Communicating Knowledge:
Articulating Divides in Distributed Knowledge Practice

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Abstract

Working together has always been a challenge, but recent trends in who we work with, about what, and across what regions, cultures, disciplines and time zones have conspired to increase the complexity of team work, and in particular the complexity of knowledge work and communication across knowledge divides. Over the past four years, I have been working with colleagues on examining the challenges, problems, and practice associated with *distributed knowledge*, with particular attention to the way distributed, multi-disciplinary teams communicate and collaborate in the co-construction of knowledge (Kanfer, et al, 2000). In coming to understand distributed knowledge practices, we have been struck by the many kinds of divides and constraints that impinge on any collaborative, multi-party endeavor. This paper explores the nature of distributed knowledge work. Borrowing the concept of *asset specificity* from organization theory, and *affordances* from the psychology and technology literature, I suggest that in order to understand work and communication problems for multi-party teams, attention needs to be paid to the *knowledge-based asset specificities* that can constrain work, as well as to the *affordances* that may expand the ability to work together across knowledge divides.

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Introduction

Contemporary trends in knowledge endeavors have increased the complexity of the work facing collaborative teams. Trends include the drive to gain competitive advantage through scientific activity that crosses disciplinary boundaries, including areas such as biotechnology, informatics, nanotechnology, as well as computing in combination with any other activity. There has also been a recent trend for granting agencies to favor interdisciplinary, collaborative teams.[1] Another trend

[1] The U.S. National Science Foundation's Knowledge and Distributed Intelligence initiative is an example.

is, of course, the rise in the use of information and communication technologies (ICTs), computer-mediated communication (CMC), the Internet, and mobile technologies, each of which are changing work co-location patterns (e.g., see Rheingold, 2003). Trends toward industry alliances represent yet another kind of endeavor that asks for interaction across organizational divides, and often also geographic and disciplinary distances (Fischer et al, 2002); and the trend to globalization brings with it both the need to work at a distance and the need to bridge cultural differences.

These many kinds of enterprises increase the difficulties associated with *distributed, collaborative practice*.[2] This paper articulates some of the more important distinctions about distributed knowledge that are relevant to the practice of distributed knowledge. Drawing on how the practice perspective approaches both knowledge and technology, this paper discusses both the nature of distributed knowledge, and the kinds of *knowledge-based asset specificities* that constrain and hinder collaboration under conditions of distribution. It is argued that paying attention to such specificities paves the way for identifying *affordances* that can be separated from current practice to enhance the ability to work together across knowledge domains and through technology.

This paper takes as its starting place a practice perspective on knowledge and technology use. This approach is important for understanding the heavy influence that practices hold on how we go about our work, what we consider important, with whom we work, and how we design technologies. A strong attachment to current practices can hinder distributed group members from pooling their work, and act as a hindrance to the accomplishment of collaborative, distributed work. The first section below briefly explains and reviews the theoretical background for the practice perspective. Then second section defines the key properties of distributed knowledge as discussed here and delimits what is meant by that term for this paper; it also outlines the many kinds of distributions that have been found in looking at distributed practice of multi-disciplinary science and social science teams (from work carried out with colleagues on an NSF funded grant). I then give attention to the idea of *knowledge-based asset specificities*, and articulate some kinds of specificities that appear to constrain distributed knowledge processes. The paper ends with a brief discussion of bridging knowledge distributions, appealing to Gaver's (1996) discussion of affordances, and the need to look as much to practices as to knowledge and technologies in supporting distributed knowledge processes.

The Practice Perspective

The practice perspective acknowledges the very real need to understand the situated use of knowledge and technologies, and nowhere is this more important than in understanding the complexities of communicating and exchanging knowledge that is tacit, i.e., build into and demonstrated through activity. The knowledge literature's distinction between explicit and tacit

[2] A term coined by Geoffrey Bowker, personal communication.

knowledge is enormously useful for considering the two sides of activity that ICTs may be called on to support, and in looking for ways to make tacit knowledge explicit, and thus available to others. However, it tends to be less useful when we must deal specifically with tacit knowledge in situ, unconverted to explicit knowledge, embedded in activity and indivisible from it. It is also less useful in explaining the development of knowledge, as new ways of doing things are created and adopted, as ideas and innovations are generated, and as groups come to understand their role, purpose and goals (Cook & Brown, 1999; Leonard & Sensiper, 1998; Orlikowski, 2002; Haythornthwaite, Lunsford, Kazmer, Robins & Nazarova, 2003).

The practice perspective stresses that new ways of doing things are inextricably tied to pre-existing conditions and constraints. Practices – including knowledge, knowing, and the design and use of technologies – emerge from and are subsequently affected by existing practices. This perspective is particularly important for moving us beyond the ‘one technology-one use’ assumption that still haunts ICT and CMC implementations. To move beyond that assumption we need to also acknowledge that a two-way process is in effect. Not only does any technology affect how we accomplish work, but the technology and its use is derived from and affected by how we do work.

Among the theories that inform the practice perspective, perhaps best known is the work of Lave & Wenger (1991), with their attention to *situated learning*, *legitimate peripheral participation*, and *communities of practice*. Their work brings learning, i.e., the acquisition of knowledge, into real life, embedding it in observation and participation in local social worlds. Also prominent in this area is Giddens' (1984) *structuration theory*, which recognizes how structures emerge from interaction and are sustained and maintained by such interaction. Authors building on structuration theory recognize that use of social technologies, such as groupware, email, listservs, chat rooms, etc., arises from group practices, including norms about what is discussed, and the language and genres considered appropriate for communication (see Baym, 2000; Cherny, 1999; Orlikowski, 1992; Orlikowski & Yates, 1994; Orlikowski, Yates, Okamura, & Fujimoto, 1995). For example, DeSanctis & Poole's (1994) *adaptive structuration* describes how specific uses of group ICT can be expected to emerge from the practices of the group employing it, which in turn reinforces that kind of use. Practice perspectives are also strong in addressing technology. For example, *activity theory* stresses the connection between practice and the technologies we work with (e.g., Engeström et al, 1999); and *social informatics* which shows how technologies are deeply embedded in socio-technical networks of action and constraint, with technologies both facilitating and constraining what is or can be done in various settings (e.g., Kling, 2000; Kling, Rosenbaum & Hert, 1998; Bishop & Star, 1996; Sawyer & Eschenbach, 2002; Lamb & Davidson, 2002).

While group action around ICT is increasingly recognized as affected by the presence and use of the technology, less well acknowledged is that technology itself emerges in response to needs and practices of the user group. As ICT practices get easier, and what might formerly have been called development falls more and more into the hands of users (e.g., as it becomes easier to adopt, implement, connect, and combine technologies[3]), how technologies are established, combined, and used rests more with those using them than with those originally designing and coding them.

When we see technologies not as something imposed from above, but instead as emerging from and modified by practice, we apply practice perspectives to the instantiations of technologies themselves. This view follows John Dewey's notion of *pragmatic technologies* (Hickman, 1999). It allows us to see technologies as both antecedent and consequent to group interaction, and groups as able to both adopt and adapt technologies to their needs (Bruce, 2003). Moreover, we see the phenomenon of technology as *continuously emergent* (Contractor & Eisenberg, 1990; Monge & Contractor, 1997), adopting for technologies the *spiral* of growth associated with the communication and "conversion" between tacit and explicit knowledge[4] as outlined by Nonaka (1994). Continuous emergence is also present in Cook and Brown's (1999) position that new knowledge emerges from a *generative dance* between knowledge possessed by the individual (in the head), and that knowledge brought into practice with the real world. Thus, both knowledge and technologies can be seen as continuously emergent.

It should not be surprising to find an overlap between discussions of knowledge and of ICTs. Computer technologies, tools, equipment, and procedures embody practices formerly held as tacit knowledge. They represent an instantiation of particular ways of doing things, and in their definition the implicit has been made explicit.[5] It is, then, the embodiment of the state of the art at the time of its creation.

> A tool is in this sense a theory, a proposal, a recommended method or course of action. It is only a proposal and not a solution per se because it must be tested against the problematic material for the sake of which it has been created or selected. (Hickman *John Dewey s Pragmatic Technology*, 1990, p.21)

[3] Simple things include setting up an email list, chat buddy list or listserv to create a place for group discussion; using a web page to post documents, and newsletters; using email to exchange documents. Slightly more complex, but still not requiring systems developers, are things like creating web sites with combinations of tools (chat, email lists, archives, digital libraries, group list management), establishing data storage and retrieval systems (databases, data entry and retrieval interfaces).

[4] Nonaka (1994) includes communication and conversion of tacit to explicit knowledge, as well as tacit to tacit, explicit to tacit, and explicit to explicit.

[5] However, see Weick (1990) for commentary on the way the instantiation of knowledge about decision making into computer programs then hides its explicitness from view, and decreases the likelihood of its review.

As a theory, a proposal, the technology is amenable to change. As much research has already shown, we often see computer technologies modified in their use as they are applied to local conditions – i.e., as the theory is adjusted in light of the "problematic material" against which it is tested (e.g., see the notion of 'reinvention' associated with the adoption of innovations; Rice & Rogers, 1980; See also the papers on the social shaping of technology in MacKenzie & Wacjman, 1999)

These perspectives, although only briefly reviewed here, all lead us to look at practice as the intervening activity between existing and new knowledge and technology. Thus, as we approach distributed knowledge practices, it is important to remember that such practices are both the design for and the outcome of ICT implementations, as well as the outcome and input for new knowledge.

What is the Nature of Distributed Knowledge Work?

Since the practice perspective leads us to pay attention to the current practices, and how they are being supported by ICTs, an initial focus for any work on knowledge and ICTs is to understand the nature of knowledge work, and particularly of the nature of the distribution that characterizes the knowledge problems. To situate this discussion, we begin by identifying some key properties of distributed knowledge that explain what aspects of knowledge practices we are discussing in this paper.

Key Properties of Distributed Knowledge

The emphasis on *distributed knowledge* means the focus is not on individual learning. We are also considering authentic, cooperative groups, working together for a common purpose. However, we also expect the group's working operation to entail some sort of distribution that activities must bridge. Although the first take on distribution is normally geographic distance, we find that other kinds of differences equally create a challenge for distributing knowledge. Moreover, ICTs are used so routinely among co-located group members that geographic distribution becomes only one element in the domain of distributed knowledge. The following key properties are important for situating the kind of distributed knowledge under discussion:

1. **More Than One :** not individual psychology, not the individual learning from an author by reading their book,[6] but the exchange between one person with knowledge to and from at least one other
2. **Non-Classroom Settings :** knowledge in practice rather than knowledge acquired or exchanged in a teaching setting

[6] Although this does in some sense fall into distributed knowledge, i.e., distributed over time, such a condition is not included in the context to be considered here

3. **Need For Exchange :** while there are many reasons why a person might not share knowledge (political, psychological), the discussion here refers to the intention to share, i.e., there is a reason, need or agreement to make the effort to share knowledge (even if not accomplished or enacted in reality) as may occur between members of an alliance, interdisciplinary research teams, software programming teams, or management teams
4. **Common Goal :** those who are sharing are focused on the same goal (again, even if not actually accomplished, and even if individuals vary in their commitment and contribution toward the goal, or even their understanding of the goal)
5. **Embedded in a Social Context :** the distributed knowledge activity takes place within a social context, e.g., within the context of a contracted alliance (which itself is embedded in the legal system, and the structure of organizations), an industry or set of industries (e.g., within the biotechnology industry, or the university system), a government granting system (e.g., funded by NSF, Dept. of Education, etc.), a university tenure and promotion system, or a scholarly recognition and reward system
6. **Enacted Through a Technology or a Tool :** whether technology is read as a "way of doing things" (as in the management literature), piece of equipment, computer technology, CMC, or system of people, equipment and setting (e.g., a laboratory; see Latour, 1987, Knorr-Cetina, 1999) the knowledge distribution and exchange process is enacted through or around technology
7. **Distributed :** some kind of distance or gap exists between members that needs to be bridged, brokered, or crossed (see below)

Distributions of Knowledge

Although distribution in geography is a significant hurdle for groups, it soon became evident that the multi-disciplinary teams studied by our group faced many more challenges than those of distance. In understanding distributed knowledge, it became obvious that there are many divides, boundaries or barriers that must be spanned or crossed. The essence of distributed knowledge is just that – that is it *distributed*. It does not reside in one place, one head, one discipline, or one time. Yet the types of distribution vary, and the attendant problems of transferring, negotiating or co-constructing knowledge also vary with these distribution types. As well, groups must learn how to work together across such divides, and this increases the overall work compared to non-distributed groups.

I propose we start with a 'lean' definition of distributed knowledge as: *a recognized gap between what one person knows and what another knows or needs to know*. It is worth taking a moment to consider the consequences of defining distributed knowledge as a *recognized* gap. It suggests that the gap must be explicit and thus known to participants. This is largely the case when interdisciplinary groups come together (for more on interdisciplinarity, see Klein, 1990, 1996; Klein et al, 2001). However, making the gap explicit may also be part of the group's process. What is often not visible are more subtle distinctions in "home" activities that affect individuals motivations and goals with respect to the work, e.g., what kind of work (programming, getting funds, writing papers) is most rewarded? What accomplishments give prestige to different disciplines or businesses (e.g., grant money, articles, books; client accounts, new products, management innovations). Groups may also bring in new members partway through their production process, and fail to see that practices that need to be transferred to new members about how the group works together (Haythornthwaite et al, 2004).

New endeavors need new procedures, and yet such *procedural knowledge* (i.e., knowing how to go about a task, in contrast to *declarative knowledge* which is knowing that a condition is true or false) is often overlooked in the drive to collaborate. Procedures and processes about bridging knowledge distributions are too often the *invisible work* (Star & Strauss, 1999) of such teams. For example, in looking at what knowledge is exchanged between members of interdisciplinary research teams, one of the surprises is how often individuals emphasize things like learning how to deal with funding agencies, or learning how to manage a discussion, rather than with sharing domain knowledge (Haythornthwaite & Steinley, 2002, in a study of a science team; Karen Lunsford, personal communication, regarding a social science team). As more pooling and crossing of knowledge domains occurs, the more we need to be alert to potential gaps in expectations about processes, and to raise them from liminal levels to cognitive awareness.

Creating a richer definition of distributed knowledge requires expanding on the nature of the gap, and examining local practices to determine the extent and nature of the gap for the group in question. Our group's work suggests the gaps that separate groups in their knowledge, and individuals from the group, act at many different layers of interaction, and are more complex than one might consider at first glance. Here are a few of the kinds of differences that make gaps between individual's understandings that are particularly relevant for distributions in knowledge (note that they do not even include the usual differences in terms of race, gender and socio-economic status, which may also play a role in distributed knowledge):

- Discipline (biology, chemistry, computer science, information science, anthropology, sociology, psychology)
    - Sub-discipline (e.g., Psychology specialties in cognition, perception, memory, development, social psychology)
    - Inter-disciplinary constellations (bioinformatics, psychopharmacology, history of technology, social studies of science)
- Expertise (novice to expert)

- Method (quantitative, qualitative)
- Level of analysis (individual, group, organization, society; micro, meso, macro; molecular, cellular, organ, body)
- Temporal units and timescales (nanoseconds, days, millennia)[7]
- Temporal range of inquiry (historical, contemporary)
- Geographic locus of inquiry (urban, rural, wilderness; water, land, shorelines)
- Setting of inquiry (laboratory, field)
- Geographic or cultural home(s) (U.S.; North America; Europe; Asia; etc.)

Making Sense of Distributions

Thus, when we speak of a gap or distance to be bridged, while we include consideration of (1) *physical distance*, we also regard as important distributions across (2) *cognitive distance* (e.g., distance in understanding (novice vs. expert), discipline (e.g., biology vs. physics), or knowledge base (software industry vs. manufacturing)); and (3) *distance in practices* (e.g., commitment to sharing, familiarity with teamwork, mutual trust, differences in reward structures, what constitutes reportable results (see Collins, 1998), and practices of data sharing (Fienberg, Martin & Straf, 1985; Haythornthwaite et al, 2004)).

With recent emphasis on interdisciplinary work, we find disciplinary divides coming to the fore in discussions of crossing knowledge bases. However, every organization also crosses many knowledge barriers. Brown & Duguid (1998) even claim that the job is more difficult for organizations than for universities because organizations, as a whole, are always striving to integrate across knowledge bases toward a unified outcome. They note that no such synthesis is called for across campuses. However, it is called for in many interdisciplinary teams and in institutes, whether or not it is achieved. Thus, we may see the kinds of divides and barriers both academic interdisciplinary research teams and cross-functional organizational teams face are of much the same kind, as are their efforts to synthesize knowledge. Thus, the literature on interdisciplinarity (including social studies of science which articulate practices both within and across disciplines, and social studies of technology), and organization theory are both relevant to the discussion of distributed knowledge. Drawing on these literatures, we can go on to articulate dimensions that lead to richer definitions of knowledge distributions.

[7] Note for example this comment by Kotamraju (1999) of the difficulties of time for online research: “Scholars studying virtual environments face the task of reconciling the time frame of social life, which is measured in life times, generations, and eras, with that of Internet technology, which is measured in weeks, months, and software upgrade versions.” (p. 471).

Asset Specificity and Affordances

Borrowing from organization theory, I find the concept of *asset specificity* helps make sense of the many distributions that multi-disciplinary, multi-faceted teams must bridge. It is also highly relevant for focusing the discussion toward what keeps fields and individuals rooted in one way of doing things and one way of evaluating what has been done. Asset specificity can be contrasted with the notion of *affordances* from psychology, which is now routinely applied to discussions of technology (Gaver, 1996; Norman, 1988; Bradner, Kellogg & Erickson, 1999). Where affordances describe what a procedure, physical object or technology "affords" an individual to do (i.e., what, by reason of its design, a technology leads or permits an individual to do), asset specificity describes the constraints on what can be done.

Asset specificity refers to the degree to which an organization is locked into certain ways of doing their work, e.g., because it can only mine ore in a particular location, its products are tied to a particular type of expensive equipment, or its reputation is built in a certain field. A high degree of asset specificity increases the organization's vulnerability to changing conditions. Williamson (1981) originally defined the concept and noted these kinds of specificity: site specificity (tie to specific location of operations); physical asset specificity (need for specialized equipment); and human asset specificity (tie to skills arising from learning by doing, and held in the people doing the job, i.e., tacit knowledge). Malone, Yates & Benjamin (1987) took up this concept again and added these aspects: time specificity (tie to perishable products, e.g., fresh foods, stock trading price quotes); procedural asset specificity (ties to particular procedures, e.g., using a particular computer system to order products from a particular supplier).

Knowledge-Based Asset Specificities

When we apply asset specificity to discussions of knowledge, we find it holds well for explaining many of the kinds of divides, and the reticence or difficulties associated with changing behaviors to carry out collaborative endeavors. Members of different disciplines and holders of different organizational roles bring with them disciplinary and role specificities that require a certain way of approaching problems, finding evidence, proposing a hypothesis, and presenting results. It is in these specificities that we lose the affordance of collaborative activity and pooling of ideas. What kinds of specificities are associated with distributed knowledge? (See also Table 1: Knowledge-Based Asset Specifities.)

Site specificity pertains to knowledge based endeavors as much as to physically based ones. Certain fields, jobs and organizational sectors are defined and granted status or success by operating in certain locations, and engaging directly with conditions in specified regions. Anthropology and anthropologists have gained recognition by living in different settlements, getting a real life sense of day-to-day activity through ethnographic studies. Similarly, biologists gather specimens from the field and observe plant and animal life in specific physical regions, while geologists in the same region observe rock and mineral deposits and formations. Each is tied to the *concept of physical space* as a defining feature of their work and field. We may even extend this to consider the "space" of the computer. Thus, simulations of biological or geological processes may be found in the space of the computer. Computational biologists thus are highly tied to the conceptual space of the computer (as well as physically to the device and its housing).

While some fields require open air, research and work in areas such as physics, chemistry, medicine, and certain branches of biology and psychology require laboratory settings and closed-air conditions. Site specificity in this case blends in with ***physical asset specificity***, but here the asset is the laboratory, the research park, and the kinds of equipment they are stocked with. Physical asset specificity also increases as fields or sub-fields are locked into the use of particular kinds of equipment, materials, or other physical resource (e.g., as computer science is tied to computers).

In knowledge endeavors, specificity also applies to the object of research. Thus, we may add ***research object specificity*** to the types that matter in bridging knowledge diversities. A research object may be people or subsets of people (e.g., children, adolescents, or seniors, novices or experts, low income earners), or animals, plants, rocks, diseases, etc. The research object may also be inanimate, including data and information, buildings, equipment, automobiles, as well as computer interfaces, algorithms, or programs. The focus may be on individual behaviors, or of people or other objects in groups of more than one (small groups, large groups, organizations, societies, etc.; traffic flow, urban planning), or on normal versus pathological cases (biological specimens; accidents sites). Collaboration across fields will be limited to the extent that different fields or roles cannot change their object of study to make it possible to pool work and knowledge. To the extent that a field is defined by what is studied, where, when, and with what techniques, the higher its specificity, and the less likely it is to be open to change in its procedures.

We can also identify another kind of specificity associated with sites and resource objects, that of ***resource specificity***. There are many kinds of inquiry that relate to the examination of rare or infrequent events, or items to which access is limited. The extent to which a knowledge endeavor is tied to rare or limited resources the greater its resource specificity, and the more difficult it is to change what is done. Where the replaceability or substitutability of resources is low, specificity is high (e.g., substituting one location for another, one group for another, one classroom of children for another, already collected data for new data). Scarce resources include those associated with rare objects (e.g., museum items, or specimens of pathogens), limited access resources (e.g., archaeological digs, children under 19, illegal behavior, sensitive information, job-endangering information), and infrequent events such as disasters, weather phenomena, physics phenomena (e.g., capturing neutrinos).

Included in resource specificity is also the ***time specificity*** noted by Malone, Yates and Benjamin (1987). Endeavors that depend on resources with limited life spans, resources with values that decay rapidly (time-sensitive information such as news, emergency responses, stock trading prices), or discoveries that carry greater value to those first in the market (e.g., medicines) show the greatest time specificity. Technologies have been highly influential in changing the importance of time specificity to particular operations. For example, while refrigeration decreases the impact of time specificity for many foods (since the value now lasts longer), computerization increases the time specificity for stock prices which now must be delivered more quickly to retain their value (in competition against other suppliers). Some knowledge domains operate almost exclusively in high time specificity conditions (e.g., those making pharmaceutical, or computing advances), whereas others enjoy a (somewhat) more leisurely pace (e.g., makers of hand-made furniture or musical instruments).

Physical assets such as laboratories, equipment and tools represent not only investment in expensive infrastructure, but also in a fixed way of doing things. They offer a degree of repeatability not available in open air, field studies. Common procedures and techniques further standardize the work of labs, particularly as such procedures become set in computer software programs that operate equipment and analyze data. Similarly, adherence to accepted methods of collecting and analyzing data reduces the variability in how work is done, and what is acceptable conduct of work in different fields.[8] These also are aided and abetted by new software tools that standardize what features of a method are accepted.[9] The extent to which a particular field is tied to particular routines and accepted methods, the greater its ***procedural asset specificity***.

Established fields also often have fixed notions about what is a proper product from their work, and who has ownership of that product. Thus, along with procedural specificity, there is also ***product specificity***. In distributing knowledge, ideas about proper products affect whether an acceptable output from research is the data that are generated or only a formally presented paper (e.g., see Collins, 1998), and whether that paper is accepted if published online or only on paper. Tenure and promotion procedures greatly affect what is considered an acceptable product for academics, and this can vary across disciplines and schools. In organizations, work that produces academic papers is unlikely to be considered as relevant as outcomes that add to the financial well-being of the company, with promotion depending on outcomes appropriate to the organizational

[8] Whether the approach is qualitative or quantitative, case study or laboratory practice, accepted ways of carrying out the work or research exist in each domain, and become standards to which each practitioner is expected to adhere.

[9] For example, new statistical routines that do not appear in widely implemented statistical software (such as SAS or SPSS) are unlikely to become standard until incorporated. On the other hand, presentation technologies such as PowerPoint have become so popular that they drive the acceptable way to present papers, and technology expectations at conference centers.

setting. The extent to which organizations are tied to their ideas of what is the right product to produce, the higher their asset specificity.

Where method is instantiated in individuals – the ethnographer, the interviewer, the survey designer – it overlaps with ***human asset specificity***. There is a deep divide among disciplines in the extent to which human assets are accepted as a fundamental part of knowledge based inquiry. Thus, while some fields and organizations herald the introspections of the individual writer, scholar, ethnographer, and visionary leader, others demand the removal of human bias from study and look to established protocols and organizational roles over individuals. Whatever the approach, the degree to which the enterprise depends on specific individuals, the greater the human asset specificity of the knowledge work.

Equipment, tools, procedures, and methods each embody a wealth of implicit knowledge. They represent the visible tip of the knowledge iceberg, and the degree to which a particular endeavor is tied to this visible tip affects the ability to respond to a change in the knowledge base. As fixed ways of doing things, equipment and procedures offer the "affordance of predictability" described by Gaver (1996), a condition important for having a common ground for working together. As Gaver points out, when new technologies come along, their unpredictability requires an opening up of otherwise closed assumptions about how work will progress:

> The unpredictability of most electronic systems has a common social consequence of forcing previously implicit behaviors to be made explicit, and of causing the unspoken to be spoken. People using such systems find they cannot easily coordinate their activities and instead have to explicitly negotiate their collaboration. (Gaver, 1996. p.120)

The same is true for bridging knowledge divides. Ways of working – including what kinds of sites, equipment, protocols are used – represent the implicit (tacit) knowledge of the field. Thus, one more aspect of knowledge specificities is the extent to which the knowledge is visible and explicit, what we will term here as ***knowledge structure specificity***. The greater the degree of implicit knowledge operating, the greater the knowledge structure specificity. This is true even if the implicitness is not recognized by participants. Again, as Gaver states

> When affordances are perceived, a tight link between perception and action may ensue. But the concept [of affordances] also is useful in describing situations in which perceptual information is misleading about possibilities for action, or those in which affordances exist but information for them does not. In general, the perceptibility of an affordance should not be confused with the affordance itself. (Gaver, 1996, p. 144)

Thus, even if the ways of working are not perceived as affordances for predictability, that does not mean they do not afford predictability. What seems evident in crossing knowledge divides is that the many kinds of affordances that are inbuilt into disciplines and industry sectors become so transparent that when they meet (and/or clash) with ways of other disciplines the differences come as constant surprises. Moreover, as disciplinary endeavors change and unfold, particularly as fields incorporate new technologies, assumptions about what other fields do or do not do becomes obsolete, again leading to 'surprises' in collaborative endeavors. Recognizing that knowledge structures exist is the first step in being able to bridge them.

One final specificity belongs to the field or endeavor as a whole. Like the knowledge structure specificity, whole fields can be in various stages of knowing what are the appropriate ways of doing work. Thus we add ***knowledge domain structure specificity*** to the list. Some problems have accepted ways of proceeding, and thus they have a high knowledge domain structure specificity. It is clear to members that certain kinds of work belongs in this domain and other kinds do not. Such fields are more highly challenged by conditions that do not fit to known patterns, and are more challenged by changes in knowledge domain boundaries and the influences of new technologies. (Readers may try on here their own field with respect to Internet research.) They do not deal well with ill-structured problems (Mintzberg), ill-structured knowledge domains (e.g., Feltovich et al); problems entailing equivocality (for which the questions leading to solutions need to be determined; Daft & Lengel, 1986); unanalyzable inputs (Perrow, 1970); changing and turbulent organization fields (Emery & Trist, 1965); invention and innovation (as embodied in "resistance to change," see Rogers, 1995). They do well with, and remain locked into, codified knowledge, accepted classifications and categorizations (Bowker & Star, 1999), problems of uncertainty (solvable by gathering more data for known questions) and analyzable inputs. How locked-in a particular field or organization is to its knowledge domain can be expected to affect its ability to enter into the unstructured knowledge domains of new interdisciplinary work, alliances or joint ventures.

Systems of Specificities

What we find from these specificities is that there are also whole systems that create and are created by each kind of work (Latour, 1987). These systems include protocols for conducting the work, systems of funding that expect to see certain methods and kinds of expenses to fit certain kinds of inquiry, government or policy regulatory commissions that oversee procedures, and reward systems that reflect expected activities. Thus, as we try to cross divides in knowledge distribution, we are also bridging divides in many more aspects of the work than whether one works in the field or the lab.

Such expectations also lead to the development of technologies, tools, and equipment that by virtue of time for development, early place in the market, or overall cost, can further structure how and what gets done. It also further structures the nature of the next problem. For example, computers, initially developed to facilitate mathematical and statistical processing, accelerated the pace of what could be done in those areas. With such tasks now easier, attention turned to collecting more data to feed into these automated processes. Now, as computerized problem solving has become routine, expectations for computation increase, and more and more fields are now asking computational questions about their endeavors. The computer has become a physical asset that few can do without, and a physical asset specificity for nearly all knowledge-based endeavors. Thus, the initial conditions (faster number-crunching) drive the way future questions are structured (How can we collect more data to feed into the analyses? How can we bypass human data entry to speed up data collection and processing?), and how technologies are then re-structured to support that new endeavors (data collection becomes widespread and automated; computation is expected in all fields). It is a continuous cycle of question and answer, need and technology, not one-off development.

Bridging Knowledge Distributions

So far we have described gaps to be bridged, but discussed little about the ways in which this can be done, or how technologies can help. As noted, technologies instantiate practice, fixing into more permanent form the vagaries of individual performance and tacit knowledge. As such, they provide a way of bridging gaps and passing on procedural and intellectual knowledge in an explicit manner. There are many means that help us distribute this explicit knowledge; we package it in routines, manuals, textbooks, instructions sets, and standard operating procedures; in tools and equipment; and as systems of people, equipment and setting. With ICT, we package it as algorithms, interface designs, data entry and retrieval forms, database structures. We even find explicit knowledge in email mailing lists, and listserv address lists which encapsulate information about who belongs to a group and/or who is interested or knowledgeable in a particular topic.[10]

Our continuous challenge in implementing technology is to codify the tacit knowledge of practice, work often performed by people external to those engaged in the practice, i.e., by business and systems analysts. Codification is achieved by spending a lot of effort in making explicit the rules for dealing with inputs. We codify routines so that we can distribute knowledge, and replicate products and outcomes without relying on tacit knowledge. In Perrow's (1970) terminology, we endeavor to devise rules for dealing with inputs so that "craft" technologies (few incoming exceptions, unanalyzable search procedures) become "routine" (analyzable search procedures), and "non-routine" technologies (high exceptions, unanalyzable search procedures) become "engineering" technologies (analyzable search procedures).

[10] ICTs often tacitly manage interpersonal connections. Inclusion on a mailing list, or access to one for sending questions, supports transactive memory systems which help people know who knows what (Moreland, 1999). Yet, when addressing a group by its name, we may not know who actually belongs to the group. Like other algorithms for decision making (Weick, 1990), mailing lists may also not be re-opened for examination, thus locking groups into (or out of) certain avenues of contact.

Yet, as we look at distributed knowledge processes, particularly at the delicate stage of creating common understanding and bridging distribution, we find one of the enduring characteristics is that this knowledge is *not-yet-codified*. Indeed, it may even be *not-yet-tacit knowledge*. The act of forming a bridge between different knowledge bases does not fall simply into the explicit-tacit dimension. No routines yet exist to be amenable to codification. Moreover, rules for coordinating work at this stage are devised more by those engaged in the activity than those external to it. Where no tacit practice exists – e.g., for working as a distributed team, combining social science with computing, crossing or integrating disciplines, collaborating – the task is to create (in Perrow's terminology) the "craft" or "non-routine" practice. At this stage, technology needs lean toward systems with interpretive flexibility, and permissive over prescriptive features (Galegher & Egido, 1990).

We can also see that even the knowledge about *how to bridge distributions* is not yet tacit, and certainly not yet explicit. Thus, companies and teams are only now learning how to be distributed, how to work with new technologies, or how to be continuously innovative. Orlikowski (2002) identifies this as *knowledgeability*, a kind of knowledge that enhances the *ability to practice*. The rapid changes associated with adoption and incorporation of computing into the practice of almost all endeavors, the increased connectivity of systems and concomitant inter-system flow of data, as well as the continuous stream of new applications and uses for computing, require that new social behaviors be applied to the practice of everyday work. These behaviors include learning about how to use and work through the new technologies, but also about how to work with others through technologies, and how to continuously adopt and adapt as even more new technologies arrive.

Examples abound of consequences and impacts of new technologies, but few explore how knowledge about practice is achieved as a result of such changes, even though this may be what is at the heart of distributed knowledge practice. However, the evidence for such learning is there. It can be found in the adoption of practices associated with CMC such as the development of online norms of behavior, new uses of language, establishment of new roles and new communication genres (e.g., Baym, 1995; McLaughlin et al, 1995; Wellman et al, 1996; Bregman & Haythornthwaite, 2003; Erickson, 1999; Yates & Orlikowski, 1992, Yates, Orlikowski & Okamura, 1999). It can also be found in how organizations learn to be distributed (Orlikowski, 2002), innovative (Massey & Montoya-Weiss, 2003), or otherwise open to continuous change (Haythornthwaite, Lunsford, Kazmer, Robins & Nazarova, 2003).

Moreover, we can see in the change in behaviors the kind of articulation of processes noted by Gaver, "forcing previously implicit behaviors to be made explicit" (p. 120). To bridge a distribution, we must step out of our routine, and become aware of the features and affordances of our ways of behaving, thinking, researching, and accomplishing work. Distributed knowledge practices require us to learn how to step back from our implicit, tacit behaviors, observe them, and then identify the essence of our work (the affordances of our work), in order to move forward to achieve this in concert with others.

Thus, to bridge knowledge distributions we need to look as much to practices as to knowledge and technologies, particularly because the latter two emanate, in a continuously emergent fashion, from the former. Important for practice is understanding that three forms of knowledge are involved. These forms are applicable in both the tacit and explicit state, and no matter what kind of knowledge is involved (e.g., know-what, know-how, know-who). There is: *knowledge*, possessed by individuals, e.g., the domain knowledge they hold about a discipline or role; *knowledge in practice*, associated with the application of knowledge in practice (akin to Cook & Brown's knowing); and *knowledge out of practice*, that is exterior to and derived from practice. What is important is not so much what we classify under any of these forms (but see Table 2), but instead to realize that as a group operates, particularly a group newly engaged in crossing knowledge domains, learning is involved in all three areas. Thus, although it may not be useful after the fact to tease out these separate 'knowledges', it is certainly useful to be aware of them as a group begins its working life.

So where does that leave us in dealing with distributed knowledge practices? First, as we look to ICTs to support distributed knowledge, we need to *look more at how collaborative distributed knowledge practices are forming the ICT solution*. Second, we need to *address the affordances that current practice support, and use those affordances as the design input for ICT to support practice*. Gaver's (1996) shows how the physical aspects of the environment can be examined for the underlying principles that created and/or are affected by such designs. In particular, he talks about the way building elevation affords access: penthouses limit access because of the extra work to reach them; store-fronts facilitate access because of their ready availability. The point is not that either is better or worse, but that they afford differential access.

If we rephrase this to see buildings as technologies, we can see the use of elevation as arising from practices about access – e.g., maintaining privacy effected by choosing a more inaccessible site – and the technology of high-rise buildings. This is in keeping with Gaver. However, in examining technologies, it is difficult to maintain a strict look at the physical environment as Gaver proposed. Because we see technologies as the instantiation of explicit knowledge, we cannot make a clear dividing line between a technology that is socially enacted and one that is physically enacted, e.g., between a routine enacted by an individual in practice, and one written into design specifications and enacted by a machine. Thus, in approaching ICTs, it seems useful to mine all technologies for their affordances, including well-accepted routines, whether fixed in physical machines, manuals of standard operating procedures, research methods, or group tacit knowledge about how to behave.

Conclusion

Building from a practice perspective, this paper has argued that discussions of knowledge and of technology bear similarities in that both are generated out of interaction with the real world, and how the three-part liaison of knowledge, practice, and technology can provide insight into the support of distributed knowledge. By examining practices, it is possible to recognize and articulate the constraints that hinder collaborative processes across knowledge bases. These have been named here as *knowledge-based asset specificities*. While various kinds of such specificities have been discussed, the important aspect to take from this discussion is that *attention to specificities* is more important than providing an inventory of their types. Similary, in discussing bridging knowledge distributions, seeing technologies as *knowledge out of practice* is more important than articulations of what kinds of knowledge may show there.

As problems involving communication and exchange of knowledge across divides of distance, cognition and practice increase in frequency, attention to current practices may both guide us to understanding why such collaborations fail, as well as to forming better practices and technologies to support them.

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Table 1: Knowledge-Based Asset Specificities

Type of Specificity	Specificity increases to the extent that the knowledge domain is tied to …	Examples
Site specificity	Operations, data collection, or experimentation in specific locations	Geographic location, ecosystems, laboratories
Physical asset specificity	Use, development, or implementation of specific kinds of equipment, as well as specific collections of equipment or physical housing for the co-location of operations	Computers, medical imaging devices, purpose-built buildings (e.g., laboratories, libraries); university campuses, research parks, medical clinics
Research object specificity	What is studied, where, when, and with what techniques	Sociology to society, medicine to people, veterinary medicine to animals, pathology to diseases, geology to rocks and minerals
Resource specificity	Rare or scarce resources, objects of study with limited access; non-replaceable and non-substitutable assets	Weather phenomena, museum objects, rare books and manuscripts, rare diseases and genetic anomalies, illegal behavior
Time specificity	Ephemeralness of the resource or of conditions surrounding the resource; ephemeralness of value associated with the resource	Time-sensitive information, perishable goods, transient phenomena; behavior of people during transient phenomena
Procedural asset specificity	Specific routines and accepted methods	Controlled laboratory studies and statistical analysis in sciences; ethnographies in anthropology; psychiatric interviews and personality tests in psychology
Product specificity	Specific expectations about acceptable products and outcomes, and their ownership	Peer-reviewed publications in academia; more efficient processes in management; financial gain in businesses
Human assets specificity	Dependent on the tacit knowledge, skills, and abilities of specific individuals	A specific person who acts as the technological guru, inter-organizational boundary spanner, visionary leader, domain expert, or machine operator expert
Knowledge structure specificity	Known and accepted practices, behaviors, and products; extent that knowledge is codified, visible, and explicit	Disciplinary rather than inter-disciplinary work; established rather than emergent fields of study (e.g., biology versus bioinformatics)
Knowledge domain structure specificity	Known and accepted domains; extent that knowledge visibly and explicitly belongs to a specific domain	Medical study of animals belongs to veterinary medicine, of plants belongs to biology versus the accepted domains for nanomaterials, nanotechnology, medical informatics, etc.

Table 2: Knowledge, Practice and Technology

	Knowledge	Knowledge In Practice	Knowledge Out of Practice
	Knowledge	*Practice*	*Technology*
know-what	book learning, declarative knowledge, domain knowledge	procedural knowledge	explicit knowledge, immutable mobiles, textbooks, tools, equipment
know-how	how to apply knowledge in practice	knowledge of how to practice (knowledgeability)	methods, routines, algorithms, manuals, tools, equipment
know-who	knowledge of who knows what; who knows who knows what; transactive memory	knowing how to work with others	organization charts, resumes, group membership, email lists, listservs, offices, organizations
know-when*	knowledge of temporal sequences, processes	knowing how to time the application of knowledge, knowing how to sequence practice	procedures, routines, chain of command, logic sequences, assembly lines
know-where*	knowledge of place and space	knowing where to apply knowledge	offices, conferences, meetings, communities, online meeting places

* Know-what, know-how, and know-who are all present in the literature on knowledge. In keeping with the knowledge-based asset specificities given above, it seems logical to add to this know-when and know-where. However, as for the specificities, it is not the listing of the many types of things a person could know that are important here, but instead the way knowledge – of any type – is brought into practice, and how technologies results from practice.