An EPA spokeswoman said the agency plans to enforce the new standard and wants a third-party group, such as the National Academy of Sciences, to review the refiners' progress in making the equipment changes necessary to meet the standard when it goes into effect in 2006.

Clinton signed off on a series of environmental protections during his final days in office. President Bush's administration has stayed some for review and overturned some. Prohibitions on new hard-rock mining sites and development in 58 million acres of roadless wilderness have been abandoned, along with the arsenic standards and the U.S. commitment to the Kyoto global warming treaty.

In most cases, the administration has said the requirements were too costly for consumers and industry and risked damaging the U.S. economy.

"The Bush administration is running an environmental policy based on economics," said Ethan Siegal, who tracks political events for institutional investors as president of Washington Exchange. "I don't think anybody should be surprised."

Oil groups such as API opposed the diesel rule during two years of hearings and public comment, and API is now is suing to delay it. API's president, Red Cavaney, wrote Whitman on March 1 to say the group is pleased with her decision to have a study.

API says the costs of new engines and refining technology would drive small refiners out of business, causing fuel shortages and price increases.

The oil and gas industry was a major contributor in the 2000 election campaign. The industry gave $32.7 million, a 32 percent increase over the $24.8 million it gave in 1996, according to the Center for Responsive Politics, which tracks campaign finance. Republicans received about 79 percent, and former oil man Bush was the largest recipient, at $1.85 million.

METADATA STANDARDS

6

Trajectories and Enactment in the Life of an Ontology

Florence Millerand and Geoffrey C. Bowker

■ There has been an explosion of scientific data over the past twenty years as more and more sciences deploy remote sensing technologies and data-intensive techniques such as magnetic resonance imaging (MRI). Just as we are increasingly monitoring and surveilling one another, we are increasingly tracking the processes of environmental change on every scale from the cell to the ecosystem. With the development of cyberinfrastructure (or, in its kinder, European coinage, e-science), we are exploring the possibilities of working with data collected in multiple heterogeneous settings and using sophisticated computational techniques to ask questions across these settings. Again, the parallel with our forms of social control is uncanny (see Foucault 1991; Luke 1999). The big questions of the day cannot be answered, it is claimed, without this facility; data from one discipline cannot build a picture of species loss that can inform policy, just as data from one source cannot profile a population in order to discipline it.

We face the question, therefore, of the preservation of, access to, and sharing of scientific data (Arzberger et al. 2004). In the traditional model of scientific research, data are wrapped into a paper that produces a generalizable truth—after which the scaffolding can be kicked away and the timeless truth can stand on its own. There has been relatively little active holding of very long-term data sets and little data reuse. In the current context, to the contrary, there is an emphasis on

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what is oxymoronically called raw data—which can be gathered together, analyzed, visualized, and theorized about to produce new syntheses. This is particularly so for the case of environmental data (Franklin, Bledsoe, and Callahan 1990), for which theories need to range over multiple temporal and spatial scales. It has been traditional in ecology for individuals or small groups to collect data in short-term projects (the length of a funding cycle) over small areas (1 square meter) (Lewontin 2000); this is no longer sufficient to the task (Bowker 2006). Ecosystems change in larger chunks of time (indeed, they follow multiple complex rhythms) and over wider areas of space than was traditionally conceived (O'Neill 2001). Thus, researchers need to be able to use data sets constructed by others and for different purposes; and they need to be able not only to reach some kind of ontological accord between the disciplines (allowing kinds and classifications to be shared) but also to be able to trust data produced by others—the traditional "invisible college" (Crane 1972) becomes a teeming city with multiple linguistic communities.

One of the major challenges for the development of a scientific cyberinfrastructure aiming to foster collaboration and data sharing through information networks is to ensure the frictionless circulation of data across diverse technical platforms, organizational environments, disciplines, and institutions. Or, to use the term of the art, to ensure interoperability. A central problem here is that the storage of, access to, and evaluation of the validity of data are extremely dependent on the ways in which the data have been collected, labeled, and stored. Although it may be possible for two colleagues in a discipline to share information about their data with a simple longhand note, there is unquestionably a need for more documentation in the case of pluridisciplinary teams working across multiple sites and scales. To deal with long-term questions, for example, a given data set may have been collected in one context using a homegrown set of protocols, often deploying outdated instruments and terminologies. The task of making those data available across disciplines and over time is, in general, an unfunded mandate—it requires a special kind of altruism to carefully code your data in ways beyond what you need for their immediate use. It is easy to see, therefore, why assorted technofixes are being discussed, debated, and to some extent deployed to address this problem set.

The resulting standards—most often conceived as being simple technical solutions—are being developed to permit the interconnection of systems and, thence, the free flow of data. The capacity for distributed, collective scientific work practice is posited on the existence of shared information infrastructures and collaborative platforms. These, in turn, require some base of shared standards. Although they are largely ignored and invisible (buried in an infrastructure or wrapped in a black box), these standards nonetheless constitute the necessary base for distributed cognitive work. In order to understand the modalities of collaboration in collective work—scientific and other—we need to understand standards.

In particular, we need to understand the forms and functions of metadata (data about data) standards (Michener et al. 1997).

Here we examine an infrastructure development project for an ecological research community—the U.S. network for long-term ecological research (LTER)—which is endeavoring to standardize its data management through the adoption of a shared metadata standard called the Ecological Metadata Language (EML). This is one of a suite of Extensible Markup Languages (XMLs)—there is Virtual Reality Markup Language (VRML) and even another EML, Educational Modeling Language (EML_2). This standardization process began in 1996, at the level of the LTER network. It crystallized in 2001 with the adoption of the EML standard by the community. It has since been the subject of a controversy that can be characterized as mission successful (by completing the implementation cycle) or success to come (by staying the course).

It is precisely these divergent visions that are the object of this chapter. We do not want to know the success conditions for the implementation of an information management standard in an organization as much as know from what *time* and according to which *point of view* the success or failure of the implementation is judged. We draw on an ethnographic study of the community to explore the alignment of diverse trajectories (Strauss 1993) in standards development. We explore this process as one of the enactment of a standard.

The Development of Information Infrastructures at the Intersection of Social Worlds

As for scientific activity in general, the development of information infrastructures for the sciences requires the cooperation of a heterogeneous set of actors—in this case, domain experts, information technology (IT) specialists, informatics researchers, and funding agencies. There is no linear narrative to be told; "The time of innovations depends on the geometry of the actors, not on the calendar" (Latour 1993, 80). In other words, we cannot track a single life cycle (development, deployment, and death) but must pay attention to the diverse temporalities of the actors. This perspective allows us to better grasp how the existence and even the reality of projects vary over time, in line with the engagement or disengagement of actors in the development of these projects or objects. Thus, although a technical object may exist in prototype form, it can be considered more (or less) real only to the extent that certain groups of actors rally (or do not) to its cause (Latour 1993).

What interests us here is the point of contact between the different trajectories of the human actors as well as the nonhuman actors in the process of standardization at work in the heart of the LTER research community. What happens in this process that leads one group of actors to formulate an alternative history to the success story? Which trajectories interact with one another, and how do they adjust accordingly? How are certain trajectories redefined?

An immediate problem is to know which trajectories to follow (Fujimura 1991; Star 1991; Timmermans 1998) because the choice of following any one, in particular, over another can lead to a different understanding of the social, technical, and organizational configuration of the study. Infrastructure studies are a useful source here because they shine analytical light on rarely studied phenomena—such as the invisible work carried out in the background by actors whose performance is considered so much the better to the extent that it is self-effacing and invisible (Star and Ruhleder 1996; Bowker and Star 1999; Star and Bowker 2002).

We conceptualize the EML standard as a support for the coordination of different social worlds: domain researchers, standards development teams, and information managers concerned with its implementation. EML was defined a priori as a solution to a set of technical problems—a solution from which will issue the one good tool that can be used by all. But this technical standard and its implementation process, in fact, speak directly to the organization of scientific work; it assumes specific configurations of actors, tools, and data. In order to explore this dimension, we deploy here the concept of enactment, developed by Karl Weick (1979). In this tradition, Jane Fountain invites us to distinguish between an objective technology, that is to say, a set of technical, material, and computing components such as the Internet, and an enacted technology, that is to say, the technology on the ground as it is perceived, conceived, and used in practice in a particular context. In this view, the way in which actors enact technical configurations such as standards depends directly on their imbrication in cognitive, social, cultural, and institutional structures. Organizational arrangements (characterized by routines, standards, norms, and politics) mediate the enactment of technologies, which in return contribute to the refashioning of these arrangements.

We propose, therefore, examining enactment in action—to trace two sets of histories of a single process of standardization, by restoring the artifacts, actors, and narratives to the context whence they emerged. This perspective permits a better understanding of the social and organizational dynamics at the heart of projects for the development of large-scale information infrastructures.

The Long-Term Ecological Research Community and the Ecological Metadata Language Standard

The LTER program constitutes a distributed, heterogeneous network of more than 2,300 research scientists and students. Formed in 1980, the network currently consists of twenty-six sites, or research stations (Hobbie et al. 2003). Each is arranged around a particular biome—for example, a hot desert region, a coastal estuary, a temperate pine forest, or an Arctic tundra—in the continental United States and Antarctica. A twenty-seventh site is charged with the administration and coordination of the group. The program mission is to further the understanding of environmental change through interdisciplinary collaboration and long-term research projects.

One of the chief challenges of LTER is to move beyond the plot of traditional ecoscience to analyze change at the scale of a continent and beyond the six-year funding cycle or thirty-year career cycle of the scientist to create baselines of data spanning multiple decades. Although the preservation of data over time, and their storage in conditions appropriate to their present and future use, has always been a priority within the different sites of the LTER network, there has been a new urgency with the development of a cyberinfrastructure projects aiming to encourage data sharing across the community.

Each of the twenty-six sites in the network takes responsibility for the management of research data produced locally; and each in general has its own information system (its own databases). An information manager is charged with the development and maintenance of local infrastructures. Across the network, then, data are stored autonomously by the different sites—a fact that renders the search for and access to data relatively complex and laborious (which, in turn, naturally militates against the network's realizing its mission). Accordingly, a project was put into place in 1996 to initiate a networked information infrastructure permitting the federation of the local databases and, thus, data exchange.

The project has encountered three major challenges: the heterogeneity of the data that circulates through the research community; their wide dispersal; and the multiple systems of coding and storing (Jones et al. 2001). Beyond the diversity of data attached to a given scientific project, there can also be an extreme disparity in their organization and formatting, depending on the collection protocols adopted. For example, data to measure the amount of chlorophyll present in a sample of seawater may be organized into separate files corresponding to the number of trips made, whereas the same measures taken over a year in a given lake may be held in one single file. Further, local cataloguing cultures generally use information (or metadata) that is not necessarily understandable outside a given research project, site, or discipline. Thus, special (personalized) measurement units can be created for the analytic needs of a particular research project (e.g., the ungeneralized unit "number of leaves per change of height in a plant"). In this context, the LTER network office soon saw the need for a set of data standards. Or, to be more precise, the need for standardized methods for the collection of metadata has been taken as the preferred solution for data interoperability.

In an ideal world, the metadata contain all the details necessary for all possible secondary users of a data set (an ideal solution that evokes Baruch Spinoza's problem—to know a single fact about the world, we need to know every fact about the world). These include detailed and diverse information, such as the names of the researchers who collected the data, the title of the project they were working on, the project summary, the key words, the type of biome, the sampling techniques, and the calibration of the measuring tools at the time of data collection. By extension, the possibility of complex analyses drawing on physical, chemical, and biological data within a given geographical area depends on the quality of the metadata. (Let us note at this point that metadata are not necessarily the only possible solution; however, they have been presented—organizationally and intellectually—as central to this community.)

Although they appear to be mere technicalities to some, metadata take on a central importance in the production of scientific theories in the degree to which they condition access to data, guarantee their integrity, and delimit their interpretative uses. When we are dealing with comparative or long-term studies, we find that material conditions change over time and space—instruments might become more accurate, for example, which indicates the need for the precise documentation of their calibration. When combining data across the disciplines, metadata do more than provide a convenient label; they structure the conversation that ensues. To use an analogy with normal language use, there are communities for whom *casualty* means "someone injured or killed" and others for whom it is simply an euphemism for "fatality." Or there are some for whom *democracy* means "rule of the people" and others for whom it is a euphemism for "capitalism." Unless we can calibrate across the communities (and it is often a difficult act of imagination to recognize how local and specific our use is) then we cannot communicate.

The EML, a metadata description language, is precisely a standardized language for the generation of metadata in the specific domain of the sciences of the environment—it is much better to use *sciences* (in the plural) here because each domain has its own configuration of classifications, instruments, dates, and places. EML is the standard that the LTER community has adopted when it is engaged in the process of standardizing its scientific data management practices.

Controversies

The process of standardization that the LTER community is engaged in has two major objectives: the promotion of interdisciplinary collaboration through data sharing and the improvement of long-term data preservation (Hobbie et al. 2003). Although both these objectives and the deployment of EML to their end are generally agreed on, conflicting voices could be heard at the moment of deployment.

Here we examine two narratives, from two categories of actors, that tell radically different tales about the EML standard as successfully implemented or as still a work in progress. The first comes from the developers of the standard, who include the experts who wrote the specifications for EML together with the coordinators of the LTER network. The second presents the point of view of those enacting the standard—that is to say, the information managers whose task it is to implement it at a given site. At the time of this study, the success narrative was carrying the day—it was already formalized, written up in reports, whereas the second one was diffuse and oral. (As, in the context of policy work, in John King's dictum, "some numbers beat no numbers every time," in the context of computer science funding, written beats oral every time.)

With respect to methods, interviews were conducted with both groups of actors, and participant observations were carried on throughout the standard implementation at two of the LTER sites. Detailed document analysis was systematically performed.

Narrative 1: "EML Is a Success: The Entire LTER Community Has Adopted It"

Version 1.0 of EML first saw the light of day in 1997 at the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara, California. It was the product of a researcher in ecological informatics working with two doctoral students. EML responded in the first instance to internal preoccupations within NCEAS, which since its creation in 1995 has been addressing the absence of tools and techniques for analyzing and synthesizing environmental data. A grant was submitted to the National Science Foundation, which funded its development.

Technically, EML is based on two emergent standards (Standard Generalized Markup Language, SGML, and XML) that were, *grosso modo*, developed to turn networked information from simple text fields into searchable, combinable databases. Its content is drawn from the main data description types in use in the domain—such as those recognized by the Ecological Society of America, itself a pioneer in preserving data sets alongside papers. Versions 1.0 to 1.4 cascaded out between 1997 and 1999. They were tested within NCEAS. Given the difficulties encountered in use, a major revision of the language was suggested (would that we could vary natural languages so simply)—and a second grant proposal was written and subsequently funded. The development team went from being three people to a collaboratory (Olson et al. 2001)—a collaborative platform based on voluntary participation and open to the whole community of environmental scientists. This open development model was not immediately successful, even though the team was able to attract some more developers, including—for the first time—a separately but synergistically funded information manager from the LTER. The development of EML went on apace, with several significant structural changes being made. Seventeen versions were produced between 1999 and 2002.

In 2001, the team reckoned that it had produced a stable version of EML (version 1.9, which was accordingly anointed with the title EML 2.0 beta). The team presented its product at the annual conference of LTER information managers, held that year in Madison, Wisconsin. Discussion was lively, but responses were extremely favorable—the information managers recognized the usefulness of such a standard for the LTER community and were moved to formally adopt EML. Version 2.0 was put into circulation; the LTER network scientific community (one of the most important communities in environmental research) adopted the standard. In short, the EML project was a resounding success.

Narrative 2: "EML Is Not (Yet) a Success: It Needs to Be Developed Further Before It Can Be Used"

At the period of the creation of EML in 1997, the LTER network sites already had in place systems for managing their scientific data. Depending on the site, these systems were more or less formalized—that is to say, they did not necessarily use the same standardized vocabularies, even if some of them, broadly speaking, used the data descriptors recognized by the American Society of Ecology—leading to the standard problem of almost compatibility. In 1996, the inauguration of a project to develop a network-wide information system stimulated discussions about standardizing data management procedures and encouraged the development of a common tool set for the information managers of the community. But there was still no central initiative covering the whole network. In 2001, the EML project received a favorable reception from the information managers, who by consensus adopted it. The implementation began.

Although some sites began the work of implementing the standard relatively quickly, most of them ran into significant problems. The standard is complex, and it is difficult to understand in its entirety. The technical tools intended to facilitate the implementation of the standard proved unusable, that is, incompatible with existing local practices and infrastructures. And, in general, there was just a huge amount of work to be done (on top of the normal workload) with minimal resources—some sites had to undertake a complete restructuring of their data management practices.

Numerous ad hoc solutions were brought to bear—for example, homegrown tools that some of the information managers shared among themselves to facilitate the work of the conversion of local systems into the format required by the EML standard.

The information managers organized two workshops devoted to the implementation of EML in 2003 and 2004 in which the developers participated. These led to the production of a synthetic "best practices" document for EML implementation, which had a material impact on implementation at a number of sites. This, in turn, led to a five-step implementation plan formulated conjointly by the information managers and the LTER network coordinators.

At the annual conference of information managers in 2005 in Montreal, progress was seen as somewhat mixed—EML implementation was seen as a complex and laborious process whose outcomes in terms of improvement of data management remained somewhat difficult to identify. EML was not yet a success—it had to be partially refactored to be usable.

Trajectories

On the one hand, then, we have a success story about the EML standard, highlighting its adoption by consensus by the LTER research community. On the other hand, we have a very mixed picture—varying widely from site to site. Whereas the first story moved into the "happily ever after" phase in 2001, the second had barely gotten beyond "once upon a time."

A simplistic reading of these two narratives would say that the measure of success of a standardization process differs as a function of the different phases one is looking at (here, the phases of conception and development of the standard in contrast to that of deployment and implementation). In other words, we could say that the information managers cannot recognize the success of the project yet at this time—they will only be able to see it once the project is finally completed. This evolutionist reading of technology development projects unfolding in an objective time frame does not advance our understanding of what really happens during the periods of emergence, development, maturation, implementation, and so forth. Further, it continues to privilege the second story over the first—considering the success of the standard as being always already assured, with full confirmation coming in the natural course of events. Thus, it favors the invention of the standard over its innovation (Schumpeter 1934), that is, its deployment and enactment (Baker and Millerand 2007).

A temporal analysis of technology development projects should seek, rather, to account for their evolution in terms of the multiple temporalities into which they are integrated. It would then become possible to account, from the point of view of the actors, for the whole set of events—including the more troubled periods when folks do not want to talk about it (e.g., it does not sound good in the next funding application) while others still seek to find a voice (e.g., because they are too low status to be heard, or if they are heard, they are not using a technical language that the developers understand).

Multiple Trajectories

It is striking the degree to which all the actors involved in the standardization process (EML developers, LTER network coordinators, information managers, domain researchers, and so on) have supported—and continue to support—the EML project. As already mentioned, neither metadata nor the EML standard was the only possible solution to ensure data interoperability through the network. Nevertheless, they all believe in the idea of a metadata standard permitting the exchange and sharing of data throughout the LTER network and beyond. In this sense, this is not a case of the imposition of a standard by one group of actors (developers and coordinators) on a hostile, resistant group (information managers or domain researchers). The latter have always been highly supportive of the project, up to including the status of EML implementation in the information management review criteria for the sites (Karasti and Baker 2004; Baker and Karasti 2005). It is at the moment of the actual implementation of the standard at a give site when critical problems emerge and discordant voices can be heard.

The recognition of these difficulties and the controversy that has ensued have contributed to bringing the status of EML as a usable standard into doubt. Two years after its adoption, an inquiry revealed that it had not yet been completely implemented in a single one of the twenty-six network sites and that the tools developed explicitly for this purposes remained largely unused. EML seemed to be a standard in name only.

The juxtaposition of these two narratives reveals the confrontation of two visions of the EML standard. An imaginary dialog, inspired by Bruno Latour's (1993) history of the Aramis project reveals the gulf between the two sets of actors:

> DEVELOPERS: "EML 2.0 exists—the bulk of the work has been done, all we need to do is implement it."
>
> INFORMATION MANAGERS: "All we need to do . . . !? But a metadata standard is just a language. No matter how perfect it is, it exists only if it's being used—if it serves, above all, to integrate data."

In other words, in 2001 the EML standard was a metadata standard without data.

We propose to read these differing perspectives on EML by restoring them to the trajectories of the actors concerned. Thus, from the point of its developers, the EML standard was, above all, one of research and development. The project goal was the creation of a standardized description language for metadata, not its materialization. Its ambition was to make itself the reference standard in environmental sciences. From this perspective, the development of the standard and its adoption by the wider research community of environmental scientists constitute the main success criteria for the project. From the point of view of the information managers, the EML standard represented a set of tools and practices for the better management of scientific data—notably by improving the quality of metadata produced within each of the sites. According to this view, the successful incorporation of this new tool—and the new modes of practice that accompany it—within local sociotechnical infrastructures constitutes the major success criterion for the EML project. Finally, from the point of view of the scientists belonging to the LTER research community, the EML standard is a technical tool that opens the door to multisite research endeavors through a better form of access to and sharing of data and that promises a better diffusion of data beyond the LTER network. From this perspective, the capacity to carry out multidisciplinary projects in very large data sets through a single interface constitutes the main criterion for the success of the project.

Trajectory Alignment

We read the implementation work carried out by the information managers as a process of appropriation (Millerand 1999) of the standard, in the course of which the work of trajectory alignment is done. The appropriation of the EML standard in the different sites worked out, in effect, as the adjustment of the technical tool to local contexts, and the adaptation of preexisting practices to new ways of working. Concretely, this entailed a real work of bricolage from the information managers seeking to incorporate a (generic) standard into a (local) context, which both gave it its purpose and permitted its use.

The trajectory of EML according to the first narrative was born of the main descriptors of ecological data in use in the domain, became a research and development project at NCEAS, and then was adopted as the metadata standard of reference for environmental sciences. It seemed to take a turn or a certain reorientation as it began to circulate in the LTER network. From that moment, the description of the EML project as one of conception, development, deployment, and implementation ceased to work. In the implementation phase, there was redevelopment work, which led to a reconsideration of the conceptual basis of the work, and then some more redevelopment for reimplementation, and so forth. The EML project was changing—the set of trajectories had to be realigned.

What happened then in this implementation phase of the standard that necessitated more and more implementation work? The information managers spontaneously responded that there was a lack of tools permitting the conversion of local metadata systems into the EML format. Equally, they complained that there was a weak understanding of real implementation processes from the network coordinators, who seemed to them to have unrealistic expectations. The problem was that data management practices are not solely dependent on the types of technical infrastructure; they are also, and above all, intimately linked to the nature of the research projects being studied and to the disciplinary and organizational cultures of the sites—in short, to the local structure of scientific work.

The following two interview extracts illustrate, on the one hand, the local and contingent nature of the scientific work being done and, on the other, the complexity of the information managers' task of cataloguing research data.

> I was getting nutrient data, and my units came in as micromoles with the micron symbol and capital M, micromoles. When I started having to go into EML, which does not have that unit, I had to figure out, well, what actually is this unit. And in digging deeper and going to our lab that processed these data I found out it's not micromoles, it's micromoles/liter. And I am not a chemist so it just didn't mean anything to me. You know, I am just organizing and posting this type of data, and so it really opened my eyes that I have a bigger issue here than I thought, you know, because here we've got people reporting things as micromoles, which is not proper. But that is just the way the work is done, and shared, and no one ever questioned it. That's kind of interesting. So I started data set by data set trying to retrofit everything back into, you know, EML. And I have this ongoing list of these custom units that I am compiling, making my best guess at and then I am going either to the actual, you know, my PI or a collaborator that gave me those data, and having to sit down with them to say can you please verify, if you were going to describe this unit

in EML as a custom unit does this make sense. Are you reporting it the proper way. Are you calling this the attribute what it would universally be called, that kind of thing. . . . (IM_L, interview, 2005, San Diego, Calif.)

This first interview extract provides an example of the locally situated work that does not yet scale as a joint measurement unit within the framework of the shared conventions of a community of practice—in this case, the LTER network. The retrofitting referred to is the occasion for a lot of cyberinfrastructure disasters—data that were understood well enough by a local group often have to be completely revisited to be understandable to a wider community. Designers persist in seeing the conversion task as being easy, but this assumes that the data being fed in are clean and consistent.

Micromoles Per Liter and Micromolar are measurement units for concentration. Technically, both are micromoles per liter, and so equivalent in magnitude. [But] their scopes are different, because micromoles per liter can be used for a particulate or dissolved constituent, and micromolar is correctly used only for dissolved. So they are not exactly interchangeable.

Micromoles Per Liter and Millimoles Per Cubic Meter are equivalent in magnitude, but different disciplines have preferences for one or the other.

[Also], if you happen to be in open ocean, you would run into micromoles per kilogram and micromoles per cubic meter, which are similarly equivalent only at sea level, because interconversion depends on pressure. . . . (IM_M, interview, 2005, San Diego, Calif.)

This second interview extract gives an example of measurement units that are a priori identical but that mean different things in different disciplinary environments.

Taking a step back, the general problem can be characterized thusly. In the grand old days of the nineteenth through early twentieth centuries, when scientific certainty was at its zenith, it seemed as if there was a clear and consistent classification of and hierarchy among the sciences. The most famous example is Auguste Comte's classification of science into a classificatory tree going from mathematics through physics and chemistry down (or up, depending on your inclination) to sociology. Each part of each discipline was divided into statics and dynamics. This was also the period of the discovery of the principle (not, be it noted, the fact) of division of labor; Charles Babbage mirrored his computer on factory production techniques—making a complex task easy by splitting it into a set of serial subtasks. Together, the classificatory principle and the division of labor created a picture of scientists as workers in a giant collective enterprise—in Jules-Henri Poincaré's terms, workers lay bricks in the cathedral of science. Some, indeed, saw the end of the period of "heroic science" as the principle of the division of labor emerged.

Nowadays we are running into the question of whether cathedrals need blueprints (Turnbull 1993). What could possibly guarantee that all these bricks will fit together into a seamless whole? There are two options—in close parallel with "blind watchmaker" positions. Either there is a higher entity (the universal scientific method and the positivist classification of science, in this case) ensuring that they all fit or there is a constant, contingent, local process of partial fitting and constant disordering that can still, in the long term, guarantee that at any one "join" there is a fit (although there cannot possibly be across the set of joins). Both scientists and information systems designers have been working largely from the former assumption. When they face the reality of the latter, they are constantly surprised—they have not been following the scientific method as faithfully as they thought (their databases are dirty; their units are ambiguous), and it does not all fit into clearly designated, separable chunks (two disciplines might both claim control over the same measurement unit).

The Case of the Dictionary as Articulation Strategy

At the start of 2005, with the tools created by the developers not yet being used by information managers and the implementation dragging on, the network coordinators began the development of a new tool intended to accelerate the implementation of the standard among the sites. In parallel—and partly in reaction to this project—some information managers initiated the development of a, in-house tool: a repertoire of measurement units.

One of the principal difficulties that the information managers faced was tied to the complexity of the work of translating their metadata into the EML language—notably with respect to measurement units. On the one hand, the dictionary of measurement units that came with the EML standard essentially cataloged physical measurement units of ecological phenomena—whereas most LTER network sites were using biological and ecological measurement units. On the other hand, it is extremely difficult to describe in a standardized language special or personalized measurement units—that is to say, units developed for some specific purpose in a research project and that only really make sense in the context of that project.

Faced with these difficulties, some information managers then began to exchange lists of measurement units (including local ones) used at their site, so as to compare their respective translations and to catch any inconsistencies. This quickly evolved into a project to transform these lists into an LTER-wide catalog of units. The plan was to produce a dynamic online tool available through the LTER intranet. The team, which until then had been made up solely of information managers, expanded to include a representative from the network office. They developed a prototype integrating the unit lists of six sites. This was presented in August 2005 to the annual conference of LTER information managers. It was represented both as an implementation aid for the EML standard and as an example of a successful collaboration between information managers and developers/coordinators.

Technically, this tool provided the information managers in the network access to definitions of measurement units in EML (including some specialized units) and allowed them to propose corrections to the EML unit dictionary and to add definitions of other units. But it did considerably more than facilitate the conversion from one format to the next—it was, above all, a work of social coordination.

These local ad hoc initiatives and the network-wide projects can be seen as strategies for re-articulating the work—on the one hand, among the information managers themselves and, on the other, between them and the developers/coordinators. The information managers did not need the tool itself as much as they needed all this work of information mediation that the enactment of the standard brought to bear: How best can we describe such and such a measurement unit? Is a given measure a local or a network one? Can this unit be added to the EML dictionary? The work of producing the dictionary of units became a tool for facilitating coordination and cooperation between different worlds. In other words, by creating a tool that could be used locally at each site and yet contributed to the improvement of the standard, the information managers created a boundary object (Star and Griesemer 1989) that was capable of supporting this articulation work between enactors and developers.

Enactment

We propose using the concept enactment to better understand the complexity of the work of the information managers. The information managers not only ensured the implantation of the EML standard and the programming of some additional functionalities that could make it operational (i.e., its implementation)—they also worked on its interpretation; that is to say, they worked on its staging (in the theatrical sense of the term), which involved coadapting the standard and local work practices. These mutual adaptations are better seen not as local resistances but as necessary adjustments without which the EML standard could not operate within the LTER community.

In what ways did the EML standard contribute to changes in the social worlds of the actors? And how did these worlds work to change the standards? These changes involved, first, the identities of the actors and their organizational structures and, second, the script of the technical tool.

New Organizational Roles and Structures

Throughout infrastructuring in general and this standardization process in particular, the information managers as a community of practice became visible within the LTER network (Karasti, Baker, and Halkola 2006). In the same way, certain aspects of their work that, until then, had been little known and recognized became explicit. In 2004, when there was an efflorescence of in-house tools in particular sites and the information managers were being integrated with the developers, they achieved "official" status as developers—that is to say, they appear on the list of credits attached to the EML documentation. The complexity of their task (taking the local and rendering it into a universal language—a task that even the engineers of Babel found daunting) was recognized.

That said, even though the transformation of organizational models within the LTER community forced a reorganization of working patterns (from site-based to a federated structure) and even though the role of information managers was considerably transformed, their status as technicians whose task is to provide support and maintenance remains dominant in the network—notably among the domain scientists. Furthermore, even though the team of experts has recognized their contribution as developers of the standard, their contribution remains ambiguous to the extent that developers retain the tendency to see initiatives from the information managers as being too local and not state of the art. Thus, the synthetic "best practices" document produced by the information managers was judged to have too many signs of its origin within the LTER community to be integrated into the documentation of the standard. (And, we hesitate to say "of course," of course, but as a matter of course the social and organizational innovation was similarly not included in the documentation of the standard).

It remains the case that the set of actions carried out by the information managers during this standardization process revealed that another organizational configuration was possible—if only at the very basic level of resource allocation. If the development of a metadata standard for a research community such as the LTER requires significant funding, then so a forteriori does its enactment within a given setting. More concretely, the information managers contributed to putting into place a new representative structure—in this case, a permanent committee formed equally of information managers and domain experts, whose mission is to ensure a representative and advisory role in the development of integrated network information management practices—the Network Information Advisory Committee (NISAC). This committee came into being one year after the adoption of the EML standard (a somewhat lengthy gestation period!), when the initial sets of difficulties forced the information managers to initiate a dialog with the domain scientists. Out of this committee came the plan to implement the standard in different stages.

Beyond this new organizational structure, a new form of collaborative work at the intersection of local, site-based work and global (network) activity was experimented with successfully. The project of building a dictionary of measurement units constituted a veritable innovation (from below) within the LTER community, to the extent that, on the one hand, it opened the way for the transformation of a local initiative into a project for participatory design at the network level and, on the other, created a new collaboration space between two groups of actors that had not been directly associated before (information managers and developers/coordinators).

Redefinition of the Standard

The standard itself has been the object of multiple versions over the course of its development (in part as a result of the new members integrated into the team), but what was presented in 2001 to the LTER information managers was a black box—a final version. The box was reopened, and not always in the same way, across the set of sites.

Thus, as we have seen, certain lacunae in the standard were identified and the implementation plan itself changed to accommodate the different rhythms of integration of the different sites. More generally, there are the kinds of difficulties that come into play when we try to enact a standard generic enough that it can in principle apply to any kind of data (Berg 1997). The EML project included a definition of a certain role for researchers—that of describing their data in this new language (Jones et al. 2001). Indeed, researchers have always been envisaged by the developers as the future users of the standard. They can both describe their data collections in EML terms and carry out complex, integrative studies using vast data sets as a result of these standardized descriptions. It is interesting to note that the role of the information managers has never been mentioned (at least not explicitly) in scenarios of EML use.

And yet, in practice, several LTER researchers refused their role—principally through lack of time (standards tend to be an unfunded mandate) and interest. It should be recognized that the implementation of the standard can double the amount of work they need to do to enter their data. Moreover, the investment in time to learn the EML language (without mentioning that of learning the conversion tools) has constituted a point of no return for many. The information managers have taken on this role that was a priori destined for others.

We can certainly read this redistribution of roles as a coming from a transitional period—and thus imagine that the LTER network researchers will get up to speed with EML to the extent that the tools become easier to use and the standard is taken up within environmental science generally. But the question of training researchers to use EML (and, more widely, to understand the new forms of information management associated with an integrated infrastructure) is at present hanging—and it seems likely that the information managers will continue to pick up the slack.

Conclusion: Infrastructural Changes

In one sense, then, the EML standard did not change anything. The division of labor remains the same (information managers are still in charge of the production of EML metadata), roles are stable (information managers contribute to the redevelopment of a standard for the LTER network while developers work on the development of a standard for environmental science in general), and local practices are confirmed (information managers share ad hoc solutions and in-house tools). Yet the EML standard has changed the world. The actors' identities have changed (information managers are recognized as developers and not merely implementers), new organizational structures have been built (information managers are now represented in the NISAC committee), and new forms of work are proposed (a collaborative space between the sites and the network has opened up).

The implementation of EML is not simply a case of upgrading an existing system. It consists, above all, in redefining the sociotechnical infrastructure that supports this articulation of technical, social, and scientific practices. These redefinitions have significant consequences socially and organizationally. Because the tools are intimately imbricated in local work practices and because the EML standard operates only within a given (social, technical, and organizational) configuration, its enactment requires infrastructural changes.

This is why it does not make sense to see standards simply as things out there in the world that have a predetermined set of attributes. In information systems, standards are in constant flux—they have to migrate between communities and across platforms. Closure is a narrative that serves a purpose, not a fact that describes an event.

We slice the ontological pie the wrong way if we see software over here and organizational arrangements over there. Each standard in practice is made up of sets of technical specifications and organizational arrangements. As Latour (2005) reminds us in another context, the question is how to distribute qualities between the two—what needs to be specified technically and what can be solved organizationally are open questions to which there is no one right answer. By assuming that specifications can exist outside organizational contexts, we have already given the game away, leading to the continual need for the kind of innovation detailed in this chapter. And the innovation is always forgotten because the same ontological mistake—made elsewhere, by other people—next time will again occasion its necessity. Indeed, a test for ontological errors in general is that, although we can say the same thing a hundred different ways over a span of years, there is no way the message can be heard *until* the organizational changes have taken place such that reception is possible (Douglas 1986). Both standards and ontologies (the one apparently technical and in the realm of machines, the other apparently philosophical and in the realm of ideas) need to be socially and organizationally bundled—not as a perpetual afterthought but as an integral necessity.

STANDARDS AND THEIR STORIES

HOW QUANTIFYING, CLASSIFYING, AND FORMALIZING PRACTICES SHAPE EVERYDAY LIFE

Edited by **Martha Lampland**
and **Susan Leigh Star**

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For those who labor long and hard to craft good and just standards, as well as for those who have suffered from their absence. On the one hand, the fight against the tyranny of structurelessness. On the other, the fallacy of one size fits all.

Harmless alone,
turning savage in crowds:
more than half, for sure.

Cruel
when forced by circumstances:
it's better not to know,
not even approximately.

Wise in hindsight:
not many more
than wise in foresight.

Getting nothing out of life except things:
thirty (though I would like to be wrong).

Balled up in pain
and without a flashlight in the dark:
eighty-three, sooner or later.

Those who are just:
quite a few, thirty-five.

But if it takes effort to understand:
three.

Worthy of empathy:
ninety-nine.

Mortal:
one hundred out of one hundred—
a figure that has never varied yet.

CONTENTS

RECKONING WITH STANDARDS

1

Susan Leigh Star and Martha Lampland

A friend, who has recently moved to the Netherlands, makes an appointment to see a U.S. tax preparer. She has no phone. She walks in to the tax office and schedules a time for the next day.

"What is your phone number, please?" asks the polite young man managing the office calendar.

"I don't have one."

"I'm sorry, I can't put your appointment in to the calendar without a phone number."

"Yes, but I don't have one."

Silence.

"Would you like me to make one up?" asks our friend.

"Oh, yes," sighs the calendar-filler, "that would be great."

"1-2-3-4-5-6-7," says my friend.

"Perfect!" the young man says. "The computer accepted that just fine. See you tomorrow!"

This short anecdote introduces one of the main themes of this book: how contemporary people interact with standardized forms, technologies, and conventions built into infrastructure. This compilation is one of a few papers and books beginning to analyze the contemporary view of this question, one that includes the growing place of all sorts of standards, formal and informal, in our everyday lives (Bingen and Busch 2006; Brunsson and Jacobsson and Associates 2000; Busch, 2000). This growth is apparent at the most minute level and at the most macro level.

In the grocery store, labels referring to standards blossom. At times even each *piece* of fruit is labeled with a number, referring to a particular farm or crop; often there is other information pointing to rules, standardized practices, or other techno-socio-agricultural constraints. Standards for the labeling of food are constantly changing, most recently including properties of its manufacture such as whether the food has been through a mill where nuts, wheat, or other allergens have also been processed. Sometimes in the United States, warnings of genetically modified organism (GMO) foodstuffs is to be found there; this is now standard in Europe. Standards for naming a product *organic* have recently been established in California; terms such as *natural* or *free range* are not standardized and, essentially, mean nothing. Outside of the market, the number and location of disabled parking spots are standardized and regulated by the Department of Motor Vehicles. This is a quick, light observation. A detailed study of even one market would reveals thousands of interlocking standards (and even more if it is one of a franchise of markets). How can we even approach this thicket?

This book considers a specific question: How have people dealt, in ordinary ways, with these millions of interlocking standards? Although the anecdote at the beginning of this chapter is meant to be amusing, it is, at the same time, deadly serious. These sorts of workarounds and stalling off computerized consequences are ubiquitous—work must get done, even though one size never fits all. The data that are missing when this happens are part of a vast domain of shadow work (Illich 1981) that can never be recovered. At the same time, these practices can be crucial to our understanding of how things really occur in the workplace. We hope to contribute here, in a modest way, to the dulling of the impulse to standardize everything that seems to grip modern organizations. We are not, in any sense, against standardizing—only against society's romance with it.

Our purpose here is hardly to compile a comprehensive history of standardization. Our goal is to show how standards are phenomena worthy of study in their own right, from multiple social scientific points of view. We hope to invite other studies of both the mundane and the arcane, the unconscious use of standards and numbers, and their very conscious use in intellectual development and research itself. Investing in forms is a cultural historical project, as is the increasing marginalization or deletion of content and residual categories (Thévenot 1984). The chapters included in this book (and the eclectic collage of examples interspersed) constitute our attempts to grapple with the phenomena of standardization and quantification in several domains: biology, public news media, food preparation, work and labor units, insurance, education, and everyday activities such as shopping.

Analytic Commonalities

To understand this romance better and to think about the human use, creation, and disuse of standards, we have built on the chapters here to analyze their commonalities. One of the results found across these chapters is that standards, as with all similar forms of compression and representations of actions:

- Are nested inside one another.
- Are distributed unevenly across the sociocultural landscape.
- Are relative to communities of practice; that is, one person's well-fitting standard may be another's impossible nightmare.
- Are increasingly linked to and integrated with one another across many organizations, nations, and technical systems.
- Codify, embody, or prescribe ethics and values, often with great consequences for individuals (consider standardized testing in schools, for example).

Let us consider each of these dimensions in turn.

Nested

When we refer to standards as being nested, we are speaking of the ways that they fit inside one another, somewhat like a set of Russian dolls (maitruska). Returning to the seemingly simple example at the beginning of this chapter, we can pull on a thread anywhere in the example and see that its implications are recursive through many systems. There are apparently tiny standards, such as the form for filling in the telephone number in the tax preparer's electronic calendar. Most people who visit a tax-preparation company in the United States have a telephone and know its number; however, for a variety of reasons, not all do. Americans who live abroad but still pay taxes to the United States may temporarily not have a phone; a homeless person may not have a phone, but may pay taxes and even require assistance in doing so; newcomers to an area may not have a standard arrangement for receiving telephone calls; and so on. The standard of *having a phone* is linked with *making an appointment*, which is linked with an inflexible, standardized *computerized calendar*. Not to belabor the point, but there are also medium-sized standards lurking in the background in a much larger, encompassing "nest"; for example, the U.S. tax code is so complexly standardized that most middle-class people pay US$300–1,000 to have someone else navigate it for them every April 15. Quite large standards and practices—what percentage of a person's income goes toward state and federal taxes, and how little a person can get away with paying—nest the small interaction with the calendar. Many very rich people pay no taxes; they have enough money to purchase tax shelters and other workarounds to the standard percentages.

Laurent Thévenot, in "Rules and Implements: Investment in Forms" (1984), argues that we are increasingly forced to make and use these sorts of standards and their attendant forms (now usually computerized, but with a sizable amount of paper still remaining). The very stuff of bureaucratic action is just such an investment in form. Content, such as a telephone number, may vary from instance to instance, but in fact the shape of the form becomes the primary human-capital investment. The flexibility of such linkages, as well as of each form, is variable. Options such as "Other" or a box labeled "Other forms of contact" would actually free up the way the form is driving the interaction. At the same time, however, the nested structure of the forms remains and is essentially not disturbed by a small number of such workarounds or residual spaces. Martin Lengwiler's inspection of the substandard human (chap. 4 in this volume) works inside the conception of a standard human, an object and set of events that is constantly being molded. Martha Lampland's work science standards (chap. 5 in this volume) are nested within a hierarchy of social inequities and a commitment to certain moral principles—principles that keep being renegotiated as work itself changes. Likewise, the privileging of chronological age is nested within structures of administration forms and rights, such as the ability to vote, drink, fight in the military, and drive (Judith Treas, chap. 3 in this volume). The formal techniques described by Florence Millerand and Geoffrey Bowker (chap. 6 in this volume), such as quantification, are nested within other standards in order to summarize information; metadata are nested within a whole system of standards.

Distributed Unevenly

With respect both to impact and obligation, sociotechnical standards are distributed unevenly. So, for example, most students in most Western countries must take standardized examinations at various stages of their schooling. This is a thorny, politically charged question. The very rich and the very poor, however, often escape the obligatory taking of the tests, or they have different relationships to it. Very rich youth may be educated in a way that is exempt from standardized testing (elite boarding schools outside the tests' jurisdiction, private tutors replacing classroom teaching standardized to the test, and so forth). Very poor young people may run away from school altogether; be educated in an environment that is not equipped to educate them about testing, rendering the test results moot; start work as children; or never achieve standard literacy through schooling. As Martha Lampland points out, the meaning of a standard, such as a work-hour, varies according to political regime and class position. When and where an individual is born matters greatly, as we see when we reach into the past to look for an uneven distribution of standards. The very definition of age is culturally variable, both unevenly distributed across historical periods and relative to the needs of states, labor pools, and who really counts.

Being able to speak English during the past years of computerization conveys a great privilege with respect to standardization. The implementation of most programs has until recently (and even now, although things are better) relied on a system of encoding, ASCII, that disproportionately disadvantaged people whose alphabet used non-ASCII characters. The examples from Swedish given by Daniel Pargman and Jacob Palme (chap. 7 in this volume) make clear the subtle but real advantages conveyed in qualities such as searchability on the Web and how the use of non-ASCII characters affects that.

Finally, for those of us who stood shocked as the CNN narratives about September 11, 2001, unfolded, we saw a disproportionate use of a standard set of images and the hardening of a story, reaching into the ways that news is made and acceptable narratives are constructed.[1]

Relative to the User and Communities of Practice (Social Worlds)

Following on the last point about uneven distribution, standard forms are also relative in their impact, meaning, and reach into individual and organizational lives. Standards, and the actions surrounding them, do not occur acontextually. There is always a kind of economy and ecology of standards surrounding any individual instance. Thus, what is benignly standard for one person at one time may be a barrier, or even a life-threatening occurrence, for another. For example, the act of presenting a passport in a standard gesture, in a standard format, works for millions of people much of the time. But, of course, some people are stateless, some states' legitimacy is questioned by other states, and some people (e.g., infants and prisoners) may be necessarily linked to others in order to enact standard citizenship. Steven Epstein (chap. 2 in this volume) speaks of different standards for different bodies, and Lengwiler (chap. 4 in this volume) talks about standard versus substandard lives (according to an insurance company). Throughout the book, this relative sense of standards is very clear. Millerand and Bowker (chap. 6 in this volume) note that standards are always relative to the infrastructure within/upon/sometimes against which they are implemented. The need for and the politics of metastandards thus arise—although the problem does not stop here; it is recursive.

Integrated

As we sit down, perhaps in the morning with a cup of tea or coffee, and answer our e-mail, we may read a greeting from a friend, a new deadline from a boss, or an argument from a student about a recent grade. Regardless of the particular words or emotional tones of the e-mails, in reading any of them, we use (invoke might be a better word) thousands of standards. For e-mail to function properly, these standards must be integrated one with the other, beginning with the source of access to the Internet (the service provider), software for presenting messages from many sources and in many formats, and telephonic and other carrier standards, and continuing right down to the machine code in the terminal or computer on the desktop and out to the Internet with its complex, evolving sets of handshakes and protocols (see Abbate 1999). The nature of this integration is profound, global (not, however, universal), increasing, and evolving. Social science theorists face new challenges in understanding exactly how this integration forms and drives action. For instance, when parents use cell phones to locate their teenage daughters and sons, is this a new form of surveil-

1. The first official meeting of the standards research group was held on Tuesday, September 11, 2001.

lance? How do families then configure themselves around the contact provided here? The older forms of checking up on and managing teen behavior on the part of parents included having them "telephone in" and meet curfews or having them remain within eyesight or in a chaperoned place. Do the caller identification numbers now enabled through a cell phone change how offspring manage information about their whereabouts? When some form of tracking becomes integrated with cell phones (such as a global positioning system, GPS) and family cars, does the resulting emotional ecology change the meaning of trust? We are beginning to study and weave answers to these sorts of questions (for example, Millerand and Bowker, chap. 6 in this volume); at the same time, the situation is moving very quickly.

Embody Ethics and Values

To standardize an action, process, or thing means, at some level, to screen out unlimited diversity. At times, it may mean to screen out even limited diversity. For example, despite the fact that transsexual and intersexual individuals have been a highly publicized, well-known aspect of modern culture for at least twenty years, almost all forms seeking demographic data have one binary choice, "M/F" (or male/female). And despite the fact that forms of partnership range from a single male and single female conjoined in one marriage for life to polyamorous arrangements with multiple genders and numbers of partners, most demographic forms ask "Married" (answer: "yes/no") or the functional equivalent. The silencing of "Other" choices here is a moral choice as well as a technical and data-collecting one. Where on a form do the transsexuals "go"? In traditional population census data (although this is changing dramatically in many places), where do people of racially mixed heritage (that is, all of us, if we carry this further) "go"? Often, individuals are forced to choose to self-silence some aspect of their lineage (see Bowker and Star 1999, chap. 5). Epstein (chap. 2 in this volume) speaks movingly of the ironies of resistance and the politics of representation in medical testing. When a person chooses one side of his or her heritage, it is often to redress inequalities conferred by the lesser status; other aspects of him or her self remain invisible. This invisibility is only one form of moral inscribing that derives from standardizing forms and processes. Others involve making things visible in a positive manner—such as including environmental data with economic assessments and including emotional stressors or physical danger with wages, where the more stressful or dangerous the job, the higher the wages, and this becomes formulaically part of pay. Sometimes, as Treas (chap. 3 in this volume) discusses, age conveys age-related benefits or honor—but just as often, it conveys discrimination. The wide range of values in design, use, and propagation of standard systems is another opportunity for social science/technology analysis. In the following section, we consider some of the ways the shadow work continues to be propagated.

Standards: Some Considerations of Invisibility

This book grows out of a research group devoted to thinking through three related phenomena: standardization, quantification, and formal representation.[2] These are phenomena, like the investment in form, that pervade modern life. For us as social scientists, one of the interesting aspects is that they have largely escaped consistent attention as sociocultural projects in themselves. The work of creating them is often invisible or deleted in descriptions of their development. Standardizing clothing sizes, developing indices of economic growth, creating computer databases, identifying the appropriate population for clinical trials in medicine, mandating testing in schools—all these procedures entail processes of standardization and quantification (and usually formal representation) (see Lynch 1991). Yet the standards, numbers, and models tend to be black boxes in their own right. They may be presented as secondary or epiphenomenal to the procedures of which they are a part: marketing for mass consumption, economic development policies, transmitting information, testing medical innovations, and supporting children's educational progress.

Talking with a production engineer, research scientist, classroom teacher, medical professional, or factory manager, we discover that their lives are filled with tasks designed to create standards or comply with existing standards. Associations such as the American Standards Institute or the International Standards Organisation (ISO) are familiar creatures in the current technological and production landscapes. Increasingly, humanities and the fine arts are filled with standards as well. Why, then, have they so often escaped social analysis?[3] Perhaps because many social scientists (ourselves included) fall into the taken-for-granted ease of seeing numbers and models, or specifications, as somehow "outside social order." Perhaps some of the neglect is due to the Byzantine politics of qualitative versus quantitative approaches in the social sciences.

Clearly, standards are also complexly related to quantification, formal modeling, and data mining, reuse, and classification. Another book or more would be needed adequately to describe the role of each of these. Quantification is the most developed historically and sociologically (see, e.g., Porter 1995; MacKenzie 2001). Some attention has been paid to formal modeling and its consequences, notably in the work of geographers and in the work of philosophers of biology (Wimsatt 1998; Griesemer 1990; see also Morgan and Morrison 1999). As a shorthand, and

2. *Quantification* is the representation of some action, being, or model through numbers. *Formal representations* are those not tied to a particular situation or set of empirical data but, rather, are a synthesis of data and a presentation of rules for combining and acting. These are often conveyed in visual form, as graphs, tables, or formulae. They may also be conveyed in narrative form, such as conventional sayings or standard characterizations of phenomena.

3. The exception here is the economic analysis of networked standards; see, for example, Paul David (1985).

to better focus, we use the term *standardizing* throughout the book. At many junctures, however, numbers and other formal tools play a critical role alongside standards, and we have tried to be aware of these moments.

Standardizing has become a central feature of social and cultural life in modernity.[4] The purpose of standardizing—to streamline procedures or regulate behaviors, to demand specific results, or to prevent harm—is rarely queried because it has come to be understood as a valuable and necessary, even if cumbersome, process. Certainly debates do take place over the extent or degree of standardization and especially about how and whether to measure the outcome of standardization (e.g., the nature and cultural bias of the IQ test and the Scholastic Aptitude Tests, SATs). But the question of whether to standardize (or quantify) *at all* is often suppressed. At times, it seems that standardizing overwhelms the primary activity—that is, the investment in form outweighs the performative content of the forms. Teachers, nurses, and psychotherapists, among others, criticize the increasing amount of time devoted to standards of care, teaching, and testing and the time lost from actually doing "the real work." These professionals frequently complain about the demands of paperwork—recording evidence for insurance companies and government agencies—that attempts to standardize their practice and its evaluation. So, too, factory managers, design engineers, architects, builders, and social workers can easily and quickly compile a lengthy list of codes and regulations that must be accommodated in their work on a daily basis. But the measuring-standardizing activity is often the only thing that people consider "real evidence of results." It is a failure of imagination to believe this.

Modern industrial and urban worlds were built with standards embedded in them. Think of any modern institution: education, the city, policing, the military, the stock exchange. Each is predicated, to some degree, on the tools of measurements, the purchase of standardized commodities (or investments in the futures of commodities) (Cronon 1991), and the measurement and formal presentation of results. And, as thoroughly at the center as these processes are, their mandate often remains unquestioned.

One simple explanation for overlooking the question "Why standardize?" is that standardization is considered to be a necessary technique designed to facilitate other tasks. We often confront standards as fully developed forms, such as an electricity grid or a health regulation. The resulting ahistoricity is another factor that allows the quintessentially sociocultural and ethical aspects of standards to be overlooked. In this sense, the process of standardization is both a hidden and a

4. Please note that standardization is *not* exclusive to modernity per se, but it has accelerated with its electronic and global forms, as already described. The distinction between a convention and a standard, or perhaps working standard, is in some instances difficult to make (Michael Evans, personal communication). Over time, what had been social conventions become increasingly standardized in formal ways, after which the difference between a standard and a convention is no longer minor but qualitative.

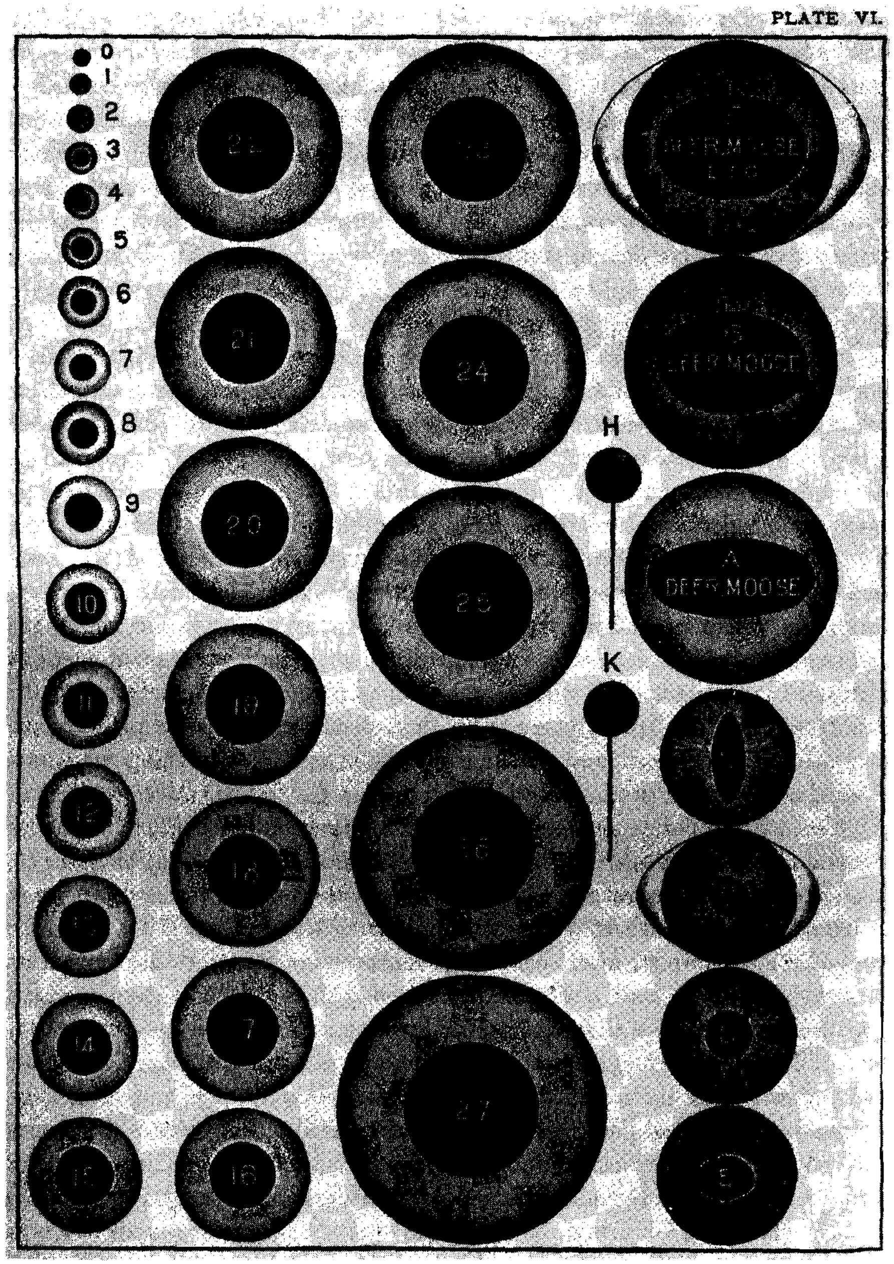
central feature of modern social and cultural life (Slaton and Abbate 2001). Or, ironically, because standards are so pervasive that they have become taken for granted in our everyday environment, they may become completely embedded in everyday tools of use. (Consider the Japanese toilets that routinely check urine to see if several medical parameters are out of line.) Residual categories (e.g., "None of the above" or "Note elsewhere classified") may help us see the boundaries of standards, for example, rare medical conditions such as being allergic to onions or having undiagnosable chronic pain.

Containing Messy Reality

Looking into the edges and detritus of infrastructure can be a messy and distasteful task. For example, in studying the history of taxidermy, Star found herself tracking down the biological supply houses that had provided items such as standard-size glass eyes for the different animals in the museum dioramas (see figure); homemade devices for shaving and softening animal skins, and other tools for preparing and preserving specimens and habitats. The glass eyes are standardized with respect to color and size, and they are designed to be "lifelike." Because taxidermy sought to take the messy scenes of hunting and capturing specimens and create in their place a clean, almost transcendental vision of nature, more of its craft skills came to require the use of standardized parts and means of working. In this, taxidermy holds common ground with medical illustration; debugging complex computer programs; and moving from the messy, noisy birthing room to a cleaned up, peaceful space.

One final, and rather comical, reason why standards may be neglected in sociocultural research into science and technology is that they are boring. They are often, as mentioned, deeply embedded in infrastructures of various sorts, apparent as wires, plugs, lists, labels, and other semicultural forms. Once these forms are noticed and examined, most social scientists do agree that they are important indeed[5]—but they escape notice, and so studying them can be lonely. Some ten years ago, in Palo Alto, California, several colleagues formed a new professional society. The idea for the society arose from a series of conversations we had about our somewhat unusual research topics—these very semicultural things that most people find quite dull. We called it The Society of People Interested in Boring Things. Among the boring topics that the founders brought to the first meetings were the inscription of gender in unemployment forms used by the city government in Hamburg, Germany; the difficulties of measuring urine output in a post surgical ward in the Netherlands, and how to design better cups for metrication;

5. Including, among others, Charlotte Linde and Susan Anderson anthropologists; Geoffrey Bowker, historian; David Levy, information scientist; Marc Berg, physician/philosopher; Leigh Star; Sigrid Müller; and later Martha Lampland.



Glass eyeball chart.

From Oliver Davie. 1894. *Methods in the Art of Taxidermy.* Philadelphia: David McKay. Plate VI.

the company mascot and the slogans used by a large midwestern insurance firm in its attempts to build corporate cultures; and how nematologists[6] use computers to keep track of their worm specimens. To put it mildly, these are not central topics in social science—yet!

How should these boring traces that bear evidence of the development of standards be studied? The authors in this book share an ecological sense of the worlds of infrastructure. Collectively, we find it necessary to deconstruct boring backstage elements. In this, we seek to restore the narratives of these standards: their historical development, their political consequences, and the smoke-filled rooms always attached to decisions made about them. This means overcoming the initial boredom of analysis and, furthermore, practicing a deeper ecology than that of input-output or systems analysis. We have to listen to infrastructure and bring imagination to understanding its components and how they work.

Listening to infrastructure does not neatly resolve into accessible questions. The relative weight of social agents and social structure has long posed an analytic dilemma. Various traditions have resolved this tension in different ways. The issue here is less one of relative weighting than of determining when and where we can identify people, objects, and emergent properties (structures) in standardizing and using standards (or not using them). Standards such as human weight charts, blood types, and electrical current now appear fixed and neutral, although this inert quality obscures the enormous amount of work needed to stabilize knowledge, freeze action, delete outliers and residuals, and facilitate use. In the course of studying standardization, the challenge has been to figure out which threads to unravel to make visible and lively the otherwise banal and interstitial character of standards and quantified or formally represented phenomena. We have interrogated stories of the inevitability of technological development and the neutrality of quantification, examined claims about standardized representations and authority, and sought to reveal the political and ethical problems at the heart of these struggles. In other words, when does a structure become a structure and when is a social actor an agent are part and parcel of the story to be told here.

Although standards become crucial (and sometimes visible) once they have been stabilized, the physical features or phenomenal manifestations vary greatly. Enormous infrastructures, such as railroad lines or urban plumbing systems (Collier n.d.), can be massive observable structures of metal and PVC (polyvinyl chloride), whereas other equally central infrastructures, such the computer language ASCII (Pargman and Palme, chap. 7 in this volume) or standards for chronological age (Bowker and Star 1999; Treas, chap. 3 in this volume) or EU environmental policy, are far less tangible. (They are argued through in hardworking committees that rarely see the light of history. At most, they may be manifested in

6. Biologists who study worms, in this case those who were sequencing the genome of the nematode *Caenorhabditis elegans.*

written documents that are rarely perused by any but their most immediate users.) But early, incomplete forms of standardization, too, set parameters within which social action takes place. In retrospect, while doing the "archaeology of things and their order," we may come to see them as clearly the product of a long series of events and actions taken to make them so.

Perhaps the most intriguing aspect of standards is their always already incomplete and inadequate (compared to some ideal) character (for a similar argument, see Barry 2001, 62–84). The push to standardize presumes the ability to constrain a phenomenon within a particular set of dimensions, as well as the ability to dictate behavior to achieve the narrowly defined dimensions that stipulate its outcome. A great deal of work is conducted to make the standard possible, and then this must be followed up by agents committed to implementation and oversight. Again, standardization is a recursive practice, necessarily historical and embedded in a series of complex events and social structures. This is quite evident in legal proceedings adjudicating the application of standards and regulations, but it is not limited to the legal domain.

Formal compliance to standards without substantial change in practice is common. Paperwork is filled out to assure the responsible authorities that regulations have been recognized, but this can be a far cry from actually fulfilling those requirements. Obviously, there is a range of behavior here, from near compliance to outright defiance of regulations. There is also a range of means to reward and punish those who step outside the boundaries of usual (and accepted) practice. For instance, accounting standards—both technical and ethical—were strongly questioned in the period following the ENRON scandal. The unethical behavior could hardly be blamed on the standards themselves. However, large shake-ups and scandals such as this leave a legacy. Frequently, they lead to a rethinking of the shape and usability of the standards. Organizations may begin to seek ways of making standards more effective in rendering an outcome that is consistent across the entire field of use.

The attempt to purify and simplify processes of standardization—through bureaucratic maneuvers or more contested legal procedures—contributes directly to the overdetermined or layered, socially and culturally embedded quality of standards. With time, this process can lead to what Callon (1998) calls "irreversibility." This is, in the first instance, a functional irreversibility—for instance, what would it take to change the meaning of a red light to "go" and a green light to "stop"? Obviously, we would have to invest untold billions, and some sort political platform on which to base the change, to achieve this reversal.

A related maturation and reification process that leads, over time, to complexly recursive standards is that developed by Wimsatt (1998) under the rubric "generative entrenchment." Small changes made early in the life of any developmental system will ramify throughout the growth of the system, becoming increasingly more difficult to eradicate. Wimsatt originally used the example of teratagens, drawing on embryology to illustrate the process. If something small goes wrong early in the development of a fetus, it will ramify systemically. If it happens late in development, it is much more likely to be trivial. So it is with standards. Small conventions adopted early on are both inherited and ramify throughout the system.

Hence, we can say that slippage (such as the made-up phone number in the introductory example) between a standard and its realization in action becomes a crucial unit of analysis for the study of standardization and quantification. Using historical analysis, this may mean analyzing irreversibilities and processes of generative entrenchment. What is being standardized, for what purpose, and with what result? When did it begin? What were its first entrenchments? What can and should be changed? Who are the actors engaged in the process of standardization, and do they change at different moments of a standard's genesis and maturation? What small decisions have ramified through the life and spread of the standards? When does a standard become sufficiently stabilized to be seen as an object or quality influencing social behavior? How do we address the objectlike quality of standards while keeping a keen eye on the necessarily historical and processual quality of its emergence, transformation, and (variably) long life? How do standards developed in one context acquire a modular character, enabling them to be moved around or to serve as templates for the development of other standards?

And as a result of this intensely social, historical process, it is necessary to acknowledge the contingent and, in some cases, arbitrary nature of the standards themselves. The confusion, anger, and frustration people express about standards are easily related to the apparent alogical or irrational character of standards. The association of standards with irrationality demonstrates, as little else can, Max Weber's powerful insight that the move toward modern rationality necessarily resulted in forms of irrationality. The iron cage of bureaucracy has perhaps become a sociotechnical cage—sticky and partly binding but also complexly structured with information architectures and human behavior. This stands in contrast to current neoinstitutionalists' arguments that change proceeds linearly and along traceable tracks.

Types of Standards

What is being standardized, and who is being standardized? What is the difference between a gold standard and a working standard? Moreover, how is the baseline for a standard determined? How does it become naturalized or standardized, so that it slips into the realm of common sense and tacit knowledge? In many cases, the causal relationships will be difficult to parse in any simple fashion. Standardized procedures are created and enforced by governmental agencies; others are created and enforced by private businesses, professions, and local regulations. Still others are created by individual labs, families, and even individuals. We bemoan some standards and laud others; we resist some entirely while gladly imposing others on ourselves.

Another set of issues crucial to the study of standardization concerns the scale and scope of a standard. Standards vary in their scope and scale. The standards for chocolate differ in both scale and scope from standards for gasoline purity. The history of modern standards is one in which the range of standards, and their relative scale and scope, has increased dramatically. This contributes to one of the astounding features of contemporary standardization bodies—the presumption that their work is necessarily global in impact. Clearly, coordinating communication over the World Wide Web or between computers in different sites has necessitated extensive work to ensure ease of data movement and flow, akin perhaps to the grand projects of building railroads and cutting deep river channels to facilitate the movement of goods in the nineteenth century (prompting the use of the metaphor of the superhighway). We must not lose sight, however, of the simple fact that standards are intensely local, in the sense that, despite their global reach, they touch very specific communities in very specific contexts.

In their book *Sorting Things Out,* Bowker and Star (1999) explore the case of the International Classification of Diseases in some detail. It is a good example of several of the issues we have raised so far; and it is, furthermore, widespread, standardized, and old (more than one hundred years old). It thus incorporates legacy systems, multiple (and sometimes competing) architectures, and hundreds of standards. It is clear in this case, also, that Western and middle-class values and foci are inscribed in the list of mortality and morbidity labels. For instance, heroin addiction and absinthe addiction are prominently featured in the drug abuse area of medical classification; petrol sniffing (widespread in the developing world) and legal addictions to pain medicines or Ritalin in the first world are ignored. When we turn to the part of the classification scheme that encodes accidents, a person may fall from an automobile or from a commode (a common accident during the care of elders at home in the developed world) but not, say, from an elephant or a carrying chair. These labels are used, among other things, to fill out death certificates and record epidemics around the globe. They are thus critical, although often invisible, resources for allocating aid and tracking international health concerns, which in turn become standardized and quantified in many ways.

Another crucial feature of standards, related to issues of scale and distribution, is a notion of degrees of delegation. How is the enforcement of standards (and their attendant moral orders) managed? Increasingly in developed states, delegation is managed via home-testing kits, through directives printed out from the pharmacist, or through a wobbly network of social workers and elder-care workers. The importance of degrees of delegation will perhaps help us distinguish between the character of conventions (discussed later), such as the manner in which a doctor treats a patient in a face-to-face encounter, and standards imposed at the state or national level for medical practice, such as provisions for cleanliness or the

ways people must dispose of toxic substances. This idea about degrees of delegation bears a resemblance to Bruno Latour's notion of "action at a distance" (1987, 219), but it is also, again, clearly informed by Weber's seminal work on modern bureaucracies and studies of complex organizations.

What Is Infrastructure?

Defining *infrastructure* is not as easy as it may seem. Along the way, we use the term, encounter it as used by others in connection with standardization. We had a commonsense notion of infrastructure when we began discussing the nature of "boring things"—infrastructure is something that other things "run on," things that are substrate to events and movements: railroads, highways, plumbing, electricity, and, more recently, the information superhighway. Good infrastructure is by definition invisible, part of the background for other kinds of work. It is ready-to-hand. This image holds up well enough for most purposes—when we turn on the faucet for a drink of water we use a vast infrastructure of plumbing and water regulation without usually thinking much about it.

However, in light of a deeper analysis of infrastructure, and especially to understand large-scale technical systems in the making or to examine the situations of those who are *not* served by a particular infrastructure, this image is both too shallow and too absolute. For a highway engineer, the tarmac is not infrastructure but a topic of research and development. For the blind person, the graphics programming and standards for the World Wide Web are not helpful supporters of computer use but barriers that must be worked around (Star 1991). To expand on our point about standards, one person's infrastructure is another's brick wall, or in some cases, one person's brick wall is another's object of demolition. As Star and Karen Ruhleder (1996) put it, infrastructure is a fundamentally relational concept, becoming real infrastructure in relation to organized practices (see also Jewett and Kling 1991). So, within a given cultural context, the teacher considers the blackboard as working infrastructure to be integral to giving a lesson. For the school architect, and for the janitor, it is a variable in a spatial planning process or a target for cleaning. "Analytically, infrastructure appears only as a relational property, not as a thing stripped of use" (Star and Ruhleder 1996, 113).

Infrastructure is part of human organization and as problematic as any other. The contributors to this book have done a kind of gestalt switch, what Bowker (1994a) has called an "infrastructural inversion"—foregrounding the truly backstage elements of work practice, the boring embedded things, and, of course, infrastructure. Work in the history of science (Bowker 1994b; Hughes 1983, 1989; Yates 1989; Edwards 1996; Summerton 1994) has begun to describe the history of large-scale systems in precisely this way. In science as well as in culture more generally, we see and name things differently under different infrastructural regimes. Technological developments are processes and relations braided in with thought and work. In the study of nematologists mentioned earlier, Star and Ruhleder listed the properties of infrastructure as embeddedness; transparency; having reach or scope; being learned as part of membership; having links with conventions of practice; embodying standards; being built on an installed base (and its inertia); becoming visible on breakdown; and being fixed in modular increments, not centrally or from an overview.

The strangeness of infrastructure is not the usual sort of anthropological strangeness, in which we enter another culture with a kind of trained suspended judgment, eager to learn the categories of that culture rather than imposing our own. Infrastructural strangeness is an embedded strangeness, a second-order one, that of the forgotten, the background, the frozen in place. It always interacts with any given culture (see, e.g., Akrich 1993 on African use of electricity systems; Verran 2001 on Nigerian uses of mathematics), but it may be both local and global, or multiply standardized and adapted.

The ecology of the distributed high-tech workplace, home, or school is profoundly impacted by this relatively unstudied infrastructure that permeates all its functions. If we study a city and neglect its sewers and power supplies (as many have), we miss essential aspects of distributional justice and planning power (see Latour and Hernant 1999; Collier, n.d.). If we study an information system and neglect its standards, wires and settings, we miss equally essential aspects of aesthetics, justice, and change. Perhaps if we stopped thinking of computers as information highways and began to think of them more modestly as symbol sewers, this realm would open up a bit.

Many aspects of infrastructure are more difficult to locate, for several reasons. First, people tend to discount this aspect of infrastructure as extraneous to knowledge or to their tasks. They, therefore, do not tend to mention them in official historical narratives (except in passing; see Clarke and Fujimura 1992b for an excellent discussion of this problem). Second, details such as materials, standards, and formal modeling assumptions do not always obviously intersect the variables and processes that are familiar to us in analyzing human interactions. The known variables such as gender, race, status, career, power, and innovation trajectories are subtly represented in infrastructures, especially as they appear in processes of standardizing and quantifying (see Stern 2002). Unearthing the narratives behind the boring aspects of infrastructure does, however, reveal (often in a very direct way) how knowledge is constrained, built, and preserved. This book is a modest witness to the bricks of the infrastructure wall that are placed there in the form of codes, protocols, algorithms, and so forth.

Intellectual Background: Science Studies

In the world of science, scholars began to study how laboratories work during the 1970s, work that later linked to these concerns about infrastructure. In Europe and the United States, notably with the publication of Bruno Latour and Steve Woolgar's *Laboratory Life* (1979), people began to explore the laboratory as a kind of anthropological field, with scientists as the tribe. *Laboratory Life* is an ethnographic examination of the production of a scientific fact. It looks at the devices (called "inscription devices" by Latour and Woolgar) used by biologists to record and preserve data. In this, Latour and Woolgar unpack the gradual deletion of uncertainty and qualifications in the statements emerging from the laboratory. They explicitly try to eschew the obvious categories that previous, more macro-scale studies of science produced: occupational stratification, the role of national cultures in science, and so forth. The idea was to approach science afresh, to look empirically at knowledge construction in a detailed, face-to-face context, much as an anthropologist would approach a new tribe (their metaphor).

With the publication of *Laboratory Life*, a window was opened to a more qualitative, intensively observational set of studies of scientific work and practice. Many were produced over the next two decades, examining such interesting phenomena as talk in the laboratory, the acquisition of manual skills in performing tests, the ambiguity of scientific objects, and the intersection of heterogeneous viewpoints in making scientific theories; by the 1990s, the research community began the systematic study of the design and use of information technologies (see, e.g., Star 1995). This development toward the "technical turn" in science studies, that is, the ethnographic study of the design and use of advanced technologies such as computers, had many research ramifications. It used many of the same techniques as the earlier laboratory studies of science; however, it also directly engaged social scientists in studying communicating machines, the emergence of the personal computer (PC) and the World Wide Web, and attempts to model human behavior. In addition, by the early 1990s, several detailed studies of the materials aspects of scientific work began to appear, many of which began to pick up other aspects of boring things, such as the humble stuff used in experiments (see, e.g., Clarke 1998) and the way equipment and its layout reflects a particular scientific commitment.

Recent studies have taken this combination of the technical turn and studies of materials deep into the investigation of infrastructure (see, e.g., Star and Ruhleder 1996). The ethnographic eye that helped reveal the inner workings of science or technology research and development applies no less to the built scientific-technical environment. Arguments about standardization, selection and maintenance of tools, and the right materials for the job of knowledge production have slowly come into center stage via this synthesis (Clarke and Fujimura 1992a). Along with this has come a rediscovery of some of the research tools germane to cognate disciplines that had previously analyzed material culture and the built environment. These include, *inter alia*, fields such as architecture (in which scholars sometimes read the built environment as a kind of text), literary theory (especially those aspects of literary theory that help hidden stylistic assumptions and narrative structure surface), and social geography (in which the values and biases inherent in such tools as maps are a lively topic of inquiry). Work on quantification and standards as structuring knowledge owes much to these fields, as well as to cognitive anthropology and linguistics, areas whose scholars have investigated the toolness and origin of various modeling systems.

An example of the study of a technical project in which infrastructure and standards are central is the sociological study of the biological effort the Worm Community Project of the early 1990s. Leigh Star and Karen Ruhleder (1996) found a world of clashing meanings between designers and users of the system. The project came just before the advent of the Web and as academe become fully saturated with e-mail users (especially in the sciences) in 1991–1994. They studied a scientific community and a custom-made system codesigned with the community. Most respondents said they liked the system, praising its ease of use and its understanding of the problem domain. On the other hand, most did not sign on. Many chose instead to use Gopher and other simpler net utilities with less technical functionality; later, of course, they turned to the World Wide Web. Obviously, this was a problem of some concern to the system developers and evaluators. Despite good user prototype feedback and participation in the system development, there were unforeseen, complex challenges to use involving standards and infrastructural and organizational relationships. The system was neither widely adopted nor did it have a sustained impact on the field as the resources and communication channels it proffered became available through other (often more accessible) means. It did provide insights for social scientists into the profound impact of the understanding of infrastructure on group interactions.

In short, the study showed that problems with local infrastructure and standardization can mean the rise or fall of expensive experiments. Each form of standardizing, quantifying, or modeling stands on top of another, supporting it but not in a smooth or seamless fashion. Some stone walls fall down; some survive for thousands of years. (The same can be said, in interesting ways, of Gothic cathedrals, many of which did fall down; see Turnbull 1993.) Thus, some forms of infrastructure are added to and maintained; some are neglected. In any event, the nesting properties of infrastructure converge with human behavior to form a complexly imbricated, messy whole.[7]

The metaphor of imbrication is important for the rest of this book, in addition to its evocative picture of uncemented things producing a larger whole. Imbrication also implies that each part may shift in character over time as the whole is edited or rearranged. Thus, a keystone at one time—a rigid standard, say—may become a minor interchangeable end stone at another, later time. The job of the analyst of scientific or technical work, and its attendant standards, therefore, is to raise these second- and third-order questions about the existence and nature of the whole classification scheme, the taken-for-granted tools used in intra- and interdisciplinary communication. One aspect of this analysis is to bring to the surface the embedded biases in representations of knowledge, both blatant (e.g., in advertisements) and subtle (e.g., in the categories in databases). "Other" ways of knowing, speaking here in the voice of modern analysts of modern systems of knowing, can become important bridges that reflect back on "our" ways of knowing. Our ethnocentrism, and our assumptions about infrastructure and standards, comes to the fore when we encounter wild (to us) representations. One rich place of encounter, as already noted, is culturally diverse and different kinds of maps. Radically different maps derive from non-Cartesian, relational, cognitive commitments, in which things such time, emotion, and trust often appear explicitly as part of the cartography.

7. *Imbrication* means partly overlapping layers (not stacks), such as we would find in a good stone fence in New England. As a metaphor, it means the heterogeneous variety of things that partially hold one another up, including discourses, actions, architecture, work, and standards/quantifications/models.

The cultural values in the representation of alternative maps, by contrast, seem fairly transparent, especially in contrast with standardized flat maps. There are underlying standard databases that feed these maps. It is not so easy to access the geographical information systems underpinning many of today's maps, especially those coordinating and standardizing metadata.[8]

Metadata are equally imbued with values, as are all maps, but these values are much harder to pick out. Sometimes this is because they are embedded in numbers or layout; at other times, it is because we rarely get a view of how the metadata are distributed, collected, standardized, or designed (Chrisman 1997). The politics of metadata rarely appears in a way accessible to users. Rather, they are distributed over the bureaucratic, cultural, and military landscapes, appearing as settings, standards, and technical aspects of user's manuals. If we wish to understand more of the deep structure of interdisciplinary communication, it is important to develop good tools for parsing metadata—culturally and politically, as well as technically.

There is much work to be done to understand all the ramifications of this deep approach to standards. We need to understand more, for example, about the behind-the-scenes decisions made about things such as encoding and standardizing, decisions made about tinkering and tailoring activities (see, e.g., Gasser 1986; Trigg and Bødker 1994), and the observation and deconstruction of decisions carried into infrastructural forms. We need to understand more about how metadata develops as well as how it fails to develop, say, in cross-disciplinary work.

8. *Metadata*, a term originating in library and computer sciences, means data about data. Metadata about a library collection, for example, tells us what *types* of documents may be found in a collection (maps, manuscripts, archives, journals, or books) but not the exact titles held by the collection. This is an echo of our introductory example—what happens if someone tries to call our friend at 1-2-3-4-5-6-7? They will encounter a form that is devoid of content.

A deconstructive reading of infrastructure quickly reveals the presence of what literary theorists call a master narrative, that is, a single voice that does not problematize diversity. This is the voice of the unconscious center, the pseudo-inclusive generic. An example of this encoding into infrastructure is a medical history form for women that encodes monogamous traditional heterosexuality as the only class of responses: blanks for "maiden name" and "husband's name," blanks for "form of birth control," but none for other sexual practices that may have medical consequences, and no place at all for partners other than a husband to be called in a medical emergency. Latour (1996) discusses the narrative inscribed in the failed metro system, Aramis, as encoding a particular size of car based on the presumed nuclear family. Band-Aids or mastectomy prostheses labeled "flesh colored," which are closest to the color of white people's skin are another example of an embedded assumption. We may uncover them one by one, as do many of the chapters in this book; however, we also need deeper theoretical analyses to guide our wanderings and also to guide our development of a better way. Millerand and Bowker (chap. 6 in this volume) speak to the double process of deconstruction and working systems juggling real-time as well as archival forms of information. Standardizing and customizing proceed in absolute, messy tandem.

Many information systems represent and encode work processes, directly or indirectly (payroll systems, time sheets, activity reports, and flow charts are among the many infrastructural tools that perform this function in the workplace). Such tools, like language itself, are always incomplete with reference to both the complexity and the indexicality of the processes represented. People are always adjusting, working around standards to get on with their jobs and their lives.

But the solution to these silences and their negative consequences is not always simply making things visible to all. For example, when analyzing the attempts by a group of nurses to classify their work processes, Bowker and Star (1999) see them walk a delicate line between visibility and invisibility. They wanted their work to be represented in order to be legitimated; at the same time, if they categorized all the tasks they did and then built the forms into hospital record-keeping to track that work, they risked having the hospital accountants and health maintenance organization (HMO) officials deskill (see Lampland, chap. 5 in this volume) their work and try to fob parts of it off on less expensive paraprofessionals. So, leave the work tacit, and it fades into the wallpaper (in one respondent's words, "we are thrown in with the price of the room"). Make the work explicit, and it becomes a target for surveillance. The job of the nursing classifiers was to balance somewhere in the middle, making their work just visible enough for legitimation while maintaining an area of discretion.

Much infrastructure is marked with this sort of invisible trouble. In academic departments, the question of what work should be visible and what should count for promotions and tenure often brings this to a head. Researchers who develop large information systems, performing and visual artists, those whose work takes a long time to come to fruition (such as architects) are often at a disadvantage with promotion committees, which may not be able to evaluate or understand the invisible work that goes into research but does not culminate in a book or an article in a refereed journal. Similar problems occur in promotion standards or standards of conduct in large commercial firms.

Boring Things

This introduction offers a short guide to the large terrain of sociotechnical understandings of standards, quantification, and formalization, with an emphasis on standardization. Like all maps, especially those showing relatively unexplored intellectual terrain, it is incomplete, deleting the work involved in making it (although perhaps not wholly, we hope), and has several places where the old "here be dragons" is drawn around the black box of future investigation. Sorting through the richness of things and ideas to create an archive necessarily raises the question of choice and the politics of representation. Not everything can be either known or kept; politics aside, there simply is not room for every piece of paper, artifact, and form of representation. Size limits become political limits: Whose ideas and whose things *matter*? So we reach another kind of one-size dilemma—on the one hand, knowledge has different sizes, metaphorically speaking (and sometimes literally speaking); on the other, the purpose of an archive is to keep stuff in anticipation of the future, and it is hard to know beforehand what will be useful. The imperative to know is paired with the ability to keep and to hold; authority arises from classification as well as from ownership. Within the computer and information sciences, there is a serious utopian dream of remembering everything equally (for instance, there is a project begun years ago by computer scientist Douglas Lenat, the Cyc project, to store all commonsense knowledge into a huge electronic encyclopedia). These visionary musings of ever-expanding storage space obscure (one more time) the politics of collection and memory (Bowker 2006). These politics are irrevocably central to constructing archival projects, even large ones such as the Cyc project. Common sense shifts as mercurially as language does; retrieval questions are still organized by algorithm, paid-for space in an information field, and other questions of social stratification. The famous search engine Google, like all commercial search engines, sells electronic real estate allowing a firm's name to come up first in a search, even though other hits appear further down in the listing. Battles over whose knowledge will be remembered and who has rights to remember it will be fought visibly in conferences and computer centers, but will ultimately reside in the structures of data themselves, including their political, commercial, and sponsorship attachments. As Lampland (chap. 5 in this volume) shows, larger-scale political events and structures influence how work is remembered, how attempts to standardize and remember it may change radically over time, and how different forms of knowing and exchange (peasant measurements and bartering systems vs. centralized attempts to measure work hours) may be at war with one another.

One of the areas barely explicated is the difference between standards and conventions of human behavior. We name as standardized many examples of rote, repeated behavior devised according to a script or proscription. We messily and intentionally, therefore, traipse into the part of the map claimed by many sociologists and anthropologists as norms of behavior, conventional types of action, or the sorts of standard actions developed around material constraints and the functions of social worlds, such as described by Becker (1982) in his fertile analysis of these processes, *Art Worlds*. Why is a play usually two to three hours long? Becker argues that this timing derives from an intersection of constraints on work. The finances of production and wages for actors, security guards, parking attendants, and fast food conveyers are such that breaking this timetable may become too expensive. Over time, this convention becomes widespread—although never absolute.

Behavioral and technical norms also influence infrastructural elements such as time of performance. Babysitters must be paid so that parents can attend a play and must be home in time to go to school at a set hour (perhaps even a standardized hour when the bells and lockout system become imbricated with standard protocols for computer systems). People train their bodies to sit for so long and no longer. In the West, the tolerance for silences, confusion, and multiple voices is variable but, as a rule, not huge.

Where do such conventions and norms become standards, quantities, or parts of formal models? As we may expect, there is a leaky border among all of these sorts of action and inscription. We have rules of thumb,[9] not written guidelines, for everyday life. They meet conventions in a loose conglomeration of quantified inscriptions, technical delegation, and actions both locally and at a distance (standards), but do not usually include transient customs such as skirt length, habitual turns of phrase, or locally specific times when meals are usually eaten.

As with all conclusions, this is clearly not a satisfactory or comprehensive exploration of how these sorts of things meet. In fact, on this view, the rule of thumb we have described is *both* conventional and standard. This book lives in the middle and offers a number of empirical examples and analytic concepts that may help us, if not to clean up the messy imbrications, at least enjoy them, understand how they work, and minimize the suffering that overly specific or underly specific approaches may produce.

9. *Rule of thumb* is itself a fascinating term, dating back to a legal term and a social system still, sadly, in full swing; in early modern times it referred to the thickness of the implement with which a husband may beat a disobedient wife. Naturally, thumbs differ, but none is as big as a baseball bat or a log for burning in the fire.