Epistemic Machineries of Environmental Online Communication

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Abstract. *This chapter attempts to understand some of the social and organization problems that confront online environmental communication in two areas: credibility of content, and the design and management of multidisciplinary systems. The approach is to see both these areas as knowledge work, where trust and credibility are critical. Using the perspective of science studies, emphasizing the situated nature of knowledge, the importance of practice, and differences across epistemic cultures, we suggest that it is useful to see some of the stresses faced in online environmental systems as resulting from the opening of black boxes and questioning of practices and assumptions that come from crossing boundaries. In the end, crossing boundaries requires a willingness to endure and work through the discomfort of meeting different knowledges, and not knowing.*

1 Introduction

Environmental understanding relies heavily on data of many kinds from many sources. Understanding the complexities of environmental conditions over time often requires combining, collating, analyzing, comparing data of many kinds form many sources. Data from unexpected or unusual sources is particularly valuable in environmental work. Old data may provide needed baseline information; amateur observers may provide detailed on-the-ground information. Interviewing people engaged in water planning in California, we found a persistent suspicion – or hope – that somewhere (in someone's bottom drawer) was exactly the data needed; that sometime in the past, for example, someone would have done an environmental assessment that could now serve as baseline data on conditions before some human intervention.

The purpose of environmental online communication is to make more available and more combinable a variety of useful information: raw data, analyses, models, projections, and so forth; in the words of the call for papers for this volume, "replacing compartmentalized knowledge with systems thinking to better manager increasing complexity, uncertainty, risk." Online communication makes it easier ever to collect and combine information generated over time in multiple places, rooted in a variety of disciplines and understandings, for differing purposes, using varied methods and formats.

There are, of course, problems. Some are technical. Other, serious problems have to do with metadata and how the world is conceptualized and described (Bowker, 2000). This chapter, however, is an attempt to understand the social and organizational problems that confront online environmental information systems in two areas in particular, which, we will demonstrate, are closely related. The first is issues of credibility and trust in the content of online environmental information systems. Potential users are concerned about the quality of content. The second is disputes about the design and management of such systems, including the many decisions that have to be made about content, functionality, policy, and operations.

This chapter is rooted in the understanding of science studies (e.g., Hess , 1997) that knowledge work is situated, distributed, and social (Van House, 2003). In online environmental communication, knowledge work is of two kinds: the work of creating and using information, including data collection, representation, and analysis; and creating and maintaining online data and systems, including databases, environmental web systems, and electronic communication channels and portals of various sorts.

It is our contention that some of the problems that we have observed in these two areas, which are often seen as local problems, signal *systemic* stresses that are, not only likely, but perhaps inevitable. We suspect that local attempts to reduce conflicts and resolve problems are likely to succeed, at best, temporarily. Furthermore, the very existence of such tensions can be self-perpetuating; that is, participants may become suspicious of others who seem not to share their understandings, and wonder whether cooperation is possible or desirable. We argue that understanding that these kinds of stresses are common and more systemic than idiosyncratic can be reassuring to participants, if they see that their local difficulties are due, not to local failures and individual differences, but to the nature of boundary-crossing knowledge work. Furthermore, a better understanding of knowledge work and of boundary crossings can help participants plan for and accommodate these stresses in any given situation.

This discussion is rooted in both empirical and analytical work. The empirical work, reported elsewhere , consists of interviews and observations in two areas of environmental work: water planning in the state of (Schiff, Van House, & Butler, 1997; Van House, 1995a; Van House, 1995b; Van House, Butler, & Schiff, 1998), and the design of a system to collect and collate California botanical observations, largely from dozens of pre-existing databases (Van House, 2002a; Van House, 2002b; Van House, 2003). The analytical basis is an approach to knowledge work rooted largely in science studies and science and technology studies (Van House, 2004), and investigations of trust and credibility in a variety of disciplines. This paper is not about California environmental information *per se*, but uses our empirical work to illuminate and illustrate our analysis of environmental work as knowledge work.

2 Empirical findings

The empirical basis of this paper comes from two related projects that we observed and participated in to varying degrees. The UC Berkeley Digital Library Project (ELIB) has been funded since 1995 by the National Science Foundation as a research project. It has consisted of a mix of computer and information science research, and the construction and maintenance of a testbed of documents, images, databases, and geographical layers. Its earliest content was primarily non-copyrighted reports and data about with the California environment, much of it government documents. Currently this project is aimed at re-inventing scholarly dissemination and use. The testbed continues to incorporate most of the earlier content, though the focus is somewhat different. Our interviews were early in the initial project, with potential environmental users, representatives of state, federal, and local agencies and non-profit organizations engaged in water planning.

Our more recent work addressed CalFlora (http://calflora.org), a project that began in collaboration with ELIB. Calflora is now an independent organization dedicated to providing scientific information about California plants for research, conservation, and education, funded by government agencies, foundations grants, and private donors.[1] CalFlora consists of a Species Database with geographic distribution, habitat, and lifeform data for the approximately 7,600 vascular plants native or naturalized in California, based on published literature and documented observations; and an Occurrence Database of over 800,000 observations of plants within California, from dozens of public agencies, herbaria, private organizations, and individuals. Calflora also collaborates with the UC Berkeley Digital Library Research Project on CalPhotos, a database of more than 29,000 photos of California plants. All these databases are interlinked with one another and a nomenclature database. CalFlora's participants include contributors and users of botanical data, representing state, federal, and local agencies, nonprofits, and individuals.

Systems like ELIB and CalFlora, commonly called Digital Libraries, consist of content, technology, and functionality. In contrast to traditional libraries, Digital Libraries of this kind, consisting largely of information that is not formally published, lack the institutional context of libraries and the publishing system. The publishing system provides both a form of quality control and a context for understanding information: an article in a scholarly journal is understood differently from one in a tabloid newspaper. Libraries such as university libraries perform a review and quality control function. If the Library of the University of California, Berkeley, includes a book in its collection, one can assume that an expert selector has made a decision that this title is appropriate for a major research library and is not, for example, the self-published rantings of an uninformed individual.

[1] This description and what follows is based on CalFlora at its most extensive. Budget uncertainties have caused CalFora to reduce its services, at least temporarily.

Digital Libraries generally include not only content but various kinds of functionality (Lynch, 2003). Calflora, for example, allows users to download the data for their own analyses, or to search the databases, and display the results in a variety of ways. It also maps observations at two different levels. Static maps present plant occurrence data at the county level. Dynamic, real-time mapping allows a user to specify a set of observations and map them at the level of resolution of each record. ELIB includes a GIS function that allows users to manipulate data layers, resolution, and a variety of other features.

The following section summarizes some of the problems, concerns, and stresses that we observed. Then we presents an analytical basis for understanding these findings. The final section presents conclusions and suggestions.

2.1 Concerns about data sharing

In our observations and interviews with people engaged in environmental work, my colleagues and I found both enthusiasm and concern about environmental online communication. The enthusiasm was about the ability to readily share data, analyses, and interpretations. Many participants, such as people from nonprofit environmental organizations, were also enthusiastic about the uses of online communication to disseminate their previously-unpublished analyses and recommendations.

The concerns about data sharing can be classified into two general areas: the concerns of information users, and those of information owners or providers. More details can be found in (Schiff, Van House, & Butler, 1997; Van House, 1995a; Van House, 2002a; Van House, 2002b; Van House, 2003; Van House, 1995b; Van House, Butler, & Schiff, 1998).

2.1.1. Information users: quality of information

Information users were concerned about the quality of information. "Quality" is a complex concept. One common concern was about the methods by which data were collected and analyzed; different disciplines have different methods, and users were concerned about whether the appropriate methods, by their standards, had been followed. Another concern was about the expertise of the data contributors. For example, within the botanical community we heard questions about observers' abilities to accurately identify taxa. Herbarium records are generally backed by specimens; field observations, however, depend on the observer's ability to identify specimens.

Information users are not only concerned about the accuracy of data and the observer's skill. They are also concerned about how the interests and biases of the information providers may shape, not only interpretations and analyses, but the data themselves. Environmental information is often highly valuable, contested, and political. We found that representatives of environmental non-profit organizations, for example, were suspicious of data from resources extraction industries. Some were equally suspicious of data from government agencies whom they saw as seeking to promote certain projects or under political pressure let certain large developers' project through the review process.

Most respondents reported some version of "I know everyone who is important in this field; if I don't know them, I doubt their data." One respondent took us through her criteria for plant identifications. A record of a sighting is less credible than a specimen. A report of a taxon in an unexpected place is less plausible than in a place where it is common. She knows some individuals or classes of people (e.g., park rangers) as experts in geographical areas; she'll trust their identification of taxa common to their area, but not necessarily of rare ones. Others are experts on a taxon, on which she'll trust them wherever it may occur.

CalPhotos has long accepted photos (with photographer-supplied metadata) from individuals, including amateur botanists, and CalFlora recently began[2] accepting botanical observation reports from individuals. Decisions had to be made about how to provide descriptive information about the observer that would allow users to assess for themselves the observer's ability to identify plants. As one person said, "You can't just ask people how competent they are." After extensive debate, CalFlora developed a form describing the observer that is linked to each of their

[2] Need to check current status; has probably been suspended due to budget.

contributions. The committee that developed this found that identifying professionals and people with no particular qualifications was not hard; the problem was "expert amateurs," people with (often considerable) expertise but no professional qualifications or training or institutional affiliation.

2.1.2. Information providers

Information owners also reported a variety of concerns. One was the burden of making their data usable by others: the work involved, and the lack of institutional resources and rewards for doing so. Others were concerned about people using out of date information. Some databases are dynamic; any snapshot of the database is soon outdated. But even owners of "static" databases reported that they updated their databases as errors were discovered and corrected. They were concerned that anyone who downloaded data from their database would soon be working with outdated information.

Information owners were often concerned about the possibility of information being misunderstood or misused. For example, government agency representatives responsible for water forecasts were concerned that their critics, unfamiliar the possible errors in water supply data and the ways in which errors were corrected, would use the supply data to dispute their forecasts. Some members of the botanical community feared that identification and location information about endangered taxa could promote their destruction rather than preservation. A common solution to this problem is to provide imprecise location information for field observations. However, some CalFlora participants were afraid that even photos of endangered species would provide useful information for, for example, people who wished to avoid the legal limits that result from having endangered specimens found on their property.

Both information users and providers, then, were concerned about the information and, by extension, the expertise, interests, biases, and values of the other parties to an information transaction. Information users were concerned about the credibility of information and therefore of its sources, personal and institutional. Information owners were concerned about possible misuse or misunderstanding of their information, and therefore, again about the expertise, interests, and values of information users.

2.2 Tensions in system creation and management

Another area of stress uncovered in our empirical work had to do with creating and maintaining information *systems*. Many online systems are the result of collaborative work by people from a variety of disciplines, with different understandings, interests, and goals. One common problem for digital libraries and other electronic information systems is that funding is often available for research, not for operating systems. The result is often that funders and designers are interested in innovative, unproven technology, while the users are looking for stable, workable systems (Weedman, 1998)

In earlier work (Van House, 2003), we found that Actor-Network Theory (ANT) (see., e.g., Law, 2001) was useful in understanding our systems as sociotechnical systems that required a confluence of interests among various participating groups. ANT is concerned with the enrollment of allies by the translation of interests: when diverse groups see their different interests as served by a common solution, they agree to cooperate. These disparate interests are continually tending to pull apart, so the stabilization of the shared solution is always temporary.

The creation of an online environmental system requires a large number of decisions of varying levels of detail about its vision and purpose, policies, funding, content, presentation, functionality, and operation. It requires a considerable amount of technical work. But a system like CalFlora, with multiple contributors of data and funding, requires continual work to cultivate, coordinate, and accommodate the needs and priorities of participants and contributors. As CalFlora's key staff members wrote:

> "...a successful strategy must give adequate attention to the sociological aspects of data sharing--the strong forces that legitimately lead institutions with large data holdings to face inward rather than outward, and the legitimate reservations individual data owners have towards anonymous data sharing. Our

> experience suggests that it is unrealistic to expect institutions to put scarce resources into sharing or standardizing data to conform to external needs or standards. It is also unrealistic to expect institutional owners to be aware of other possible uses of data developed for particular internal purposes, or to readily embrace an ethic of open data access" (Dennis & Morosco, 2000).

Much of this work is invisible. Star and Strauss (1999) write about "articulation work", the often-invisible work needed to keep things on track. Just one example of articulation work in environmental online systems: periodically users email CalPhotos with corrected plant identifications. Many of the photos were contributed by photographers whose plant identification skills are not perfect. Who (if anyone) reviews the photos and suggested corrections and decides whether the proposed identification is correct? Bowker and Star (1999) demonstrate that infrastructure disappears when it works; similarly, much of the work of creating and maintaining online systems is only apparent when it fails.

3 Resources for addressing these problems

Although these may seem like different classes of problems -- those related to the data, and those related to the creation and management of online systems – they have some fundamental commonalities rooted in the nature of knowledge work, and specifically in this work as crossing boundaries.

3.1 Trust

Collaborative work of any kind requires trust. Trust enters into the success of online environmental systems in two ways: not only must the participants in the creation of the system be able to work cooperatively, but the information creators and users must trust one another.

3.1.1. Trust and knowledge work

IT is enmeshed in knowledge work. First, IT supports knowledge work. We contend that this is a two-way relationship: IT needs to be designed to support knowledge work, and knowledge work changes to adapt to and take advantage of the capabilities of IT. Secondly, the design and operation of information systems is itself a form of knowledge work.

Trust relationships are a major part of knowledge work. Most of what we know we learn from others. Accepting others' work as a resource for our own is, among other things, efficient.

Networked information is increasing the importance of trust and credibility and undermining pre-existing practices of assessing and demonstrating trustworthiness. People are increasingly faced with assessing information that has not been filtered by a publishing system, divorced from the context that makes it understandable, and from unknown sources. Who are these information sources and what do they know? Are they who the purport to be? Are there any monitoring mechanisms to tell information providers or potential users when information is of poor quality? Are there penalties for misrepresentation? These judgments are not, in themselves, new. What is different is that information technology and networked information are making them more prevalent, and changing the means by which they are made and the evidence available.

Designing IT to support collective knowledge work requires an understanding of both pre-existing practices and criteria of trustability, and their translation into a networked world. How do individuals and groups evaluate knowledge claims? How do they determine whom they trust? What is trust in this context? What is its role in knowledge work? How does the group communicate to its members what is known and who is deemed to be trustworthy? How does the individual evaluate the group's decisions?

System designers are not the only ones to determine how technology will support trust relationships: system users adapt on-going practices and develop new ones to use the available technology to address their needs to assess and to demonstrate trustworthiness.

Trust is necessary for what Giddens (1990)calls time-space distanciation, which is a characteristic of contemporary society, the replacement of face-to-face, personal interactions with impersonal systems Luhmann (1979) calls modern trusting "system trust" -- trust without familiarity. Giddens agrees but argues that face-to-face relations remain important. He proposes that face-to-face relations and expert systems come together at what he calls "access points,'" the people who are our contacts with expert systems, such as doctors. Shapin (1994)ends his study of seventeenth century English experimental science and its practices of authority and trust with a reflection on contemporary science and concludes that "trust in known persons" (p. 415) remains a key element in scientific and other forms of knowledge. He notes, for example, the importance of conferences and informal interaction among colleagues working in the same research area.

3.1.2. Approaches to trust

A variety of disciplines are concerned with how people demonstrate their own trustworthiness and credibility and assess others'. One approach, common in economics and political science, typified by the papers in Gambetta (1988), focuses on division of labor, contracts, and exchanges. Much of the current discussion of trust in philosophy and social theory is concerned with the role of trust in the workings of society. Trust is often seen as either a determinant of or an outcome of social capital (Fukuyama , 1995) (Putnam , 2000) which stabilizes communities, exerts control, and induces cohesion without overt rules and enforcement mechanisms.

The collective nature of knowledge foregrounds a third type of trust, which has been called epistemological trust (Davenport & Cronin, 2000)or the granting of epistemic authority (Goldman , 1999)or cognitive authority (Wilson , 1983). While deception may be a problem, probably the more common problems are (unstated) bias and (in)competence or (lack of) capability, or authority in the source. For example, in our earlier work in environmental planning, we found that participants doubted information from those with whom they held conflicting goals and values. Environmental organizations distrusted information from resource extraction industries, and sometimes both distrusted data from government agencies.

Credibility or capability are particularly difficult to evaluate when we must rely on people with expertise other than our own, as in Giddens' expert systems. Competence is relative: we recognize degrees and spheres of competence (Wilson, 1983). The assessment of cognitive authority is often a two-stage decision: is the person capable, and is the domain relevant? For example, I may trust that a person is an expert astrologer, but may not accept astrology as an appropriate basis for my decisions. The point is that we are concerned with whether the source of information or knowledge is someone we can rely upon, someone whose information we are willing to accept and incorporate into our own work or decision-making.

Capability, however, is a potential. Good work is a combination of knowledge, capability, and propensity to appropriate behavior. This kind of trustworthiness relies on what Aristotle called ethos, consisting of competence, character, and goodwill (Constantinides & Swenson, 2000). People may differ in how much effort they exert, or how responsible they are about doing the best that they can under given circumstances. Some have called this "character" (Ben-Ner & Putterman, 2001) or "virtue" (Constantinides & Swenson, 2000). This may include a concern for others' welfare, respect for process for adherence to rules or principles, and reliability or responsibility. Mechanic and Meyers' findings regarding patient trust of physicians may also indicate that patients believe that a physician who is attentive and caring is going to take the situation seriously and make her best effort.

3.1.3. Conditions of Trust

A central question in the various literatures about trust is the conditions that promote (or undermine) it, and the processes and criteria by which people judge one another. One major shortcoming with most of this literature, for

our purposes, is that it is generally about one-to-one trusting relationships, not communities or "networks of trust" (Baier, 1986).

Among the relevant factors are the characteristics and history of the truster. A propensity to trust may be based on past experience, innate trustingness, or values: some place value on being trusting. Some might say that trustingness is a function of gullibility or a lack of critical capacity. Trust and distrust are often self-confirming (Jones, 2000). One who has found her trust justified in the past is more likely to trust in the future. A distrusting person is less likely to take the kind of risk that would disconfirm her expectations.

The characteristics of the trustee are also important, including various personal characteristics from which trustees may make inferences about that person's trustworthiness; the person's experience or expertise; and reputation, which is presumably based on others' experience with the trustee. Professional and other kinds of credentials and institutional affiliation are taken as indications of institutional approval.

Another characteristic of the trustee that is sometimes addressed is interests or motives, perceived or inferred (Nissenbaum, 2001). Since trust is about future behavior, past experience is an imperfect indicator; motives may be more reliable determinants of future behavior. Doubts about another's motives can undermine trust even when there is no evidence to support distrust, such as our findings about people in environmental organizations sometimes distrusting state agency personnel.

The relationship between the two parties is also relevant. Prior interaction will contribute to the trustor's knowledge about trustee and their history of mutual trustworthiness. The stage of the relationship may also be significant, as trust often builds over time, with repeated interaction. Tomkins (2001) hypothesizes an inverted U relationship between information and trust over time. Early on, people (and organizations) don't need much information about one another because not much is at stake. As the relationship gets more interdependent, people need more information about one another. In time, however, the relationship is more stable and sustainable and added information is not needed.

Empirical research shows that face to face interaction generally improves trust (Riva, 2002); people often believe that they are better able to judge people whom they meet face to face. Ekman's (1985) research on the role of face, posture, and voice in revealing deception indicates that there is considerable truth to this.

Another key element in the relationship between the trusting parties is similarity or shared culture. Shared culture may provides culturally-specific clues concerning trustworthiness (Fukuyama, 1995.)It increases the chances of the parties sharing important values. In earlier research, we found that the perception of shared motives and values affected how people engaged in environmental planning evaluated others' information (Van House, 2002a; Van House, 2002b). Shared culture also can provide a basis for solutions to newly-emerging problems of credibility and trust. Shapin's (1994) impressive study of trust in the development of seventeenth century English experimental science demonstrates that the newly emerging field adopted preexisting gentlemanly practices to solve the problems of credibility and trust.

Shared culture and social networks have an added practical effect: people who expect to have future interactions, or who expect the information about current behavior to be available to future partners via a their social network, have incentives to be trustworthy (Ben-Ner & Putterman, 2001).

A final set of influences has to do with the larger social context. Groups and societies tend to differ in their trustingness and whom they trust (e.g., family members versus others) (Fukuyama, 1995).

In sum, members of the same community or social network are likely to have a greater propensity to trust one another. They will have knowledge about one another through their own experience and others'. Expectations of future interaction, between the same parties or with other members of the group who will know about past interactions within the group, create an incentive to behave in trustworthy ways. Shared culture, values, interests, propensities, language, and practices will increase the likelihood that each will behave in ways that the other will find acceptable, and that participants will be better able to (or believe that they are better able to) interpret clues about others' behavior, interests, motives, values.

3.1.4. Trust and Electronic Information

Discussions about trust and the Internet most often address contract-like arrangements, e-business, system security, or deception in interpersonal interactions (Donath, 2000); Friedman, Kahn, Jr., & Howe, 2000) (Olson & Olson, 2000b) (Schneider, 1999). In contrast, underlying many of the stresses we described above is epistemological trust. Research in human-computer interaction (HCI), computer-supported cooperative work (CSCW), and computer-mediated communication (CMC) offers some useful insight into the factors that promote or undermineepistemic trust in a networked world.

The literature on the credibility of Web resources asks to what extent people use questionable information from the Web, and describes evaluative criteria for web sources, both descriptive and normative. While experts stress the importance of the credentials of the information source or sponsor, Fogg and his colleagues (2002) found that non-experts paid far more attention to the superficial aspects of a site, such as design, than to its content or the credentials of its sponsors.

However, many users of networked information do pay attention to the capabilities and potential biases of the information provider. Networking may make it easier to collect information about others. Transactions and reputation may be more visible, such as through reputation mechanisms at sites like eBay and ePinions. It may be easier to link behavior across time and place with an identity - e.g., some CalFlora participants reported that participants reported that reviewing all the observations contributed by one person helps them to judge that person's experience and expertise (Van House, 2002b).

One major problem with networking, however, is identity: we may not know who the other person is, or whether we are being deceived about their identity. Identities may not be linked to offline identity, history, reputation, and accountability, or to other online contexts. People can change their identities, or multiple people may share one identity.[i] Sites like eBay try to regulate the frequency with which people change identity and to link online and offline identity behind the scenes (which is common when money is at stake).

Information may not even have an author or source; if there is no author, who is accountable (Nissenbaum, 2001)? Who is responsible for keeping information up to date?

Among the factors found to promote trust computer-mediated communication are continual and frequent interaction (Iacono & Weisband, 1997), informal and face to face interaction and richer communication channels (Olson & Olson, 2000a) which provide more information, cognitive and affective, and cultural and personal cues. Olson and Olson (2000) describe the value of what they term common ground: knowledge that participants have in common, and shared experience and norms. This is based in part on general knowledge about the person, and in part on specific knowledge gained from interaction.

In computer mediated communication, participants may use discourse and rhetoric to establish legitimacy and authority. In a study of online self-help groups and hobby groups, Galegher et al. (1998) found that some such strategies were unique to CMC, some not. They noted that personal experience, while weak evidence in other areas, was strong in self-help groups.

4 Social Construction of Knowledge

The concept of social construction of knowledge goes beyond saying that we rely on others to save us the effort of investigation. It contends that the community plays a critical role in determining what we take to be true, and how we develop knowledge. Constructivist approaches contend that most knowledge claims are underdetermined, that is, most of our observations of the world are open to multiple interpretations. What we believe to be true and whom we believe are not determined (solely) by nature or reality, but by our interactions with others.

This approach insists that there is no "view from nowhere" – knowledge is always situated in a place, time, conditions, practices, and understandings. There is no single knowledge, but multiple knowledges. Nor does knowing take place in the head of the individual but in interaction with others and with the world. Epistemic subjects are not (just) individuals but collectives – social worlds, communities of practice, work groups, and the like.

This stress on the local, accomplished nature of knowledge give an important place to practice. Practice theory (Pickering; 1992;)Schatzki, Knorr Cetina, and Savigny, 2001)emphasizes the role of people's actual, daily, embodied activity, often including skills, tacit knowledge, and presuppositions, as well as their interaction with others and with the material and other resources, in the construction of social order and knowledge. Practice is generally understood to belong to specific "fields of practice" (Schatzki, 2001); practice differs according to conditions.

Science studies emphasizes science as practice, not simply as knowing -- the practice and materiality of scientific work and the production of scientific knowledge. Science is doing, intervening; it is performative. This extends to other domains of knowledge. "Knowledge...does not stand outside of practical activity: it is made and sustained through situated practical activity" (Shapin, 1994, p. xix). Similarly, Knorr Cetina (1999)emphasizes "the acts of making knowledge" (p. 9), including how participants generate and negotiate outcomes.

Artifacts, tools, and technologies contribute to the practical accomplishment of work and of knowledge. Among the artifacts of knowledge work are representations of various kinds, include images, graphics, and all kinds of documents and texts, and also metadata. Texts are both products and resources in knowledge work. The constructivist approach to science inverts the connection between object and representation: representation creates rather that reflects the world (Lynch, Michael and Woolgar, Steve , 1990)**.** Social practices and representations are construed as actively constituting the objects in the world. The work of representation gets "deleted" (Star, 1995), which makes invisible the choices that are made and by whom, and what gets left out. Questions of agency permeate practices of representation: :who represents whom or what? What counts as subject, and what as object?

Critically important in the social construction of knowledge and practiced-based approaches is the community. Lave and Wenger (Lave & Wenger , 1991) (Wenger, 2000; Wenger , 1998) developed the influential notion of "community of practice," which emphasizes the mutuality of community, knowledge, activity, and social practice. Learning is not located in the mind of the individual, but in the relations among practitioners, practice, artifacts, and the social organization of communities of practice. Communities of practice imply "participation in an activity system about which participants share understandings concerning what they are doing and what that means in their lives and for their communities...A community of practice is an intrinsic condition for the existence of knowledge, not least because it provides the interpretive support necessary for making sense of its heritage. Thus, participation in the cultural practice in which any knowledge exists is an epistemological principle of learning' (Lave and Wenger, 1991, p. 98).

People learn to construct and interpret representations in the course of becoming members of communities of practice (Lave & Wenger, 1991); (Goodwin, 1994). Practice and representations are constitutive elements of communities of practice. Becoming a member of a community of practice is, in Lave and Wenger's formulation, not acquiring knowledge and skill but a change of identity.

A key element of communities of practice is what Lave and Wenger call Legitimate Peripheral Participation. Newcomers master the knowledge and skill required and become full members by participation. They observe and work with masters; they see and hear how the work is done; they take on, not just the skills, but the understandings and values of the community. LPP dissolves dichotomies between cognitive and embodied, abstraction and experience, learning and being.

A related approach to understanding knowledge and its relationship to practice, artifacts, and communities is Knorr Cetina's (1999) notion of epistemic cultures, "those amalgams of arrangements and mechanisms – bonded through affinity, necessity, and historical coincidence – which, in a given field, make up how we know what we know. Epistemic cultures are cultures that create and warrant knowledge" (p. 1; emphasis in original).

Culture, as Knorr Cetina uses it here, incorporates elements of practice, history, and meaning. Knorr Cetina is interested, not in the content of knowledge, but in "the machineries of knowing composed of practices" (p. 10), the "smear of technical, social, and symbolic dimensions of intricate expert systems" (p. 3). These knowledge machineries, "conjunctions of contentions and devices that are organized, dynamic, thought about (at least partially), but not governed by single actors" (p. 11) are both technical (e.g., scientific instruments) and social (e.g., how decisions are made).

Epistemic machineries are constitutive, not only of knowledge, but of the knowers. She presents the scientists as "enfolded in" these machineries, conventions, devices, practices. To become a scientist is to be shaped by, to fit into, to see the world in terms of, these practices, understandings, and organizations.

In high energy physics, she argues, the epistemic subject, the knower, is the collective, the experiment. She describes this field as having what she calls post-traditional communitarian structures: "attempting to implement collective ways of working that downgrade the individual as an epistemic subject and emphasize instead such communitarian mechanisms as collective ownership and 'free' circulation of work." (P. 165)

A critical part of her argument is that epistemic cultures and machineries are diverse, not just between science and non-science, but even within science. In her book she demonstrates similarities but also differences between the two lab sciences of high energy physics, where work is highly collective, and molecular biology, which she describes as being largely individual, even within labs full of people.

However, science has long required the sharing of information and work across not only individuals but fields. Elsewhere (Van House, 2003) we have considered Digital Libraries as what (Star, 1989); Star & Griesmer, 1989) has labeled "boundary objects. Scientific work has always required information that can be used by multiple users and communities for a variety of purposes, retaining its integrity across space, time, and local contingencies without losing its specific meaning in a local setting. They describe boundary objects as both plastic enough to adapt to local needs and have different specific identities in different communities, and robust enough to maintain a common identity across sites, and be a locus of shared work. They identify several types of boundary objects. one is repositories, "ordered piles of objects indexed in standardized fashion" (Star and Greisemer, 1989, p. 408). Their example is the University of California, Berkeley, Museum of Vertebrate Zoology (MVZ), a collection of specimens of amphibians, birds, mammals, and reptiles, with extensive, standardized metadata – whose records are now part of ELIB.

4.1 Trust and Epistemic Communities

Putting this all together, we can paint a picture of epistemic communities held together by understandings and values, shared practices of doing their work, common artifacts and uses and understandings of them, and ways of describing the world. People learn how to do the work, what's considered good work, and who is considered to be a capable practitioner by watching, listening, and doing. Learning requires participation, doing the work and interacting with other practitioners. Differences across epistemic communities means that, at best, people will be uncertain about the capabilities, interests, values, and goals of people from outside their group.

From the discussions of trust from other fields, we can conclude that people who know that they share, not only practices, but values, interests, meanings, understanding, and friends and colleagues are more likely to not only trust one another, but to feel confident in their ability to assess one another's capabilities. Ways of understanding the world, as well as their methods of work, are shared within epistemic communities and differ across them.

Collaborating across epistemic cultures throws into question taken-for-granted practices, understandings – even language. The uncertainties and stresses of online communication can be seen as attempts at cross-cultural communication and cooperation – no wonder difficulties arise.

5 Analysis and implications

On online information system is the locus of shared work. It is also the place where multiple epistemic communities have to reconcile their different approaches to work and knowledge. Building and maintaining a system may involve a variety of groups who contribute content, do the work of design and operation, use it, and fund it. The content supports the shared work of information providers and users, in this case, environmental work. The power of an online information system is in the integration of its heterogeneous elements, its flexibility, and its usefulness to multiple professional communities. But this same flexibility and ease of communication may destabilize the

processes and standards of knowledge creation by mixing participants and information from multiple epistemic cultures with differing goals, practices, values, and understandings.

Trust is necessary in shared work of all kinds. Epistemic trust is necessary for knowledge work. Trust as a basis for social order applies here, too, as mutual trust makes it easier for diverse groups with different understandings and needs to be willing to coordinate their work. Within epistemic communities, shared practices, artifacts, values, and taken-for-granted understandings contribute to rust and efficiency. If we can accept the work of others unquestioningly, or at least feel confident in our ability to evaluate their work and understand the uses and limits of their data, we don't need to invest our time and effort in examining or duplicating their work. Within epistemic communities, social networks often provide both information about members, and incentives for people to do their best work, knowing that their reputations will be affected. A combination of systemic and interpersonal factors both facilitate people's evaluation of one another, and provide a level of quality assurance

Networked information – and the creation of networked systems – facilitates, even requires, the crossings of social and technical boundaries and of epistemic cultures Crossing these boundaries may call into question that which is taken for granted within communities, opening black boxes, and challenging the established cognitive order. Shared practices and understandings can no longer be assumed; the indicators of credibility may be questioned or missing; inscriptions and data may be used in ways not envisioned (or accepted) by their creators. Methods and practices that are unquestioned within some groups are scrutinized and sometimes found wanting by others. Online information systems potentially destabilize the processes and the hierarchies of credibility and power relations.

The argument here is that the networking of digital information has made these epistemic machineries more visible, in part by instantiating them in system design, and in part by facilitating the flow of information, including previously closely-held data, among epistemic cultures. It has also made them more unstable, as clashing epistemic machineries make business-as-usual no longer possible, creating new problems of credibility and competence, and making more visible the negotiations by which knowledge groups grapple with these problems. (For example, when different disciplines had different standards of quality control for data, the ELIB technical staff had to decide what they were going to do at the system level.)

Online systems may have opened some black boxes by opening to examination assumptions and methods that are unquestioned within epistemic communities. Some, however, close other black boxes. Some online environmental systems offer analytical and search tools that are opaque to the user, requiring users to trust the system and therefore its designers. Knowledgeable uses may be frustrated when they find it difficult to understand, evaluate, and trust what the system is doing. Other, more naive users may unknowingly accept inappropriate decisions that the system makes on their behalf. For example, GIS software often chooses among the many analysis options for polygon overlay and chooses a method for the user (Chrisman, 2003). Different methods give slightly different results; the user may never even know which method was used, and the implications for her findings.

Innovations in networking and information technology also enable new practices, representations, and functionality. Innovations in technology and practices are, at least in their initial versions, often based on pre-existing practices. For example, Bijker (1995a) includes a picture of an early bicycle that looks like a horse, complete with artificial horsehead and saddle. But information technology may change the social and material bases of knowledge work, not simply convert pre-existing methods to electronic. The boundary crossings enabled by online communication can raise conflicts about which pre-existing practices will govern. For example, in combining data from a variety of sources, CalFlora has had to reconcile differing policies that originate in the different goals of the participating systems. One source of prolonged negotiation was the choice of the appropriate level of quality control on submissions. One stakeholder organization is a state agency whose regulatory function requires a high level of confidence in the data. In their own system, observations are entered only after review, resulting in a backlog. Other stakeholders prefer a less-certain but more extensive database; for them, erroneous observations are a small price to pay for comprehensiveness.

Seeing online environmental communication as crossing epistemic cultures and mixing epistemic machineries has implications for understanding and operating these and similar systems, and for research.

First, it cautions us to be sensitive to the variety of communities' existing practices of knowledge creation and work and indicators of credibility. A successful information system has to fit with these practices. In particular, the system

has to articulate with participants' hierarchies of credibility and processes of establishing trustability for people to be willing to use and contribute to it. And these vary across communities of practice.

Second, the work of translation is on-going, and difficult. The problems and tensions identified in these interviews are indicative. A multidisciplinary, inter-organizational information system in an area as complex and frought with conflict and the environment is not likely to settle into an easy equilibrium of interests. We can expect conflicts, compromises, and jockeying for advantage among various stakeholder groups.

These differences can result in deep conflicts. One observed source of tension, for example, was among the academics, government employees, and representatives of non-profit organizations involved in these projects. At times each group had deeply different ideas about how the systems should be designed and used, and what constituted good work and a successful system. There were also differences in how decisions should be made. Some of these differences were at times quite rancorous.

There is currently much discussion within the technical design community about involving users in the design of technology, but how (and whether) it is done varies. This analysis suggests that high-order user involvement in information system design is critical but also extremely sensitive. Only members of the knowledge community fully understand the complexity of their network of practices, tools, and participants, including their processes and criteria of credibility, and how the information system might interact with them. However, the question of who is to be involved, which communities, can become even more uncertain–if both the value and the threat of networked information is its ability to cross the boundaries of communities of practice, which communities are involved and how are their differences reconciled?

Understanding an online information system as a boundary object helps us to see DLs as continuous with past boundary spanning practices in science and other areas; but this doesn't resolve the present tensions.

Online systems need to be evaluated, not just for how well they perform their intended functions and meet targeted users' identified needs, but for their interaction with work, practices, artifacts, and communities. Evaluation needs to be targeted to specific user communities and tasks, with the understanding that such systems have interpretative flexibility (Pinch & Bijker, 1987); (Bijker, 1995a); (Bijker, 1995b): they are different things to different groups. This makes evaluation more complex and uncertain, but also more realistically aligned with users' concerns and with the changing array of users and other stakeholders. Evaluation needs to address, not just service delivery, but also the organizational issues around the creation and maintenance of the system, its stabilization as a heterogeneous network, and the on-going enrollment and coordination of resources and participants.

As for research, an emphasis on culture, on participants' actual, situated practices and understandings, suggests a reliance on ethnographic research methods, the study of activities in their natural settings, of what people actually do as well as their own accounts of their behavior (Van House, Bishop, &Buttenfield, 2003).

Suchman's (2001) reflections on the construction of technological systems are useful here. Also writing from a perspective of multiple knowledges and varied epistemic communities, she reflects on her experiences working across the boundaries between users and designers. Crossing boundaries, she says, means "encountering difference, entering onto territory in which we are unfamiliar and, to some extent, therefore, unqualified" – and uncomfortable (p. 25). Useful system design requires the on-going creation of situations for "the meeting of different partial knowledges" (p. 25)...in "an increasingly dense and differentiated layering of people and activities, each operating within a limited sphere of knowing and acting that includes variously crude or sophisticated conceptualizations of the others" (p. 30). This isn't easy, and it inevitably creates conflicts and misunderstandings across groups. But this is necessary if online environmental communication is to make a difference in environmental work.

In summary, networked information systems are the loci of a web of relations among different epistemic communities, including varied suppliers and users of data, technologists, and others engaged in system design and management, people from various institutional bases, and with differing agendas for the system and for the information that it contains and helps to create. Wherever people are working at the boundaries of knowledge communities we will see differences and disconnects, negotiations and assessments. The boundary crossing work of designing and building systems, populating them with content, and keeping them operational requires work at comfortable boundaries, and the exercise of mutual trust.

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[i] A student told me of a participant in a Russian language chat group who seemed to be online all the time and to speak with different voices at different times – other participants assumed that one identity was being used by several Russian government agents to monitor the discussion.