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Understanding the Role of Objects in Cross-Disciplinary Collaboration

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In this paper we make a case for the use of multiple theoretical perspectives—theory on boundary objects, epistemic objects, cultural historical activity theory, and objects as infrastructure—to understand the role of objects in cross-disciplinary collaboration. A pluralist approach highlights that objects perform at least three types of work in this context: they motivate collaboration, they allow participants to work across different types of boundaries, and they constitute the fundamental infrastructure of the activity. Building on the results of an empirical study, we illustrate the insights that each theoretical lens affords into practices of collaboration and develop a novel analytical framework that organizes objects according to the active work they perform. Our framework can help shed new light on the phenomenon, especially with regard to the shifting status of objects and sources of conflict (and change) in collaboration. After discussing these novel insights, we outline directions for future research stemming from a pluralist approach. We conclude by noting the managerial implications of our findings.

Key words: cross-disciplinary collaboration; epistemic object; boundary object; activity theory; practice-based studies; infrastructure; boundaries; artifacts; ethnography
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Introduction

One of the most notable characteristics of postindustrial society is that work is increasingly accomplished through collaboration among interdependent groups of disciplinary specialists (Bechky 2006, Clegg et al. 2002, Lawler et al. 1992). A mounting number of social theorists have argued, moreover, that a characteristic feature of modern sociality is that it is increasingly mediated by objects and material artifacts (Knorr Cetina 1997). In this paper we build on previous research on the role of objects in cross-disciplinary collaboration by making a case for the use of multiple theoretical perspectives. Such a pluralist approach highlights that objects can perform at least three types of work to support cross-disciplinary collaboration: they provide the motives and drive for collaboration to emerge, they allow participants to work across different types of boundaries, and they constitute the fundamental infrastructure of the activity.

Our contribution is threefold. First, we develop a novel analytical framework that organizes objects according to the roles they play in collaboration and the theoretical lens taken. Second, we argue that examining the role of objects through different theoretical lenses allows us to see that the role and function of particular objects can change during the course of collaboration. The same object can thus take center stage or shift into the background at different times. The key finding here is that the type of work objects perform in conditions of collaboration derives not only from their inherent nature but also from the nature and unfolding of the activity itself. Third, we argue that a pluralist perspective allows us to better understand sources of conflict and potential breakdown in collaboration. Here, we observe that a particular object can assume a different type of role for the different actors engaged in collaboration at any moment in time—an object being a motivator for some while at the same time being a background for others, for example. This can be an important source of conflict in collaborative work—one not recognized previously—that can impede (or drive) further collaboration.

We illustrate our arguments by drawing from a longitudinal study of the day-to-day practices of collaboration among scientists engaged in a cross-disciplinary project in the domain of biomedical engineering. Thus we follow the advice of authors such as Orlikowski (2002) who suggest that the work performed by objects becomes apparent only when we focus on how experts from various disciplines collaborate *in practice*, starting

from the premise that cross-disciplinary collaboration is a social accomplishment. Although we do not subscribe to the idea that objects *alone* can explain cross-disciplinary work, recent work does suggest that objects perform an active role that needs to be unpacked and better understood (Carlile 2004, Okhuysen and Bechky 2009, Orlikowski 2007).

We stand, of course, in a long line of authors who have addressed these issues (see Orlikowski 2010, Rafaeli and Pratt 2006 for a discussion). In organization science, interest in objects and artifacts has gone hand in hand with the development of so-called "practice-based" studies (Nicolini 2011; Orlikowski 2002, 2007; Osterlund and Carlile 2003) and the parallel raising of emphasis on the social and material nature of organizational practices. As Orlikowski (2007) puts it, the practice-based approach respecifies organizing processes in terms of practices and foregrounds that "materiality is integral to organizing, positing that the social and the material are *constitutively entangled* in everyday life" (p. 1437, italics in original). We submit, however, that in organization science there has been a tendency to give prominence to one specific approach—the notion of a "boundary object" (Carlile 2002, 2004; Star 2010; Levina and Vaast 2005; Star and Griesemer 1989). Indeed, this approach has sometimes been stretched so far from its original formulation that its utility has been questioned (Zeiss and Groenewegen 2009). In short, when all objects become boundary objects, the explanatory power of the theory is undermined.

In this paper we try to reverse this tendency by mobilizing, instead, a plurality of alternative theories to study the role that objects play in supporting cross-disciplinary collaboration. Accordingly, we look at objects not only as boundary devices but also as epistemic things, objects of activities, and infrastructures. Building on our empirical study, we illustrate the insights that each of these approaches affords into practices of collaboration. By working these theories together, we are then in the position to offer a more systematized account of the role that objects play in collaboration and to propose new avenues for research.

The rest of this paper is organized as follows. We start by introducing four approaches to the study of objects in cross-disciplinary collaboration. We then use our case study of the development of a new bioreactor to foreground what each approach has to offer, by way of understanding the different roles that objects play in this context. After discussing the objects' commonalities and differences, we propose an analytical framework that provides a systematic way to investigate the work they perform in cross-disciplinary activities from a pluralist perspective. We conclude with a discussion of the novel insights and implications that this framework offers for the understanding of collaborative work.

Exploring Cross-Disciplinary Work Through Objects

The idea that objects should be included in explanations of collaboration is not new. Almost half a century ago, researchers from the Tavistock Institute theorized coordination in workgroups as part of a "socio-technical system," indicating that material technologies and artifacts played a central role in organizing processes (Trist and Bamforth 1951). This idea has subsequently become a characterizing trait of contemporary social studies of technology, with authors such as Latour (1996, 2005) arguing that the stability of human social orders beyond particular contexts of action can only be explained when one allows for the work performed by objects—symbols alone do not resolve this puzzle. Objects allow us both to act at a distance and to make our interaction endure beyond the present. What makes human sociality distinctive, then, is that practices are not merely constellations of intersubjectivity; they are also constellations of "interobjectivity" (Latour 1996, p. 234). Latour is only one of many contributors to a now large body of work that, according to Suchman (2007, p. 261), provides compelling empirical demonstrations of "how capacities for action can be reconceived on foundations quite different from those of a humanist preoccupation with the individual actor living in a world of separate things."

Focusing on the role of objects also complements recent work on collaboration, especially by authors belonging to the North American interactionist sociology of work (Bechky 2003, 2006; Strauss 1993) and organization communication traditions (Taylor and Robichaud 2004). Although these authors have contributed significantly to the understanding of the practices of collaboration (and coordination)—bringing to the fore the processes entailed and their emergent, provisional, and often conflictual nature—they have, nonetheless, tended to foreground human agency as the main source of alignment.[1] Thus, their main focus has been on discursive practices and interpretation processes that allow people with different backgrounds to work together. In this paper, in contrast, we analyze in detail the work performed by objects in cross-disciplinary collaboration, persuaded that an orientation toward objects is likely to significantly improve the understanding. Following Star (2010), we understand objects as something people act toward and with (p. 603). Although the material dimension of objects matters, such materiality derives from action, not from a sense of prefabricated stuff or "thing"-ness (Star 2010). A theory or representation can thus be a powerful object with very concrete material consequences (Swan et al. 2007).

Conceptualizing Objects in Cross-Disciplinary Collaboration: Beyond Boundary Objects

Much recent organization and management literature has accounted for the role of objects in cross-disciplinary

collaboration using the notion of "boundary objects." The idea derives from the field of science studies, and it highlights the capacity of certain types of artifacts to support collaboration across diverse specialist groups by acting as "boundary objects" (Carlile 2002, 2004; Carlile and Rebentisch 2003; Levina 2005; Star and Griesemer 1989). Boundary objects are defined by their capacity to serve as bridges between intersecting social and cultural worlds. Anchored in, and thus meaningful across, these worlds, they create the conditions for collaboration while, by way of their interpretive flexibility, not requiring "deep sharing."

Although the concept of the boundary object is extremely powerful, in recent years it has been used increasingly as a sort of deus ex machina, a one-size-fits-all explanation that is mobilized any time collaboration across boundaries is discussed and is attached (often incongruously) to a disparate array of artifacts and situations (Star 2010). However, if the idea of the boundary object is stretched to explain *all* the types of work performed by material and symbolic entities, then its original heuristic capacity to explain phenomena of collaboration, thought mediation, and translation is lost (see Zeiss and Groenewegen 2009 for a discussion). The notion works extremely well when used to shed light on how, through an object that resides amid different social worlds, groups cooperate without consensus, tacking "back-and-forth between both forms of the object" (Star 2010, p. 605). However, when used as a "catch-all" notion, it precludes deeper analytical inquiry. Hence Trompette and Vink (2009) suggest that in many cases, "the fact of qualifying an artifact as a boundary object would therefore appear to dispense authors of even marginally-nuanced analysis . . . [the] complexity of interactions between social worlds is often forgotten to the benefit of simplified modelization of the articulation between two worlds via a boundary object" (pp. 8–9).

We argue that stretching the idea of a boundary object to the point where it tries to explain everything (therefore explaining nothing) is, in fact, unnecessary, because other complementary theories exist that can provide persuasive accounts of some of the phenomena under discussion. For example, a different take on the study of objects and collaboration is manifest in the work of Knorr Cetina (1997, 1999), who suggests that the capacity of objects to support collaboration derives from their being experienced as "epistemic things" (Rheinberger 1997, p. 28). Objects becomes epistemic when they embody what one does not yet know. Because of this open-ended nature, they acquire a deep emotional holding power and generate intimate attachment that creates social bonds, either because their complexity requires joining forces or because the drive and desire toward the same object constitutes the basis for mutual recognition and sense of belonging (or both; see Knorr Cetina 1997).

Further explanation on the role of objects stems from activity theory—a development of Vygotsky's psychological tradition (Kaptelinin and Nardi 2006). Authors within this tradition (which predates the idea of boundary objects) emphasize that collective action is inherently object oriented and that the pursuit of some kind of object(ive) is what motivates collaborative work. The collective object of an activity is thus the organizer and motivator of the community that revolves (and evolves) around it. In contrast to the other two traditions, however, activity theory scholars underscore that because of its collective origin, the object of the activity is, by definition, emergent, fragmented, and contradictory. Collaborative action is thus maintained around the pursuit of a partially shared, partially fragmented, and partially disputed object (Miettinen and Virkkunen 2005). Finally, to these approaches one can add a fourth that although not specifically associated with the study of cross-disciplinary work helps complete the picture. This approach stresses that we take notice, also, of the host of objects that constitute the infrastructure (or scaffold, as Orlikowski 2007 puts it) of daily work activities. Although they are often forgotten, numerous "boring objects" (Star 1999) combine to structure, anchor, and enable collaborative work.[2]

Although these four approaches have their own distinctive followers, debates, and studies, our contention is that they also share a number of common basic assumptions and, hence, can and should be used together. For example, all agree that collaboration and sociality are practical accomplishments; that social action is mediated by material and symbolic artifacts; that social phenomena such as groups, communities, and institutions are the results of organizing work (not given entities); that social structures are both mediums for, and outcomes of, human activities; that action and environment are mutually and recursively constituted; and that human actors are driven both by rational consideration and emotions, desires, and passion. At the same time, each approach illuminates different ways in which objects trigger and support collaborative work across specialist groups and thought worlds (Dougherty 1992). We should, therefore, resist using any one of them to cover the whole wide spectrum of phenomena involved in cross-disciplinary collaboration.

In the sections that follow, then, we mobilize these multiple theoretical "lenses" in order to develop new insights into the role objects play in the accomplishment of collaborative work. The empirical study, next, demonstrates how, when used in combination, these theories can produce a level of understanding about the role of objects in collaboration that none of them could achieve when used in isolation. The novel insights that derive from this juxtaposition of approaches make up the final part of the paper, together with signposts for further research.

Methods and Empirical Context

The data discussed below are drawn from an 18-month focused ethnography of cross-disciplinary working in a scientific research project conducted at an internationally renowned British research institution. A focused ethnography takes a particular phenomenon or situation delimited in time and space, instead of an entire cultural system, as its object of inquiry (Alvesson 1996). In other words, our approach was to zoom in on the actual practice of collaborative working (Nicolini 2009). One author attended most of the monthly or bimonthly scientific project meetings (nine in total, of which five were taped and later transcribed) and took part in other formal and informal events and gatherings, from lunches and impromptu meetings to seminars and presentations. Several periods of observation (about three weeks in total) were also conducted in each of the laboratories involved in the project in order to document in detail the scientists' work in the context of their daily routines. Where possible, the observation was integrated with pictures and short videos.

In addition, semistructured and ethnographic interviews (Spradley 1979) were conducted with all the members of the research community ($n = 23$) at three different points in time, generating sequences of interviews for the same scientist. All interviews and the five meetings were transcribed verbatim. To facilitate joint analysis and increase confidence in the findings, the third series of interviews was conducted jointly by two of the authors. The dialogue and "triangulation" between researchers was especially helpful in surfacing the interactional micropolitics implicit in the interviewing process (Silverman 2007). This was helpful during the analysis phase because we could take into account not only what the respondent told us but also what he or she was trying to achieve when talking with us (see Gubrium and Holstein 2007, Silverman 2007). For example, by reflecting together on how the interviews unfolded, we realized how much the senior members were trying to take credit for the successful collaboration by promoting human-centered accounts in which their role figured predominantly. Finally, we collected all project documents and scientific papers produced during the initiative.

Analysis and Interpretation

Data analysis was carried out collaboratively among the three authors using field notes, interim ethnographic reports, and the transcripts of the interviews and meetings. At first, we worked independently and inductively, interrogating the data for emergent contents and interactional patterns and recursively going back and forth between transcripts, original recordings, and field notes (Yanow and Schwartz-Shea 2006).

Our attention to the role of objects emerged during the observation in the form of a puzzle generated by a discrepancy between what we observed and the results of previous studies by Knorr Cetina (1997—as discussed below). After identifying this particular theme, we worked separately to generate interpretive hypotheses and met at regular intervals to compare notes and discuss possible meanings. We moved back and forth between data and theories, interrogating our field materials to check whether our emerging claims were supported by the data and, conversely, whether the theory helped us making sense of our empirics (Yanow and Schwartz-Shea 2006). The process continued throughout a writing process that was very much a collaborative effort. It follows that although this paper is strongly grounded in an observational study, it (the paper, not the study) is not an ethnography of collaboration. Rather, the aim of this paper is to comment on the affordance of different theories, using empirics as illustrations. Accordingly, the field materials are intended mostly for illustrative purposes and to allow our argument to "come to life" and not as a complete description of the process of collaboration, a task that goes beyond the aims and scope of the present contribution.

The Bioreactor Project

The observed project was a complex and "groundbreaking" attempt by a cross-disciplinary group of scientists to develop a bioreactor, introducing engineering principles into the culture of stem cells. According to one of the principal investigators,

> Right now, stem cell culture is actually more art than science.... What I want to do is to...introduce engineering principles, so the ultimate goal would be to culture cells reproducibly.

The reactor was thus aimed at removing an existing bottleneck in the growth of stem cells constituted by the lack of real-time, online, in situ, quantitative information with respect to cellular behavior. The long-term expectation was to develop a system capable of generating reproducible, well-characterized, regenerated "designer" tissues and organs that would meet strict regulatory criteria for clinical applications.

The construction of the bioreactor was uncharted territory in that it involved developing a novel, three-dimensional environment for growing cells; putting in place a monitoring system; and finding out which parameters, when manipulated, influenced the stem cell culture (and how they interacted with each other). This endeavor required the integration of expertise of scientists from different disciplinary backgrounds and involved academics from different departments and research centers (namely, biomedical engineering, chemical engineering, bioengineering and bioprocessing, molecular microbiology, and infection), plus several external experts in the field of hematology (blood stem cells were used for the experiments), stem cell biology, biosensing, and electronics. The bulk of the work was carried out by three

small groups of researchers, each comprising a senior scientist and one or more junior researchers in charge of, respectively, building the sensors, designing and manufacturing the bioprocessing module (the "electronics bit"), and assembling the whole thing and running experiments to test the viability of the system.

Most development work was carried out independently by the three groups in their own labs, with the groups working from milestones agreed upon at monthly meetings. Between meetings, scientists communicated on an ad hoc basis via e-mail, phone calls, and mutual visits. Although the project members originally thought about using project repositories and other information technology (IT) facilities to support cooperation, they intentionally settled for an open, informal, and "low-tech" way of interacting.

Boundary Objects: Making Collaboration Possible

Theory on *boundary objects* (Bartel and Garud 2003; Bechky 2003; Boland and Tenkasi 1995; Carlile 2002, 2004; Levina and Vaast 2005; Pawlowski and Robey 2004; Star and Griesemer 1989) suggests that objects become boundary objects when they function as translation and transformation devices at the disciplinary or professional boundaries between different work communities. Boundary objects are thus flexible, epistemic artifacts that "inhabit several intersecting social worlds and satisfy the information requirements of each of them" (Star and Griesemer 1989, p. 393). They are flexible because they can have different meanings in the various communities, professional groups, departments, etc., and yet their structure is common to all these groups so that they are recognizable to them and can serve as a means of translation. A large array of objects has been discussed as boundary objects; these include repositories, standardized forms, sketches and drawings, workflow matrices (Carlile 2002, Star and Griesemer 1989), physical and IT objects, prototypes (Bechky 2003, Carlile 2002, Pawlowski and Robey 2004), and more abstract objects such as metaphors (Koskinen 2005), narratives (Bartel and Garud 2003, Boland and Tenkasi 1995), or processes and methods (Swan et al. 2007).

"Boundary objects" are ascribed particular functions. First, they provide a shared language that allows idiosyncratic knowledge to be represented in a structure that is known on the other side of the boundary (Carlile 2002). This structure has to be sufficiently loose to allow for interpretive flexibility across the knowledge boundary so that it can be enacted and appropriated by the various working communities (Bartel and Garud 2003, Star and Griesemer 1989). Second, they provide concrete means to specify and learn about differences and dependencies across a boundary (Carlile 2002). Their tangible nature makes it possible not only to uncover different meanings and perspectives but also to understand the concrete implications of these differences, thus enabling "perspective taking" (Boland and Tenkasi 1995). Finally, boundary objects provide a form of "reification" around which the practices of the various actors and the coconstructions of an emergent, shared meaning can be coordinated (Wenger 1998).

Although boundary objects are seen to play an important role in coordinating cross-disciplinary work, *boundary-spanning activities*, such as face-to-face meetings, visits to each other's loci of practice, or internships, are necessary to support their role (Levina and Vaast 2005, Wenger 1998). These collaborations form around boundary objects and are also mediated through them. The combination of reification (through the objects) and participation (through involvement in meetings) is important to surface and clarify the ambiguity that is inherent in objects used in various contexts of practice.

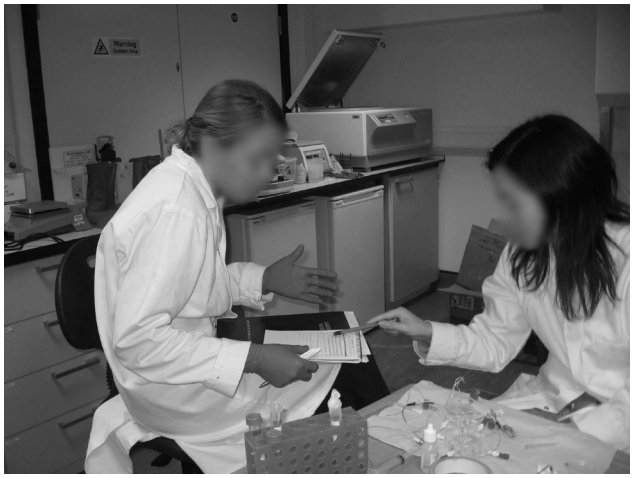
Boundary objects within the bioreactor project included the joint papers, shared analytical methods (i.e., design of experiment method), representations of results of the experiments (e.g., in PowerPoint slides), and the bioreactor itself with its constituent elements (i.e., sensors, electronic board, connectors, computer). In the following discussion, we focus in particular on two of them: the bioreactor (and its components) and the PowerPoint slides showing experimental results.

The Bioreactor: Containing and Fostering Learning Across Boundaries

The bioreactor represented not only the direct object(ive) of the project but also the main means through which the collaboration was structured. It functioned as a boundary object that coordinated the work across the multidisciplinary team often without making it necessary that the various subteams learn much from each other. An example that illustrated this point was the collaboration between the sensor specialists and bioengineers. The sensor specialists developed the sensors, calibrated them, and physically brought them to the laboratory of the bioengineers, who then installed them in the bioreactor and carried out the experiments. The bioreactor (or parts of it) recurrently brought the two experts together and provided them the ground where collaboration could unfold, as in the occasion captured in Figure 1, where the sensor specialist is seen discussing the results of the experiment with the bioengineer in the bioprocessing laboratory.

The bioreactor constituted, in a very real sense, the physical center and organizer of many encounters. Handling parts (as in the picture) and referencing the reactor in discourse and documents allowed these experts to work together and to reconcile different meanings given to the topic on which they collaborated, particularly concerning the importance afforded to certain aspects (each

Figure 1 Sensor Specialist (Left) in Discussion with Bioengineer (Right) Over the Sensors (Disposed on Table)



of them aimed at publishing in different journals that would value one type of data over the others). The modularity of the bioreactor facilitated the multiple translations necessary for the project to proceed. Thus each component enabled and supported cooperation between two or more selected groups of scientists, so the collaboration emerged more as an intricate pattern of situated exchanges and local translations rather than a single well-ordered project. The bioreactor example reminds us, then, that boundary objects often constitute configurations so that translation does not depend only on one object but on many. The bioreactor functioned as a boundary object also by appearing in more than one guise in the interaction. In Figure 1, for example, the researchers focus on two objects, the actual sensors (on the table, on a white piece of cloth) and their translated representations (on the notebook held by one of the researchers). The reactor thus appears both in the material and ideational dimensions, and it is by virtue of this multiplicity that it can work as translation operator (Star and Griesemer 1989).

This example of the bioreactor also illustrates that boundary objects delimit the need to learn across the boundary of practice. This is because they carry details that can be understood by both parties, but neither party is required to understand the full context of use by the other because the object itself takes care of performing such mediation. As one bioengineer stated,

> I don't need to understand how sensors work. I need to know very little about them—for example, whether they are working or not and how I can tell. Then later, how do I convert the potential into the actual meaning of that concentration.

The boundary object thus allows the researcher to operate in condition of partial ignorance. However, what *was* learned through the interaction with the boundary object regarded the *dependencies* across the specialized practices of the various groups (Carlile 2002). This was illustrated by an example of collaboration between the sensor and electronics specialists. As one biologist, regarding the connector piece between the sensors and the electronic board, put it,

> The connection of the sensor created a lot of problems. It was not only inconvenient, bulky, and heavy, but the connection was not good enough.... We didn't realize that until we physically built the elements together and started working together.... (Researcher)

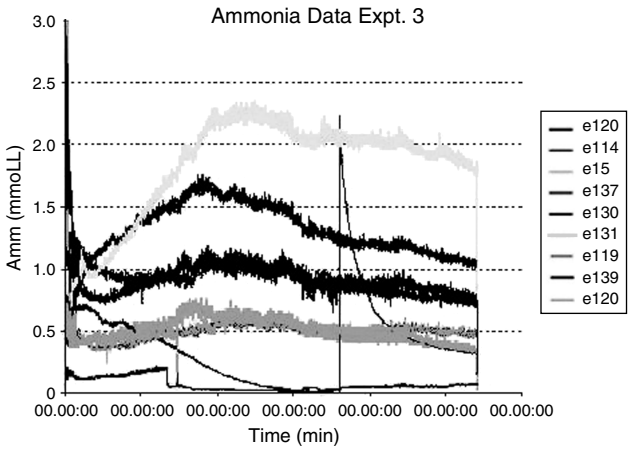
Thus, although during the early development stage the concept of the bioreactor acted as a boundary object, its gradual transformation into a material object changed both the characteristics of the collaboration and what was learned across the disciplinary boundaries. The collaboration was shaped by the material nature of the object and not only by its functional qualities.

Visual Slides: Sensemaking Around an Interpretatively Flexible Artifact

The *slides* projected during the monthly meetings and smaller informal work gatherings (as depicted in Figure 2) made up another interesting boundary object. These meetings usually involved subteams and individuals reporting separately on the progress with their parts of the bioreactor and also on conferences, commercialization steps, or joint papers. These interactions visibly switched gears when structured around a projected slide showing, for example, the results of the groups' experimental work on the bioreactor, with discussions quickly becoming very focused and participative, as the following excerpt shows:

> [*The junior bioengineer who has conducted the latest experiment with the bioreactor is presenting the results standing near to the slide screen. After illustrating the*

Figure 2 Slide Projected During a Meeting Showing the Results of a Conducted Experiment



results of a failed experiment in which the cell culture was contaminated, she puts up a new slide (*see Figure* 2) *and says*]

Junior bioengineer: "But then we had the second set of data, and unfortunately one of these sensors went bad again for whatever reason. We're not quite sure. You see this weird trend. It just starts dropping . . . ."

[*The ensuing activity aimed at interpreting the meaning of the "weird trend" is conducted with people standing in turn and getting close to the screen. Point at the projection they start generating, discussing, discarding, or simply leave hanging for further consideration a number of working hypotheses.*]

Senior electronics specialist: "Is the process taking into account calibration?"

Junior sensor specialist: "They have been calibrated."

Senior sensor specialist: ". . . do you all smooth the raw voltage before you do that conversion?"

Junior electronics specialist: "We do Y readings, right?" [*Several talking at once.*]

Senior bioengineer: "Can you go back? This noise, are we sure this is noise? . . ."

[*The exchange is conducted like a nicely choreographed dance, with people approaching the screen, pointing at the curve, and then going back to their seats.*]

The group, faced with an apparently inexplicable result (sudden drop of ammonia), used the slide in a way analogous to the drawings and doodles used by the designers described by Henderson (1991) and the architects studied by Ewenstein and Whyte (2009). Like the professional model maker in Henderson's account who "walks across the room to fetch a drawing so that he can point to its various parts" (1991, p. 448), the scientists working on the bioreactor used the projection to organize their collaborative discovery. This was made possible by the tangibility of the object. Its material presence also helped to break up the linear flow of the discussion ("Can you go back?"). The slide thus provided a means to *anchor* or "reify" (Wenger 1998) an agreed-upon, albeit tentative, understanding. It not only translated between the various ways of knowing of the specialists but also acted as a mnemonic device for the shared understanding developed in their earlier discussion around the visual, being flexible enough to anchor and refer to the meanings developing within the conversation and to allow for deliberations about future action and collaboration.

Epistemic Objects: Collaboration as the Organization of Desire

Although the notion of boundary object sheds light on the process of cross-disciplinary work, it tells us little about *why* people make the effort to search for alignment to begin with. For this purpose, we can mobilize the idea of the epistemic object, originally introduced by Rheinberger (1997), as an attempt to foreground the power of material objects (in contrast to ideas or concepts) as driving forces in knowledge development. According to Rheinberger, an object of investigation that is in the process of being materially defined functions as an "epistemic thing." Epistemic things and objects embody what one *does not yet know*. They are open-ended and work as a source of interest and motivation by virtue of their "opacity, their surplus, their material transcendence," which is "what arouses interest in them and keeps them alive as targets of research" (Rheinberger 2005, p. 406).

This concept has been further developed by Knorr Cetina (1997, 1999), who explored more deeply the power stemming from this particular category of objects. First, building on psychoanalytical categories, she traced the source of this power to the dynamic of "wanting" and a lack of fulfillment generated by the object. In simple terms, knowledge objects resemble an open drawer filled with folders extending indefinitely (Knorr Cetina 1997, p. 12). It is this lack of completeness that generates energy and emotional investment on the part of the scientist. The attempt to fill this void fuels the attachment for the object but also paradoxically specifies ever further issues and the sense of lack lack, so that the process is self-fueling. Second, she argued that epistemic objects, and the pattern of wanting they generate, keep together not only individuals with their objects but also collections of individuals.

How Working on Something That May Never Exist Acts as a Source of Motivation

In our study we saw how the epistemic object could, in certain conditions, account for the drive that kept the project team in motion. Consider, for example, the following snapshot:

> I follow S. through the lab while he is preparing the polymer he will use to build the new prototype sensor. S. moves between the hood where he is cooking "a new batch" and the experiment bench. I ask whether he is going to be here for long. He nods affirmatively. He hasn't yet cracked the problem of how to make the sensor work, and this makes him frustrated. "I'll be here as long as it needs. It might take several long nights. It is between me and it now. No matter how long it takes."
>
> (From field notes)

This is a typical example of the compulsion to know, which is fueled by the fact that it remains largely unfulfilled (Knorr Cetina 1997, p. 22). We can assume that what drove the young researcher to spend long hours in the lab was not only his (very low) remuneration or the promise of a glowing academic career but also the sense of lack produced by the unfinished nature of

the object. Unlike other material artifacts (e.g., pipettes, flasks), the epistemic object (the possibility of a new sensor) triggered a form of desire and attachment that had a libidinal, rather than calculative, origin. Such desire, however, was destined to remain partially unfulfilled because the final knowledge of sensors could never be fully attained. Any time the researcher came closer to capturing it, he or she would articulate new possibilities, which in turn extended the need to move forward. The researcher was thus caught in a self-perpetuating process of object-centered sociality based on the mutuality between object and expert subject (Knorr Cetina 1997).

As Knorr Cetina (1997) observed, emotional investment toward the epistemic object was not limited to individuals but also operated as the engine of solidarity among groups of scientists from different disciplines. Consider the following excerpts from one of the interviews:

> Things fell in place really in April. Sensors were working, M. and A. went to the USA for the live demo of the bioreactor . . . and he won an award . . . . We are riding high on excitement in terms of the technical aspects that are working, but [we have a new challenge] unless we show functionality, we would have ultimately failed . . . it's the whole thing we are presenting, not individual components . . . . (Senior researcher)

The bioreactor raised new questions while answering others so that the solidarity was nurtured by the promises of new things still to come.

At the same time, blue-sky talk and discussions about possible future applications were a constant in most of the meetings. The researchers—in particular the lead investigator—often talked about the next generation of reactors ("once we crack this one, we can move to a 3D one"), new applications ("we could use the reactor to measure cow fertility . . . it is a big market in the U.S."), and new challenges ("in terms of electronics, the next step could be miniaturization"). By prospecting a landscape of further puzzles and new possibilities for future satisfaction, which stemmed from an object that had only partially revealed what it had to offer, she attracted the attention of her colleagues and tried to foster closeness. She was, in a real sense, organizing by desire—jelling the group by stimulating attachment and a desire to know.

How the Nature of the Object Induces Different Ways of Working

A feature of the idea of epistemic objects, which is not central to boundary object theory, is that it explains why solidarity happens and also what form it may take. The idea here is that the "structure of wanting" generated by the object is partially reflected in the organization of the scientific practices that emerge around it. The incompleteness of the object described above does not, in fact, simply occur or "turn up." In modern society (both scientific research and elsewhere), generating questions and trying to answer them depends on a complex division of labor and interdependencies. The emergence of an epistemic object introduces a form of a collective obligation toward it—an emotional affiliation that becomes a morally binding force among the coresearchers. Any infraction of the collaboration can now be subtly construed as an infringement of the collective obligations toward the "structure of lack" displayed by the object. The object, in effect, turns a collection of researchers into a "proto-community."

How such proto-communities will be organized cannot be considered in isolation from the epistemic object around which they emerge. For example, Knorr Cetina (1999) attributes (in part) the differences she found between the ways of organizing scientific work in high-energy physics and molecular biology to the nature of their epistemic objects. She argues that high-energy physics is organized in terms of large, lengthy, and complex experiments that require collective activity among experts from different institutions. Molecular biology, in contrast, is organized around physical laboratories in which individuals remain the central epistemic subjects. These laboratories typically exhibit a hierarchical "two-level" structure in which a limited number of senior scientists oversee the work of a larger number of junior colleagues working on individual projects. In contrast to members of high-energy physics projects, these researchers were connected either by being colocated or because they provided each other assistance, not because they coproduced knowledge.

Contemporary high-energy physics is also characterized by a "negative, self-referential episteme built around sign systems," whereas molecular biology "is orientated towards positive knowledge built from the manipulation of objects in an experiential regime" (Knorr Cetina 1999, p. 80). She suggests that these differences in the nature of the epistemic object and the practices of knowing explain why high-energy physics moved away from the "lab model" and toward liberal circulation of knowledge, liquid social relationships, and an equalitarian form of management driven by content and not by hierarchical positions. In this "post-communitarian" sociality, where cognition is distributed and collaboration is the norm, interaction is based on neither altruism nor commonality but instead on the requirements of the object itself.

The same principle was operating in our study, although our analysis revealed an interesting twist. First, the bioreactor project was run by a small group of "equals" from three different departments who contributed in an egalitarian manner. Second, there was a lot of communication, with researchers visibly crossing disciplinary boundaries and working in each other's labs. The information often flowed horizontally, and it was

quite common for people to contact each other across departments to discuss how to interpret data. This is not, according to Knorr Cetina, how molecular biologists usually act.

Things became clearer when we focused in on nature of the object, especially during the monthly project meetings. All participants noted that these meetings were quite different from other events. The crucial defining characteristic was that, instead of being (only) forums in which people reported progress, showed off results, and fought for resources, they were sites where actual cross-disciplinary work was accomplished. During each meeting there were several moments in which the pattern of interaction shifted gears: existing disciplinary barriers seemed to disappear, and people asked open questions across occupational boundaries. This change of gear consistently corresponded with the appearance of (a representation of) the object—the presentation of slides—in the room. Consider how the interaction around the ammonia slide (discussed previously) continued:

> *Senior bioengineer*: "Can you go back? This noise, are we sure this is noise?..."
>
> *Senior sensor specialist:* "That's what my question is, whether it was noise. ..."
>
> *Second senior electronics specialist*: "It's not the electronics. ..."
>
> *Senior sensor specialist*: "So it's clearly not the electronics, and the next question is, if you had one of the sensors, back to when concentration wasn't changing, you hoped, would that show it?..."
>
> *Senior bioengineer:* "Can you go back again? Can I ask you something—we see in the beginning, let's take this one, the noise, would that correspond to the stability and the longevity of the sensors? I tend to believe that this is noise. ..."
>
> *Second senior electronics specialist:* "Have you recorded which day of the week it is on which place in the graph? ... We could say you expect funny things to happen on Saturday and on Monday."
>
> *Junior bioengineer:* "OK, I'll take note of that."
>
> *Second senior electronics specialist:* "Power lines are changing. The noise environment is changing. The electromagnetic environment is changing and so on.... There was a famous case in the States. They built a wonderful system of gravitational detectors and they had a positive reading for gravitational noise. It turned out it was one power plant dropping off-line. The signals arrived in the correct synchronizations, and there was a very sizable disturbance on all detectors."

In this example, the appearance of the epistemic object generated collective problem solving sustained by discursive practices such as questioning, framing (i.e., connecting clues in the light of others until the whole acquires some sense), probing, and telling "war stories." Although events like this are well documented (Orr 1996), they tend be reported within established occupational communities where those interacting share a common background. What was important in this cross-disciplinary context was that the apparent shift in patterns of interacting could not be attributed to some form of preexisting solidarity but was, instead, induced by the object that infused energy and passion and participated in organizing the interaction. None of the experts or subteams alone could make sense of what the object threw at them. These molecular biologists were behaving like Knorr Cetina's high-energy physicists because their epistemic object was of a similar nature—the scientists were not discussing natural phenomena but representations, or an "order of signs" (Knorr Cetina 1997, p. 64). These were inherently ambiguous and in need of interpretation; the focus was on understanding the negative (e.g., the limits of the machinery) as well as the positive (e.g., the likely behavior of stem cells). Of course, leadership skills, good intentions, egalitarian beliefs, rational calculation, and unconscious drives were all at work. However, the pattern of interaction among these experts could not be understood without making reference to their object of work. In short, they felt like a community and worked as a community because of what they were after and not simply because of who they were.

Activity Theory: Collaborating Without Sharing

A third way of explaining cross-disciplinary collaboration through objects is offered by cultural historical activity theory, a tradition stemming from the work of Vygotsky and Leont'ev (Engeström 1987, Kaptelinin and Nardi 2006, Leont'ev 1978). As with the approaches above, this suggests that human activity is always object mediated in that it depends on an array of cultural artifacts for its accomplishment (Engeström 1995, Leont'ev 1978). These artifacts enable purposeful action, connect agents to their social surroundings, and embed into the activity the history that they embody. Activities are also oriented toward an object. Objects are thus understood as "prospective outcomes that motivate and direct activities, around which activities are coordinated, and in which activities are crystallized... when the activities are complete" (Kaptelinin and Nardi 2006, p. 66).

According to activity theory, objects provide the direction, motivation, and meaning for the activity. In the words of Leont'ev (1978, p. 66), "the object of an activity is its true motive." This is similar to the idea of epistemic objects. The proponents of this approach, however, identify three additional characteristics of objects—their emergent, fragmented, and constantly expanding nature—which shed further light on cross-disciplinary collaboration (Engeström 1987, Miettinen and Virkkunen 2005). Objects are depicted then not only as instruments of translation (as per boundary objects) and sources of attraction (as per epistemic

objects) but also as triggers of contradictions and negotiation. Recognizing these characteristics helps us to explain the potentially conflictual nature of collaborative activity.

The Emergent Nature of the Object of Work

Cultural historical activity theory highlights, on the one hand, that collaborative activity emerges around a specific object such that the division of labor, the rules and tools to be used, and the position and identity each member will assume all depend on the particular object of work. On the other hand, the theory prescribes that such an object is also the result of the interests of the community that gathers around it (Miettinen and Virkkunen 2005). The object is, in this sense, partly given and partly emergent; it is both projective (constructed through the negotiation or ignoring of the different interests represented in the community) and objective (instantiated in, and through, the product and services that are the outcomes of the activity). Because of its material manifestation, the object can always retroact on the community that generated it and "bite back," as Engeström and Blackler (2005) colorfully put it.

Think, for example, about the patient as the object of work of different professionals in the same hospital. Each of them will have a slightly different way of constructing the object of their common activity: whereas for the surgeon the patient is a body to repair, the nurse will see it as person to care for, and the administrator as a client to charge (and satisfy). The organization of care in the hospital (length of stay, for example) depends, in part, on how these different views of the object are worked together. Dissatisfied patients may then, quite overtly, "bite back."

In the case of the bioreactor, the projected shape of the final artifact and the composition of the community that would pursue it emerged in the early phases of the project:

> ...S. got an idea of what he wanted to do he asked around who was in a good position for taking care of such aspect...the "thing" kept on changing at every round of mails.... (Senior researcher)

The functional complexity (Law 2002) of the artifact was thus directly linked to the division of labor and the people it forced to collaborate. Each constituent group, however, retained its own interests, which were provisionally aligned (but not eliminated) by the emergence of the collective object. This in turn affected both the imagined and the realized nature of the object itself:

> The original target of the project was much more ambitious.... Then the [funding body] required that we reduce the scope and the money for the project...certain things had to go...the partnership was thus remodeled accordingly.... (Senior researcher)

The object of work could not, however, exist exclusively in the realm of imagination. Rather, it held different elements together because it was concretely present in the world. As one of the researchers put it, "It was mostly after we had something concrete that we really started working together." The object of the activity was a moving target, reflecting the historically embedded, and continuously evolving, practices and expectations of collaborating scientists.

Community Without Unity

Viewing the object from the perspective of activity theory suggests that it can be regarded as a "problem space" into which actors bring various skills and conceptual tools to negotiate the object(ive). It follows that the object is necessarily partial—it is not visible in its entirety to any one of the participants. At the same time, because it is composed of heterogeneous elements (each rooted in a different professional practice and discourse), the object is inherently multiple and may hold together orientations, interests, and interpretations that are potentially contradictory (Miettinen 2005, Miettinen and Virkkunen 2005). Cultural historical activity theory highlights then that the sociomaterial community performed by the object is not an integrated whole in which parts move in harmony but rather a "community without unity," where contradictions and conflicts abound.

In the bioreactor case, one example of the contradictory nature of the object of activity was reflected in the different temporalities of the disciplines involved:

> We electronic engineers operate in terms of nanoseconds. You [biologists] work with minutes, hours, and weeks. If you need [to gather data every so many] minutes electronics is superfluous...or at least we have nowhere to publish our results. (Electronics engineer)

Here, temporal misalignment became a problem for the electronic engineers in that the object failed to serve one of the main interests of the group ("we have nowhere to publish our results"). Differing temporalities also became an issue when expectations and delivery times did not match. For example, building, testing, and calibrating sensors followed a tempo that was at times much longer than the pace of other disciplines, which created misunderstandings and frictions.

A second type of contradiction, often apparent in cross-disciplinary work, came from the tension between divergent interests. In the bioreactor project, this was particularly evident between academic and commercial interests. Commercial considerations were continually introduced into the conversations around the bioreactor through references to potential practical applications and marketability of the emerging object. This in turn created conflict between the members in the group:

> They think about commercializing this product, but I am still in the stage of just proving that the science

> is working and just to prove the concept that could be helpful for this particular approach. I think that's the difference. (Senior researcher)

The constructed and realized nature of the object thus regulated the degree of involvement of the partners to its joint creation, creating a community where some were more equal than others. At the same time, the object, even when materialized, could hold diverging interpretations that generated other types of conflict.

> We took a decision not to patent anything because we don't believe that any of the individual components are patentable or really worthwhile. If we can make a system that works, then there is a way to protect it and so forth, but the keyword is something that works. (Senior researcher)

In sum, viewing collaboration through the lens of activity theory highlights that the object is not only in transition, it is also multiple, heterogeneous, and potentially conflictual (Law 2002). The mutuality performed by the object is thus far from a smooth fusion of intents and goals—an ideal that underpins many models of collaboration. It is important to add, however, that the contradictions generated by the fragmented nature of the object are not necessarily barriers to collaboration but also opportunities for innovation. This is because, when surfaced, they can trigger "expansive" learning (Engeström 1987). For example, the conflict emerging from the temporal misalignment between disciplines, outlined above, resulted in the enrollment of a new member in the project. The enlargement of the team in turn triggered a reshuffling in the division of labor and a redefinition of the identities of the members in the sensor group as well as of the nature of the reactor (the expert had slightly different ideas on which type of sensors to use). As the newcomer was a very senior researcher, the existing sensor expert automatically became relatively junior, also creating the conditions for new issues to emerge. The contradictions stemming from the complex nature of the object became then an inexhaustible source of change that kept the sociotechnical whole in constant motion.

The Material Infrastructure of Collaboration

The three theories discussed above foreground a number of important and, at times, critical ways in which objects enable and sustain cross-disciplinary work. It should be added, however, that only rarely do objects take center stage in discussion. Most of the time, in fact, they remain in the shadow of other practices, as illustrated in the short vignette below.

> M. enters the small room she shares with another researcher. She quickly checks her e-mails efficiently opening and closing several messages. She finally slows down to read one of them. She then turns towards me. With her usual patient smile she announces: "This is from S. Something came up.... The meeting has been postponed by two hours. I have to tell all the other people...sorry." She then reaches for a piece of paper hanging on the side of her computer screen. This is a phone list of all the members of the team. Holding it in front of her, she picks up the computer and smiling again she tells me, "I will call A. first...she is the only one usually on time...I need to catch her before she leaves the lab.... (From field notes)

Think of the humble "phone number list" in this example. It is not certainly a major motivational factor, neither has it inspired any significant boundary spanning. Yet without it, collaboration would be much more difficult. Taken alone it seems insignificant, but when considered as a part of the complex ecology of objects that supports the daily work of the group (including e-mail and telephone), its work becomes more apparent. Orlikowski (2007) uses the term "scaffolding" to describe the work of this ecology of mundane objects, or the "stuff" of everyday life. Recognizing limitations of the scaffolding metaphor (Swan 2006), we prefer to use the term "material infrastructure" (after Star and Ruhleder 1996).

Star and Ruhleder (1996) make a case for a broad understanding of the notion of infrastructure as any web of objects "that emerges for people in practice" and allows them "to resolve the tension between local and global" (p. 112). In their view, "an infrastructure occurs when local practices are afforded by a larger-scale technology, which can be used in a natural, ready-to-hand fashion" (p. 112) Accordingly, assemblages of objects become infrastructures in relation to specific organized practices. Infrastructures are not external to practice—they are never "already there," ready to be used—but are a way of looking at certain aspects of the inherent materiality of human sociality. In this sense, we should ask "*when*—not *what* is an infrastructure" (Star and Ruhleder 1996, p. 113). All types of objects can potentially become infrastructure. As such, they are "black-boxed," or invisible at one moment, but can become the very topic of an activity at a different time. For example, in our case the computer system used to support the circulation of e-mails, until a decade ago, was itself the focus of the attention of scores of researchers, practitioners, and organizations.

The perceived stability of infrastructure is, therefore, only an optical effect because infrastructures are embedded and "sunk into, inside of, other structures, rather like Russian dolls" (Star and Ruhleder 1996, p. 113). In the example above, we foregrounded the computer, but we took the electric power it uses for granted. The more "sunk in" an infrastructure is, the more we tend to consider it stable. For this reason some authors propose a distinction between universal *service infrastructures* and *work-oriented situated infrastructures* (Hanseth and Lundberg 2001). The former provide

(in principle) services to all citizens, whereas the latter are developed to support specific work tasks and work practices (Hanseth and Lundberg 2001, p. 365). This distinction can be fruitfully used as an analytical tool to distinguish between the mundane objects that support cross-disciplinary collaboration in our case study, as illustrated next.

The Work-Oriented Infrastructure

All forms of collaborations need to be set up in the first place. We are very used to describing this aspect of collaboration in terms of human agents (leaders, projects managers, and the like), and we forget that objects also play an active role. For example, when asked how the project came about, the senior investigators invoked first a canonical "intersubjective" explanation:

> We had individual working relationships. C. and M. had worked together. T. and C. had worked together. So . . . we had these meetings all in a group, trying to come up with what we want and how we were going to do it.
>
> (Senior investigator)

On closer inspection, however, the process was heavily supported by a complex array of material artifacts:

> I didn't know S. before. I had heard of him but I never met him in person. I was involved via e-mail. All the initial exchanges were conducted via e-mail . . . . He circulated a high-level proposal and then asked each of the teams to fill in the gaps . . . each one had to write their own bit . . . . I believe we had a meeting only very late, to ensure that the whole thing looked like a project and not like pieces assembled together . . . which is very often what happens in multidisciplinary meetings . . . .
>
> (Senior investigator)

The story here is one of interobjectivity. The collaboration was effectively structured through the circulation of a document (the project proposal). This material object operated as an intermediary that translated and aligned different interests (Latour 2005). "Filling the gaps" in this document, as the informant put it, helped in aligning competencies and stabilizing reciprocal roles in an exercise of mutual enrollment. When sent to the funding body, the document cemented the collaboration, entangling the mutual commitment in a further web of material implications that would make dissolving the partnership much harder than it would have been had it been based on a verbal agreement only.

A number of other equally invisible things supported and facilitated collective work once the project was set up. For example, the senior researchers talked about the need and importance of establishing a "project repository." However, one of the junior researchers was more skeptical:

> Yeah, they talk about this project repository all the time . . . but I do not think it will happen . . . to stay in touch we use mostly e-mail . . . see [*she says pointing at the screen of her computer to the folder with all the e-mails she received from others*], we work together mainly by sending each other e-mail.
>
> (Junior researcher)

This extract shows how the e-mail system actively, albeit silently, supported cross-disciplinary collaboration. It should be added that being an infrastructure is not a quality of the object per se but a relational property emerging from the specific practice. That e-mails have become a situated infrastructure for this group, becoming deeply entangled in their practices of collaboration, does not imply that this is the case for all forms of collaboration.

The Service Infrastructure

The array of work-oriented objects discussed above are also nested within, and built on, a further set of "sunk-in" infrastructural arrangements—what Hanseth and Lundberg (2001) call the universal service infrastructure. These arrangements (e.g., the power grid that provides the electricity) are further removed, taken for granted, and learned as part of membership. For this reason, in normal conditions the infrastructure tends to become "invisible" (Star and Ruhleder 1996). Consider the following example, derived from our fieldwork:

> The meeting is taking place in a lecture theatre as the usual meeting room is now busy [the meeting has been postponed]. The members of the team are sitting scattered across several of the long rows of desks. They struggle to face each other, turning uncomfortably on the chairs which rigidly face the blackboard at the bottom. A. has brought the first prototype of the new sensor. The small object is passed from hand to hand while A. explains the challenges she faces. People have to stand up and carry the object around to the other members. A. has to stop several times. One of the participants has to ask her twice to repeat what she says as he was busy circulating the artifact. One of the members of the team whispers to me, "I hate this room . . . it is so much easier to work upstairs [in the meeting room where the group usually meets]."
>
> (From field notes)

The vignette shows that the conversation itself is enabled (and in this case constrained) by the meeting room. The room makes the meeting possible by allowing people to find each other. It also actively "tries" to structure the conversation in a noninterdisciplinary way by separating participants and forcing them to face the imaginary lecturer instead of each other. The example also reminds us that most infrastructures, such as the room, become present only when they stop performing their supporting functions. In sum, although infrastructural objects may have a relatively marginal and indirect impact on cross-disciplinary collaboration, they cannot be completely ignored. Boring things, as Star (1999) calls these types of objects, should feature in any object-focused, or "objectual," theory of cross-disciplinary collaboration.

Table 1 Differences Between the Theoretical Approaches for Studying Objects in Cross-Disciplinary Collaboration

	Material infrastructures	Boundary objects	Epistemic objects	Activity objects
Affordances of objects in cross-disciplinary settings	Everyday mundane objects support and shape collaboration in their conjunction (they form an ecology of supporting objects).	Objects act as translation and transformation devices across various thought worlds. They make cross disciplinary work possible.	Objects fuel cooperation and generate mutuality and solidarity by triggering desire and attachment and creating mutual dependencies.	Objects motivate the collaboration and direct activities. They hold together different types of knowledge, and in so doing, they generate contradictions and trigger innovation.
Disciplinary, professional, and cultural boundaries	Objects become infrastructure when boundaries are uncontested and fall into the background.	Boundaries are foregrounded and potentially problematic for aligning understandings and interests: they need to be overcome.	Boundaries are only partially relevant: foregrounded is the common pursuit and collectiveness.	Boundaries between activities are only considered when they become a source of tension and contradiction.
Completeness of objects	Objects are taken for granted, or "black-boxed," and only become visible in case of breakdowns.	Objects are open and malleable only inasmuch as they are interpretively flexible across boundaries.	Objects are incomplete, emergent, and expansive, which gives them their performative character.	
Conflict	Objects can resolve the tension between local practices within large-scale technologies by creating assemblages of objects.	Conflict is backgrounded, yet objects can shed light on the pragmatic implications of different forms of knowing (what is at stake).	Distinction, difference, and conflict are temporally suspended or backgrounded, and the union/attachment with the object of desire is stressed.	Conflict is foregrounded because the multiple nature of the object produces contradictions between elements triggering creative remedial work.
Novelty	Novelty is backgrounded: the more objects become infrastructure, the more they are considered stable.	Novelty lies outside the objects themselves and is located in the environment or task at hand.	Novelty emerges from the inner development of an existing practice.	Novelty emerges from addressing the emerging contradictions through expansive learning. The productive role of objects is emphasized.
Historical conditions	The historical context, politics, and authorship are embedded and materialized in the shape of the infrastructure.	Little attention is given to the wider historical conditions.	Epistemic objects are grounded in historically developed "knowledge cultures."	Through individual and group motives, the object of work translates locally wider historical conditions as well as societal ideas, ideologies, and discourses.

Discussion

In the previous section, we examined the role of objects in cross-disciplinary collaboration through four different theoretical lenses and made an argument for a pluralist approach. Table 1 summarizes our discussion of what each approach affords in terms of its view of objects; how complete (closed) they conceive them to be; and how they relate objects to boundaries, conflict, novelty, and the historical conditions of cross-disciplinary collaboration. We have argued that these approaches can be beneficially used together because they share some common assumptions (and some historical antecedents). For example, all question, in different ways, the commonly held notion that collaboration requires some form of "deep sharing," emphasizing that sharing and understanding can be partial and provisional—a sort of "community without unity," to paraphrase Corlett (1989). This partial sharing can in turn be achieved thanks to the bridging or containing work performed by objects—for example, the bioreactor in our case—that allow similarities and differences to coexist. However, each approach also offers unique insights into the work of objects, foregrounding particular aspects (and backgrounding others).

Juxtaposition of approaches is one thing. What one does with this juxtaposition, of course, is another. In this section then we build from this discussion to develop a novel analytical framework that helps to organize the different types of work objects at play in supporting cross-disciplinary collaboration and that should be useful for those wishing to adopt a pluralist approach. Inspired

by the work of Wartofsky (1979) and building on the strengths of the theories summarized in Table 1, we propose that the role of objects can be conceptualized according to a three-level hierarchy, arranged in terms of increasing symbolic externalization in relation to actual practices of collaboration. The framework is shown in Table 2.

At the first level, as illuminated by the theory on material infrastructure, collaboration is sustained by a number of tertiary objects and artifacts, such as buildings, rooms, furniture, documents, computers, and communication systems. These constitute the basic sociomaterial infrastructure without which collaboration (and other types of work) would be impossible. Many of us will have experienced this when the room for a project meeting becomes suddenly unavailable or our e-mail system stops working. Next, collaboration is supported by a number of secondary objects of collaboration. These can be either material or symbolic objects. They can thus be artifacts or, more often, representations of artifacts or portrayals of how artifacts are used (e.g., recipes, norms, and routines). Secondary objects of collaboration can facilitate (or hamper; see Oswick and Robertson 2009) collaboration, but they seldom trigger it, fuel it, or provide the motivation that sustains it. Most boundary objects would fall in this second category. Their function is that of bridging different types of boundaries—they do not explain how these boundaries came about in the first place (if there is no collaboration, there are no boundaries). For this we need to study primary objects, which have the capacity to explain what motivates and fuels the collaboration in the first place. Thus primary objects explain both the why and how of the collaboration, whereas boundary objects mostly shed light on the how.

The framework suggests that researchers adopting a pluralist approach focus attention on all three types of objects. It also suggests that each of the theories discussed above is particularly apt at shedding light on different aspects of this hierarchy of objects. The infrastructural approach is especially good at foregrounding the material nature of collaboration. The boundary object approach is particularly good at taking into consideration the material objects used as translation devices; the wider context in which the translational work is carried out and the forces that motivate collaboration largely remain bracketed. This motivational aspect is especially evident, however, in Knorr Cetina's work (which, as we have seen, can be construed as a theory of emotional attachment with and through objects) and in cultural historical activity theory (where the presence of objects constitutes the primary reason why people act together in the first place). The framework suggests, therefore, a "division of labor" between the theories; it is in this sense that we claim that it is fruitful to use them together rather than to stretch any one approach until it covers the same ground as the others (expanding the definition of boundary objects to include abstract objectives as well as material objects, for example[3]).

The framework, however, not only provides a more complete description of the different roles that objects play in cross-disciplinary collaboration but can also be used to shed new light on the phenomenon that the single approaches were unable to account for alone. Our analysis suggests then that different types of object were more useful at different stages of a cross-disciplinary endeavor. For example, primary objects—such as the vision of reengineered "designer" tissues and organs—were prominent in the early stages of the collaboration, being used by principal scientists from established scientific disciplines to mobilize commitment (and funding) to this new field of study as a whole. Secondary objects (such as experimental designs) entered the picture later (during the first preproject meetings) as the idea of the bioreactor became an epistemic object around which collaboration took shape. Tertiary objects continued to remain in the background unless they were suddenly promoted or called into play, as in the case when the group had to prepare a new project proposal to obtain further funds.

The framework can also be used to trace the dynamic and transitional status of objects. Thus our findings suggest that the same object may change its role and status over time, moving across the cells in the table, so to speak. The example of the sensor (discussed earlier) is a case in point: its role changed from being a primary object to a secondary (and for some of the participants,

Table 2 The Role of Objects in Cross-Disciplinary Collaboration

	Main function	Theoretical approach	Examples from the project
Tertiary objects of collaboration	Provide the basic "mundane" infrastructural support of collaboration	Infrastructure theory	E-mail system, phones, documents (project proposal), built environment
Secondary objects of collaboration	Facilitate work across different types of boundaries	Boundary objects	Visual slides, bioreactor, shared analytical methods
Primary objects of collaboration	Trigger/sustain/motivate the cross-disciplinary collaboration	Epistemic objects Activity objects	Bioreactor

tertiary) object of collaboration and back as collaboration developed. Hence, referring to the framework in Table 2, we can propose that collaboration objects follow a trajectory or have a career (Engeström and Blackler 2005); not unlike actors on a stage, they perform certain functions (as epistemic or boundary objects, for example) and then disappear behind the scenes until the plot requires them to resume center stage. Such a trajectory can unfold at the local project level or on a grander scale. For instance, the computer that sat in the background, or the growth factor used for feeding stem cells, not long ago constituted an object of attachment for other experts, just as the sensors were now doing for the scientists studied in our case.

This finding raises in turn a number of interesting questions as to why, and under what conditions, such transitions take place. Although a thorough investigation of these issues goes beyond the scope of the present paper, our study does offer a few interesting insights. If we step back and look at history, for example, whereas the career of objects might as appear to follow a trajectory from the primary to tertiary (as in the case of the computers mentioned above), in the short term, we would expect this journey to be much less linear and more tortuous. As we have seen in the case of the sensor, objects tend to move back *and forth* between roles—what at the beginning of the project appeared to be a trouble-free and almost taken-for-granted element escalated quickly into a stubborn primary object. Whereas the notion of hierarchy suggests an orderly and irreversible transition from one level to another, our study suggests that a focus on microlevel practices would reveal a much less linear kind of journey.

Our study also allows us to make suggestions, although tentative, as to why objects may transition through the hierarchy of attention and interest. Often, transitions had to do with the material constitution of objects and their capacity to retroact on the activity. This was the case with the sensors discussed above and also with the shape of the container where the cells had to be grown. That container had to be redesigned several times to accommodate the requirements of the different groups—first, it was too small to fit the sensors; then it was too shallow to accommodate enough cells; it then was wrongly shaped to fit into some of the machines where the cells would be analyzed. In these and other examples, the material difficulties of engaging with the object brought it sharply into focus and required its status to change. Of course, it was not only "negative breakdowns" (i.e., problems) but also generative changes that foregrounded objects. For example, although considered a mere technical issue at the outset of the project, one of the infrastructural aspects of the bioreactor—the electronic board used to collect and send the monitoring data to the computer—started to attract new interest and generated attachment when one of the students in a different part of the lab successfully produced a transmitter small enough to be fitted on top of the sensors. The switchbox could suddenly become a remote receiver, although now the challenge was how to collect very weak radio signals reliably and accurately over a long period of time. Although we are unable to be conclusive here, future research may be able to assess systematically whether the transitions in the roles of objects result from the challenges and opportunities objects encounter during the activity.

Our study, and the framework, thus underscores that the specific role objects play in supporting collaborative efforts results from relations with other objects and other aspects of the activity and does not derive from some assumed essential characteristic of the object itself. Objects thus become "boundary" or "epistemic objects" because of the position they occupy in the processes of collaboration and because of the nature of the issue at hand. Although certain artifacts are more likely than others to become objects of collaboration, the attempt to produce rigid and conclusive classifications is likely to fail. In our case, for instance, there were actually several sensors used in the project, but only one operated as a boundary object because of its particular relations with the other elements in the project and the material difficulties it created. In a different project and ecology of objects, the same sensor could have easily remained part of the infrastructure, sunk in the background. In this sense, our framework accommodates nicely the findings of Levina and Vaast (2005), who argue that that whether objects perform boundary (or other) functions cannot be always anticipated as objects become scaffolds for cross-disciplinary collaboration within a specific context of use. Repositories, standardized forms, drawings, plans, and charts—to name just a few of the best-known examples of boundary objects—are likely candidates because of their interpretive flexibility, but they are always and necessarily only candidates. And although some artifacts are more likely than others to become boundary, epistemic, or activity objects, we should also consider that some more humble objects, like a piece of paper, may actually perform better in certain conditions than more obvious (and expensive) candidates.

Finally, our pluralist analysis sheds light on some of the difficulties of cross-disciplinary collaboration, suggesting that serious problems may arise when different specialists in a cross-disciplinary project perceive the object differently in terms of its status. As we noted above, the attribution of status to objects has critical implications in terms of mutual expectations and the capacity of the project to succeed. As in the example of the sensor, conflicting perceptions across specialist groups on whether an object is "just" infrastructure or a challenging scientific problem can get in the way of collaboration, creating unrealistic expectations, misunderstanding, and a lack of trust among participants. Difficulties in delivering what is perceived by some as a

straightforward piece of a kit may induce the problem to be construed in terms of others' lack of skills or insufficient effort—exactly the opposite of what happens when the same artifact is construed as a primary object(ive).

Misperceptions around the status of objects could also create other problems, of course. What counts as a powerful motivator for some may, for example, not constitute an object of attachment for others (as in the example above, when the scientist complains that "we have nowhere to publish our results"). The resulting problem may be a project lacking in energy or one where the energy is unevenly distributed. Our point is, however, that these sources of conflict (and generation) only become apparent, and thus open to deeper understanding, when one assumes a pluralist approach.

Conclusion and Implications

We have argued in this paper that different theoretical approaches are useful in combination as a pluralist "toolkit" to analyze the role of objects in cross-disciplinary collaboration. We have proposed a novel analytical framework with which researchers are better able to understand and trace the shifting roles of objects in collaboration. It is important to note that we do not see these approaches as constitutive elements from which a monolithic or integrated theory of objects in cross-disciplinary collaboration should (or could) be built. Our proposed framework suggests, on the contrary, that a pluralist approach, based on a division of labor between different theories, can promote understanding in a way that none of the approaches taken individually is able to. Our intent has not been to criticize existing theories such as boundary objects but to expand their heuristic power through complementarities and synergies.

A fruitful avenue for further research would be to build on the framework developed here to trace and explain systematically how objects transition in terms of their role and the direct (or indirect) impact that this has on collaboration. Our analytical framework suggests that objects can change status within the same project and/or over longer time spans, and although we have hinted at why transitions happen, this is a subject for more research. Our analysis also indicates that the "career" of objects may not look like an orderly trajectory as much as a messy, iterative journey. This is because objects acquire their particular performative character—it is not given. A critical question to ask when analyzing the role of objects in cross-disciplinary collaboration is not only "what" (what objects are used? what are their characteristics?) but also "when." The framework also helps us to point out that objects can not only support but also create obstacles to successful cross-disciplinary collaboration. Objects can, in fact, create misunderstandings and tensions. A further question to be asked, then, is what is the meaning of this object and for whom.

We would like to conclude by noting some implications for the management of cross-disciplinary collaboration. Our discussion indicates, then, that as part of the effort to lead such type of collaboration, managers should consider whether the common effort is supported by the necessary ecology, or "landscape," of collaboration objects. Using this kind of pluralist framework and the theories upon which it builds, it might be possible for managers to be more sophisticated in terms of the practical conditions they put in place for cross-boundary collaborations to succeed. Three questions can be asked in this regard: first, whether an appropriate range of objects are in place; second, whether the right objects are used at the right time; and third, whether people attribute different roles to the objects in question.

In our study, for example, we noted that the sessions in which cross-disciplinary participation was higher corresponded with the appearance of open objects that could work as epistemic things. People participated more when they were exposed to objects that presented a puzzle, required investigation, and visibly posed a challenge. Accordingly, "closed" PowerPoint presentations were eliminated, and in their stead, participants started to bring to the meetings actual data or pieces of the bioreactor itself so that others could see them, touch them, and connect directly with both the challenges and the achievements of the group as a whole. The framework helps to interrogate the potential strength of a cross-disciplinary collaboration by observing its objectual dimension and the objects that are mobilized.

In terms of the "when" question, this issue has become particularly relevant in view of the increasingly number of management and policy initiatives aimed at nurturing cross-disciplinary collaboration, creating "communities of practice," and instituting knowledge-sharing networks or other forms of distributed collaboration. Many of these kinds of initiative assume that intrinsic, not only extrinsic, incentives are at work. Our framework allows us to question whether the object around which the community is convened works at a primary level and is therefore strong enough, appealing enough, or engaging enough to sustain the collaboration in the first place. Our framework also cautions that ignoring the transient nature of objects can lead to costly mistakes. Arguably, in fact, many initiatives to promote knowledge and best practice sharing in organizations falter because the proponents fail to realize that although at the outset the initiative operates as a primary object (participants take sharing itself as the object of the activity), over the course of time this is likely to change. Unless new objects are introduced to fuel the collaboration, the initiative is destined to lose momentum or even fade away for lack of energy. Inventors of social media have been forewarned.

Finally, our study warns managers to expect different objects to be perceived and understood differently

by the individuals or group participating in the cross-disciplinary effort. Probing the different understandings and managing the tensions and conflicts that may emerge from differences in the status attributed to objects by collaborating partners are two critical factors that may make the difference between a successful and unsuccessful cross-disciplinary endeavor.

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Endnotes

[1]For an extensive discussion on a more-general "artifact myopia" in organization and management studies, see especially Rafaeli and Pratt (2006).

[2]As we explain later in the paper, we treat this aspect last because infrastructures often only become visible once other objects have been foregrounded.

[3]In the framework we treat the three categories as distinct for analytical purposes. However, we acknowledge that given the historical commonalities between these theories, the potential for overlaps does exist—hence our use of the clause "particularly apt" in the text. For example, boundary objects at times also function as primary movers (although this applies to some but not all the participants), and primary objects often work as translational devices. We are grateful to one of the reviewers for pointing this out.

References

Alvesson, M. 1996. *Communication, Power and Organization*. Walter de Gruyter, Berlin.

Bartel, C. A., R. Garud. 2003. Narrative knowledge in action: Adaptive abduction as a mechanism for knowledge creation and exchange in organizations. M. Eastery-Smith, M. A. Lyles, eds. *Handbook of Organizational Learning and Knowledge Management*. Blackwell, Malden, MA, 324–342.

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

Bechky, B. A. 2006. Talking about machines, thick description, and knowledge work. *Organ. Stud.* **27**(12) 1757–1768.

Boland, R. J., Jr., R. V. Tenkasi. 1995. Perspective making and perspective taking in communities of knowing. *Organ. Sci.* **6**(4) 350–372.

Carlile, P. R. 2002. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organ. Sci.* **13**(4) 442–455.

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

Carlile, P. R., E. S. Rebentisch. 2003. Into the black box: The knowledge transformation cycle. *Management Sci.* **49**(9) 1180–1195.

Clegg, C. W., T. D. Wall, K. Pepper, C. Stride, D. Woods, D. Morrison, J. Cordery et al. 2002. An international survey of the use and effectiveness of modern manufacturing practices. *Human Factors Ergonomics Manufacturing* **12**(2) 171–191.

Corlett, W. S. 1989. *Community Without Unity: A Politics of Derridian Extravagance*. Duke University Press, Durham, NC.

Dougherty, D. 1992. Interpretive barriers to successful product innovation in large firms. *Organ. Sci.* **3**(2) 179–202.

Engeström, Y. 1987. *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research*. Orienta Konsultit, Helsinki, Finland.

Engeström, Y. 1995. Objects, contradictions and collaboration in medical cognition: An activity theoretical perspective. *Artificial Intelligence Medicine* **7**(5) 395–412.

Engeström, Y., F. Blackler. 2005. On the life of the object. *Organization* **12**(3) 307–330.

Ewenstein, B., J. Whyte. 2009. Knowledge practices in design: The role of visual representations as epistemic objects. *Organ. Stud.* **30**(1) 7–30.

Gubrium, J. F., J. A. Holstein. 2007. The construction mosaic. J. A. Holstein, J. F. Gubrium, eds. *Handbook of Constructionist Research*. Guilford Press, New York, 3–12.

Hanseth, O., N. Lundberg. 2001. Designing work oriented infrastructures. *J. Comput. Supported Cooperative Work* **10**(3–4) 347–372.

Henderson, K. 1991. Flexible sketches and inflexible data bases: Visual communication, conscription devices, and boundary objects in design engineering. *Sci., Tech. Human Values* **16**(4) 448–473.

Kaptelinin, V., B. A. Nardi. 2006. *Acting with Technology: Activity Theory and Interaction Design*. MIT Press, Cambridge, MA.

Knorr Cetina, K. 1997. Sociality with objects. *Theory, Culture Soc.* **14**(4) 1–30.

Knorr Cetina, K. 1999. *Epistemic Cultures: How the Sciences Make Knowledge*. Harvard University Press, Cambridge, MA.

Koskinen, K. U. 2005. Metaphoric boundary objects as co-ordinating mechanisms in the knowledge sharing of innovation processes. *Eur. J. Innovation Management* **8**(3) 323–335.

Latour, B. 1996. On interobjectivity. *Mind, Culture, Activity* **3**(4) 228–245.

Latour, B. 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford University Press, Oxford, UK.

Law, J. 2002. On hidden heterogeneities: Complexity, formalism, and aircraft design. J. Law, A. Mol, eds. *Complexities: Social Studies of Knowledge Practices*. Duke University Press, Durham, NC, 116–141.

Lawler, E. E., S. Mohrman, G. Ledford. 1992. *Employee Involvement and Total Quality Management: Practices and Results in Fortune 1000 Companies*. Jossey-Bass, San Francisco.

Leont'ev, A. N. 1978. *Activity, Consciousness, and Personality*. Prentice Hall, Englewood Cliffs, NJ.

Levina, N. 2005. Collaborating on multiparty information systems development projects: A collective reflection-in-action view. *Inform. Systems Res.* **16**(2) 109–130.

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

Miettinen, R. 2005. Object of activity and individual motivation. *Mind, Culture, Activity* **12**(1) 53–69.

Miettinen, R., J. Virkkunen. 2005. Epistemic objects, artefacts, and organizational change. *Organization* **12**(3) 437–456.

Nicolini, D. 2009. Zooming in and out: Studying practices by switching theoretical lenses and trailing connections. *Organ. Stud.* **30**(12) 1391–1418.

Nicolini, D. 2011. Practice as the site of knowing: Insights from the field of telemedicine. *Organ. Sci.* **22**(3) 602–620.

Okhuysen, G., B. Bechky. 2009. Coordination in organizations: An integrative perspective. *Ann. Acad. Management* **3**(1) 463–502.

Orlikowski, W. J. 2002. Knowing in practice: Enacting a collective capability in distributed organizing. *Organ. Sci.* **13**(3) 249–273.

Orlikowski, W. J. 2007. Sociomaterial practices: Exploring technology at work. *Organ. Stud.* **28**(9) 1435–1448.

Orlikowski, W. J. 2010. The sociomateriality of organisational life: considering technology in management research. *Cambridge J. Econom.* **34**(1) 125–141.

Orr, J. E. 1996. *Talking About Machines: An Ethnography of a Modern Job*. Cornell University Press, Ithaca, NY.

Osterlund, C., P. Carlile. 2003. How practice matters: A relational view of knowledge sharing. M. Huysman, E. Wenger, V. Wulf, eds. *Communities and Technologies*. Kluwer, Dordrecht, The Netherlands, 1–22.

Oswick, C., M. Robertson. 2009. Boundary objects reconsidered: From bridges and anchors to barricades and mazes. *J. Change Management* **9**(2) 179–193.

Pawlowski, S. D., D. Robey. 2004. Bridging user organizations: Knowledge brokering and the work of information technology professionals. *MIS Quart.* **28**(4) 645–672.

Rafaeli, A., M. G. Pratt. 2006. *Artifacts and Organization: Beyond Mere Symbolism*. Lawrence Erlbaum Associates, Mahwah, NJ.

Rheinberger, H. 2005. A reply to David Bloor: "Toward a sociology of epistemic things." *Perspect. Sci.* **13**(3) 406–410.

Rheinberger, H.-J. 1997. *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*. Stanford University Press, Palo Alto, CA.

Silverman, B. S. 2007. *A Very Short, Fairly Interesting and Reasonably Cheap Book About Qualitative Research*. Sage, London.

Spradley, J. P. 1979. *The Ethnographic Interview*. Holt, Rinehart and Winston, New York.

Star, S. L. 1999. The ethnography of infrastructure. *Amer. Behav. Sci.* **43**(3) 377–391.

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

Star, S. L., J. R. Griesemer. 1989. Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–1939. *Soc. Stud. Sci.* **19**(3) 389–420.

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

Strauss, A. L. 1993. *Continual Permutations of Action*. Columbia University Press, New York.

Suchman, L. A. 2007. *Human–Machine Reconfigurations: Plans and Situated Actions*. Cambridge University Press, New York.

Swan, J. 2006. Commentary on Wanda Orlikowski's "Material knowing: The scaffolding of human knowledgeability." *Eur. J. Inform. Systems* **15**(5) 467–469.

Swan, J., M. Bresnen, S. Newell, M. Robertson. 2007. The object of knowledge: The role of objects in biomedical innovation. *Human Relations* **60**(12) 1809–1837.

Taylor, J. R., D. Robichaud. 2004. Finding the organization in the communication: Discourse as action and sensemaking. *Organization* **11**(3) 395–413.

Trist, E., K. Bamforth. 1951. Some social and psychological consequences of the longwall method of coal-getting. *Human Relations* **4**(1) 3–38.

Trompette, P., D. Vinck. 2009. Revisiting the notion of boundary object. *Revue d'anthropologie des connaissances* **3**(1) 3–25.

Wartofsky, M. W. 1979. *Models: Representation and the Scientific Understanding*. Riedel, Dordrecht, The Netherlands.

Wenger, E. 1998. *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press, New York.

Yanow, D., P. Schwartz-Shea, eds. 2006. *Interpretation and Method: Empirical Research Methods and the Interpretive Turn*. M. E. Sharpe, Armonk, NY.

Zeiss, R., P. Groenewegen. 2009. Engaging boundary objects in OMS and STS? Exploring the subtleties of layered engagement. *Organization* **16**(1) 81–100.

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