, S. (2010). Inter-epistemic power and transforming knowledge objects in a biomedical network. *Organization Studies, 31*(12), 1667-1686.

Nicolini, D., Mengis, J., & Swan, J. (2012). Understanding the role of objects in cross-disciplinary collaboration. *Organization Science, 23*(3), 612-629.

Power, M. (2015). How accounting begins: Object formation and the accretion of infrastructure. *Accounting, Organizations and Society, 47*, 43-55.

Scarbrough, H., Panourgias, N. S., & Nandhakumar, J. (2015). Developing a relational view of the organizing role of objects: A study of the innovation process in computer games. *Organization Studies, 36*(2), 197-220.

Star, S. L. (2010). This is not a boundary object: Reflections on the origin of a concept. *Science, Technology & Human Values, 35*(5), 601-617.

Star, S. L. (2015 [1989]). The structure of ill-structured solutions: Boundary objects and heterogeneous distributed problem solving. In G. C. Bowker, S. Timmermans, A. E. Clarke & E. Balka (Eds.), *Boundary objects and beyond: Working with leigh star* (pp. 243-259). Cambridge, MA: MIT Press.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, `translations' and boundary objects: Amateurs and professionals in berkeley's museum of vertebrate zoology, 1907-39. *Social Studies of Science, 19*(3), 387-420.

Star, S. L., & Ruhleder, K. (1996). Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information Systems Research, 7*(1), 111-134.

Table 1. Summary of Boundary Object Properties with Global-Local Distinction

	Properties
Global Properties (Shared Use)	Ill structured, "plastic" Shared and shareable Relatively stable, durable and recognizable
Local Properties (Local Site Use)	Well structured, i.e. fitted to local context Able to satisfy informational requirements Recognizable, i.e. reasonably clear usage and properties
Enabling Work	Tacking back and forth between global and local

Table 2. Data Inventory and Timeline

Stage	Timeframe	Data type	Quantity	Original data format
Fieldwork and Scope Selection				
	Fall 2004 to Winter 2006	Initial Interviews	7	Notes; 4 were formally recorded and transcribed.
		Secondary data	58	Published materials and publicly available documents from various Grid computing development projects
	January to October 2007	Observational data	3 weeklong meetings with 32 sessions related to development and adoption of Grid computing	Field notes including journals of observational notes and on-scene memos
		Informal interviews	17	Formal recordings and transcribed interviews.
In-Depth Data Collection on Three Cases[4]				
	Late 2007 to Winter 2009	Formal interviews with Grid innovators and counterparty brokers.	33	Formal recordings with transcripts
		Secondary data	~19	Published materials, publicly available documents, and internal project documents obtained from Agent, Astro and Neuro.

[4] Three projects were chosen to allow comparative detail, while also retaining appropriate depth. The three projects ran in parallel, allowing systematic examination of how different projects met with varying degrees of success over the same time. For systematic theory building, this was supplemented with iterative induction. Comparative research requires an adequate degree of communality among the studied cases, hence case selection was limited to initiatives targeting fields of science.

Table 3. Case Comparison Table

Case	Character of Scientific Field	Project Maturity	Participating Organizations	Interviews*
Agent-based modeling (Agent)	Newer field that studies the behavior of human and non-human “agents” using simulation techniques	Exploratory tests started in 2005. With additional developments in 2006, and because of the lab composition, this case was somewhat mature.	1	10
Astronomy (Astro)	Well-established field to study celestial objects	Starting in 2003, this was the most mature case	17	8
Neurobiology (Neuro)	Interdisciplinary research area related to both medicine and social science.	Starting in 2005, this project was considered a pilot. At the time of the fieldwork, it was relatively immature.	5	8

* *An additional 18 interviews were conducted with innovators who took part both in these projects and in projects to introduce Grid computing into other fields.*

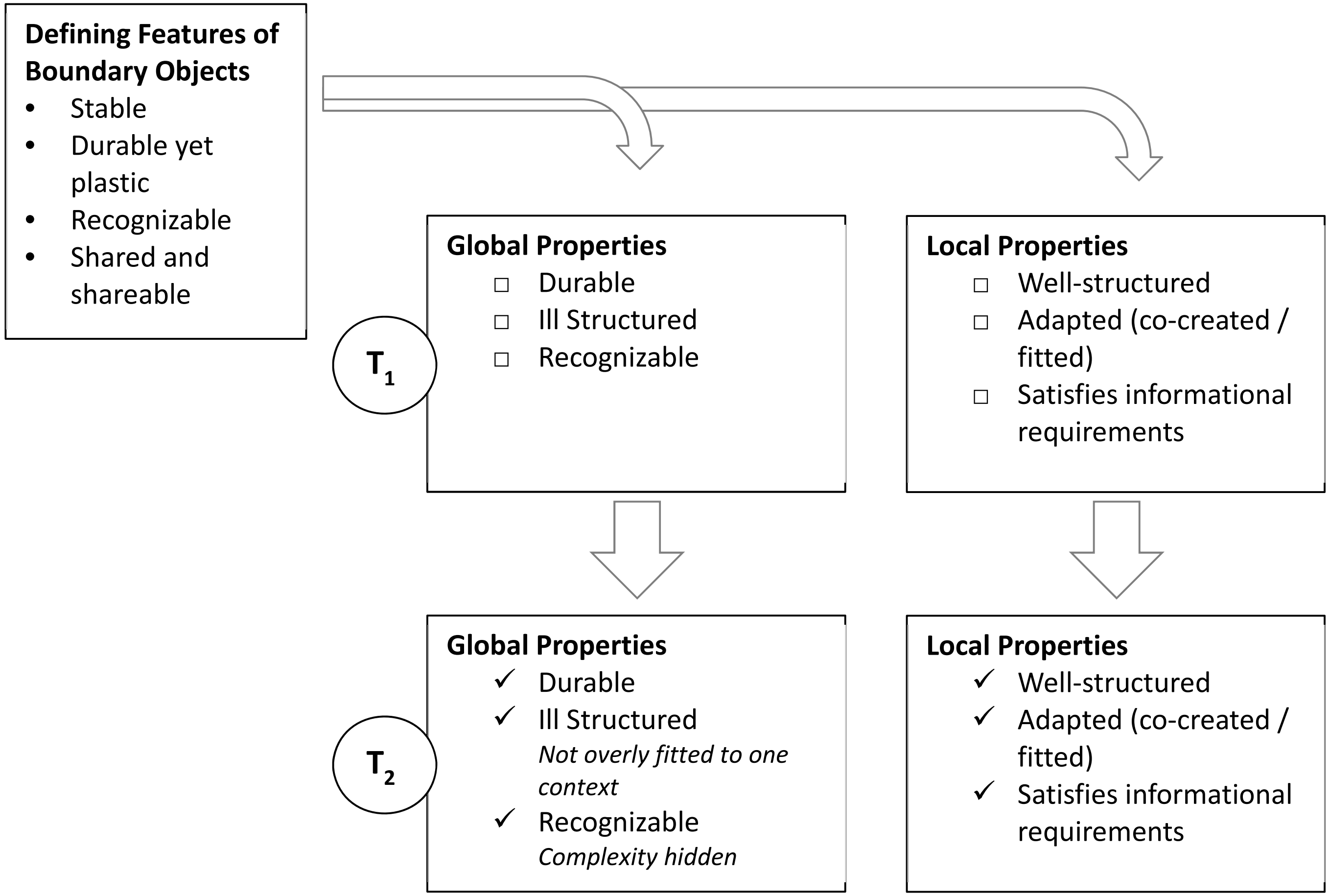
Table 4. Data Exemplars for Key Properties of Boundary Objects

Stage	Theme	Data Exemplars – Boundary Object Creation	Stage	Theme	Data Exemplars – Boundary Object Stabilization
Boundary Object Creation	Needing plastic yet durable features	The transitions [across data types] aren't smooth. When you are dealing with the physical sciences, all you are doing is translating analog to digital. There is nothing arbitrary. It is an operational definition. When you move into physiology … you have to make a decision whether it is an artifact or a real physiological event. So you have a whole set of parameters. An artifact would be something like a movement that moves your electrodes a little, and you get a faulty measurement. From a physical science point of view every measure is a real measurement. Now we move into human behavior, speech, and activity and we start having a whole set of issues that define what is it that we want to study (Interviewee #54, neuroscientist).	Boundary Object Stabilization	Durable yet plastic with black-boxing	I won't compromise simplicity. It needs to be simple, it needs to be composable [in system design]. It can't impose new ways of working, or ways of developing infrastructure just because there are new ways of doing stuff out there… So, you put effort into designing the interfaces. From our project's perspective, a lot of the investment made in the last couple years has been not in core infrastructure, but in developing APIs and interaction mechanisms that go around that infrastructure—so that you've got different mechanisms for different communities. A community isn't going to change the way it's interact[ing] with something. Even if it does interact with electronic resources at the moment it is not going to want to move from that particular mode of operation (Interviewee #16, Grid developer).
	Factors inhibiting sharing across	They are not astronomers and so they don't understand the kind of queries [Astronomers run]… The developers are interested in the development aspect of thing. And what's simple to them is totally opaque to the astronomer… and they can't or they may not be interested in finding ways to make that much more transparent and that's being part of the problem of this translation (Grid developer in Astro).		Solutions for sharing across	It [communication] really is a problem, and I don't know that I have a good answer for how we do this other than trying to identify some people that really have some understanding of the computer science but really do understand the domain science. Sometimes that could be people that are into the main science community that, for whatever reason, happened to have a little more computational events to them [than scientific innovators]. In some cases, it's somebody that just has moved fields over time: who was in one of the fields and has moved into computer science and is interested in both. And then, we can kind of try to help bring them in as a kind of as a go-between or, as a, I don't know, a "strengthening person" (Interviewee #47, Grid developer).
	Motivat-ions blocking Grid recogniza-bility	What you see are the limitations [of Grid developers] and those are based upon of their vision of the world and their goal: to proselytize and proliferate bigger and faster machines. Our goals as neuroscientists are to get technologies that aid in our ability to quantify our data, to analyze our data, to look at the integration across different data streams, to understand and to build stronger and better theory. They are not in that world. They have to be brought in (Interviewee #54, neuroscientist).		Recogniz-able as global and local	Everybody is always resistant to change, unless they can be shown enough benefits to justify the cost of change… From the Grid perspective, in order for us to get really widespread adoption, we've got to make it easier for people to use and implement. We've got to create a software solution that makes it more transparent—that the end user doesn't realize or need to know that their work has been executed on the Grid… We have a lot of vertical industry solutions for that very reason. The industry segment terminology and the [different] type of problems they solve are incorporated directly into these solutions. The terminology is built into the solution. It is crafted for that particular industry segment (Commercial Grid developer).

Table 5. Boundary Object Creation and Stabilization with Global-Local Split

	Initial Creation	Mindset Shift	Stabilization
Global Properties	Overly standardized to high-energy physics, not recognizable	Releasing well-structured mentality, becomes more ill-structured	Ill-structured, but relatively stable, durable, plastic, shareable and recognizable
Local Properties	Not suited to local use and information needs, not shareable	Begins active process of co-creation, tacking back and forth	Fitted to local context with reasonably clear usage and properties, tacking back and forth

Diagram 1. Boundary Object Properties of Grid Over Time



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Title:
Boundary Objects and the Technical Culture Divide: Successful Practices for Voluntary Innovation Teams Crossing Scientific and Professional Fields

Date:
2019

Citation:
Coslor, E; Kertcher, Z, Boundary Objects and the Technical Culture Divide: Successful Practices for Voluntary Innovation Teams Crossing Scientific and Professional Fields, Journal of Management Inquiry, 2019, Forthcoming

Persistent Link:
http://hdl.handle.net/11343/212143

File Description:
Accepted version