Network Science,"Invisible" Information Managers in the Production of a Scientific Database

Florence Millerand

Original text: Millerand Florence, 2012. La science en réseau, Les gestionnaires d'information 'invisibles' dans la production d'une base de données scientifiques. Revue d'anthropologie des connaissances 6(1):163-190. DOI : 10.3917/rac.015.0201.
Translation by Daniel Brant. Translation review by Karen Baker.

Special Issue: "Small Hands in the Information Society"

NETWORK SCIENCE
"Invisible" Information Managers in the Production of a Scientific Database

Florence Millerand

Abstract

Contemporary network-based technological developments in the sciences draw attention to new forms of work, or even new categories of workers. Based on an ethnographic study of an American ecological research network, this paper focuses on the work of information managers, the "invisible technicians" who are in charge of managing scientific data in laboratories. The paper shows how the development of a large-scale database project goes hand in hand with processes of establishing different degrees of visibility for information managers and their work, It discusses issues related to the invisibility of data documentation work, particularly this invisibility's impact on scientific knowledge processes. The invisibility of information managers appears to be related to a fundamental aspect of their work, « articulation work », characterized by activities of bricolage, translation and deletion. The invisible work of data management and documentation is that of endlessly redoing and reinventing.

Keywords: invisible work, invisible technician, information manager, metadata, standard, infrastructure

Introduction

The scientific community is currently experiencing major technological developments in terms of digital infrastructures based in networks that facilitate, among other things, the circulation and sharing of research data beyond institutional and disciplinary borders. Following the first large science data banks in biology (cf. the GenBank or the Protein Data Bank), a similar movement is developing in other scientific domains, most notably in the natural sciences where current scientific challenges (climate change or biodiversity for example) require the sharing of large quantities of multidisciplinary data. As a result, scientists have constituted gigantic data warehouses that innovatively juxtapose new fields and create new types of work and workers in the scientific community.

The question of the production of these new scientific installations remains relatively unexplored. They are, however, of critical importance. How we classify, record, and stock data, information, and knowledge inextricably shape how we know (Goody, 1979; Bowker, 2006). Bowker has shown how the construction of databases in the field of biodiversity contributed to the organization and classification of the natural world in a way that unavoidably excluded certain spaces, entities, and temporalities (Bowker, 2000). We have shown how the choice of a digital standard for stocking and sharing data in the environmental sciences privileged *a priori* one disciplinary perspective over another by facilitating access to physical environmental data rather than biological data (Millerand and Bowker, 2008, 2009). Beyond their epistemic and scientific stakes, classificatory systems, terminological norms, and conventions can also render certain categories of actors and activities visible (or invisible), and, in so doing, produce a certain ordering of the world – for example, via the institution of a certain division of labor associated with certain mechanisms of social and professional recognition (Bowker and Star, 1999; Desrosières and Thévenot, 1988 ; Thévenot, 1986). As a result, it is important to examine the behind-the-scenes construction and implementation of such infrastructures in order to comprehend, on the one hand, the role of the materiality of their support and, on the other hand, the diversity of actors and activities involved.

This article focuses on a group of actors and activities rarely placed in the spotlight and commonly referred to as "technicians," a catchall term for all technical work. More precisely, it examines the work of information managers who, in the context of research laboratories and groups, ensure the management of research data which generally includes such activities as processing, conserving, stocking, collecting on-site data, and analyzing. From an empirical study based on an American network of ecologists (henceforth designated as the "Network" with a capital N), this article aims to improve our understanding of the role of information managers in scientific activity, and more precisely to envision the processes by which the work of these "invisible technicians" is rendered visible or invisible (Shapin, 1989) in the specific context of the development of a large database. I will show in this case study how the constitution of a network-wide database involved different processes of making the information managers and their work visible and invisible, and how this led ultimately to a partial redefinition of their role in the Network.

To begin, I will present the methodological and theoretical elements in order to situate this inquiry. I will then expound on the empirical study and the research terrain on which I base my arguments in this article. Following this, I will develop an argument in two parts. First, I will describe the work of information managers and insist in particular on the activity of documenting scientific data. I will propose an explication of the invisibility of information managers and their work by relating it to a fundamental aspect of their work, which I understand as "articulation work" according to Strauss (1985, 1988, 1992) and characterize, in the specific context of the management of scientific data, as activities of *bricolage*, translation, and deletion. Second, I will show, in the course of developing the database, how information managers become both partially "visible" – insofar as their new role or responsibilities are acknowledged – and "invisible" – insofar as a large part of their work has the effect of making them invisible. I will discuss the stakes making the activities of data documentation invisible in particular for the production of scientific knowledge. I will conclude by suggesting avenues of analysis for taking into account and studying the work of technicians in the contemporary development of digital infrastructures in the sciences.

Technicians, Infrastructures, and Invisible Work

> In the laboratory, technicians are just technicians. In the official history of scientific achievements, they do not exist by their name, race, gender, or identity but only by their function (Timmermans, 2003, p197).

Laboratory technicians, the small hands that work to advance science right beside researchers, have long been absent, not only from historical narratives of scientific discoveries (Shapin, 1989), but also from the work of sociologists of science. Recently, new work has opened the way for questioning research regarding the work of these "small hands," or those actors with little visibility in the production and circulation of knowledge, whether it be the contribution of amateurs (or the "non-scientific") (Mukerji, 2009; Epstein, 1995) or technicians in the broader sense of the term (Barley and Bechky, 1994; Shapin, 1989; Cambrosio and Keating, 1988; Lynch, 1985; Collins, 1974; Goodwin, 1995; Timmermans, 2003). Studies of laboratories have directed attention to the practical work of the production of scientific facts. In so doing, they have underlined the role of intermediary actors like technicians who work to link the entities of the physical world (the measurement of a quantity of carbon) to the symbolic world (the biomass of a forest), the particularities of a local experimentation to a system of knowledge (Latour and Woolgar, 1979; Traweek, 1988; Lynch, 1985; Knorr-Cetina, 1981). Though they have a key role in operations of "translation," notably in the production of "inscriptions" (Latour and Woolgar, 1979), the contribution of technicians is rarely analyzed in and of itself (from the perspective of a sociology of scientific work), but rather nearly always as a function of their contribution to the production of scientific knowledge (from the perspective of a sociology of knowledge) (Barley and Bechky, 1994). In the end, work that has examined technicians' role in science by questioning of the social organization of work in laboratories remains rare.

For non-technicians, technicians' knowledge and savoir-faire are generally perceived as being complex, or even obscure and their role as being above all a secondary role in the service of other, more intellectual, tasks at the forefront of scientific activity like writing scientific articles (Barley and Bechky, 1994). Moreover, scientific milieus are said to have a propensity to devalue collaborators with lower social status (Shapin, 1989) not only because the latter have a "support" role (technicians work for the researchers they assist) but also because the knowledge they hold is essentially a "contextual" knowledge that is certainly indispensable, but whose prestige is less compared to "formal" knowledge (Barley and Bechkey, 1994). As a result, technicians – like the precise nature of technical work – remain most often "invisible" (Star and Strauss, 1999).

However, technicians have in reality diverse tasks for which they mobilize vast sums of knowledge, whether theoretical or practical. Thus, Lynch (1982, 1985) shows how laboratory technicians in neurobiology who manipulate the electronic microscopes marshal both theoretical knowledge (and therefore certain scientific theories) and situated knowledge to identify anomalies and artifacts that the neurobiologists themselves are incapable of locating. In a different domain, Orr (1996) shows how technicians who are specialized in the repair of copy machines possess in-depth and sophisticated levels of knowledge about the machines that rival the engineers who conceived them.

In the laboratory, technicians are the actors nearest to the instruments and data that constitute the work of the laboratory ('the lab') in which their daily tasks involve close contact with the material infrastructure of scientific work. Beyond the scientific sphere, the notion of material infrastructure commonly evokes the idea of vast technological systems (like railroad networks and electrical systems) that are generally transparent to the user, laying in the background of social activities and only appearing visible in the event of outages (Star and Ruhleder, 1996). It is interesting to make a parallel with the work of technicians tasked with the maintenance of such systems, which also generally appears only when problems arise. In these cases, performance is judged on how well their work remains invisible. Contemporary digital infrastructures, of which the internet is perhaps the most emblematic example, are no exceptions to this rule.

The study of such infrastructures in the context of scientific milieus extends the analysis – heretofore centered on scientific fact or technical device to the socio-technical infrastructure, understood as a "knowledge production system" (Star and Ruhleder, 1996). This shift refocuses the study on the processes of constructing infrastructures, on the one hand, and takes into account their materiality, on the other. Star (1999) advises us to go backstage and to practice what Bowker calls "infrastructural inversion" (Bowker, 1994), or, in other words, to bring to the forefront these infrastructures that have traditionally been taken for granted. From this perspective, the study of work accomplished in practice or "in action" (Latour, 1987) rather than the study of the discourse of the actors reveals the existing gaps between those who do the work and those who are recognized for it.

Furthermore, paying attention to the material infrastructure, to objects and their "equipment" (Vinck, 2006) may allow actors or activities not regularly appearing in spontaneous or official discourse to become accessible (Vinck, 2009). The proprieties of objects, the way they are "equipped" (Vinck, 2009), materializes invisible infrastructures composed of standards, categories, and conventions (Bowker and Star 1999) that, while enabling their circulation, inevitably constrain it. Choosing certain categories and certain formats to describe scientific data is unavoidably characterized by the exclusion of others, for example when one indicates the name of the laboratory rather than that of the researcher as the author of data. Thus, databases are also sites of representations and political struggles (Bowker, 2000; Meyer, 2009; Waterton, 2010).

My inquiry here is based on the notions of "visible work" and "invisible work" formulated by Strauss in his studies of disease and hospitals (Strauss, 1988, 1992; Straus et al., 1985). Others have extended these distinctions to the study of the epistemic stakes of classificatory systems (Bowker and Starr, 1999) and to systems of representation in computer science (Suchman, 1995). "Invisible work" most often evokes a group of misunderstood activities (the informal tasks of diffusing information in an organization, for instance) or a marginalized category of actors generally at the bottom of social and professional hierarchies (the work of housemaids, for example) (Nardi and Engeström, 1999). But it could also involve highly specialized or abstract work activities requiring the management of information or knowledge (the work of research data management in a laboratory, for example).

I adopt a stance in which "no work is inherently visible or invisible; we 'see' work through a selection of indicators" (Star and Strauss, 1999, p.9). An activity may *become* visible or invisible depending on the context and, notably, on the power relations in place. The tension between the visible and the invisible is the object of constant negotiations (Star and Strauss, 1999). Making an activity visible may lead to social recognition for the work and the worker, but it may also result in the reification of work and open the way to new forms of control (Suchman, 1995). In the case of nurses studied by Bowker et al. (1995), the attempts to make their work visible (and, more broadly, their profession) collided with the need to maintain the ambiguous and personal character of certain tasks, for example the comfort of the dying in their final minutes of life. Finally, if making work visible necessarily implies its objectification and a certain *a priori* appreciation of its value, a large part still escapes formal codification. Each attempt to make work visible irreducibly leaves a portion invisible (Voirol, 2005).

One possible avenue for considering the linkage between the visible and the invisible is to question the definition of work and what counts as work, for whom, and depending on whom, can – or must –work be visible or on the contrary invisible? The notion of "articulation work" developed by Strauss (1985, 1988, 1992) is opposed to routine work, which is ordered, fixed, delineated beforehand and may be taken for granted. Articulation work refers to all the activities that bind a group or series of tasks, actors, or environments. In the words of Strauss, it is "that which accomplishes work" (Strauss 1988). Concretely, this articulation work essentially rests on (largely invisible) activities of planning, organization, evaluation, mediation and task coordination which enable the "articulation" of elements by a larger group (tasks, individuals, technologies, environments, etc.). Making articulation work visible recognizes the first-hand importance of the process – its ambiguous and embryonic nature – over that which is produced, quantifiable, and predictable. It also recognizes the value of those who are responsible for it and whose role is overly misunderstood and underestimated (Star 1991a). As such, coordination roles in general offer a useful example.

Choosing to account for the work of an underrepresented category of workers in sociological studies about scientific work inevitably contributes to the visibility of a particular point of view (Star, 1991b). In so doing, it becomes possible to explain differently the success or failure of technical innovations and to bring to light the processes that make visible/invisible people and their activities. Laboratory work is also a moral and political activity in which the contributions of actors are not evaluated in the same way according to status (Shapin, 1989), race (Timmermans, 2003), or gender (Garforth and Kerr, 2010).

The Case of Information Managers in a Scientific Network

The arguments developed in this article are the fruit of an ethnographic study conducted among an American network of ecologists. Founded at the beginning of the 1980s, the Network represents the largest scientific community in its domain with more than 2,000 researchers and students divided among 26 sites (or research stations) and a 27th site for the administration of the Network. Fundamentally interdisciplinary, the Network combines more than 60 fields from climatology to zoology including plant biology, geology, and limnology. Each site brings together a team of a dozen researchers on average for the study of a particular biome (a group of ecosystems particular to a given region, for example a hot desert or a coastal estuary). At each site there are also variable epistemic cultures. In fact, even if the Network's ecologists share a certain vision of Nature and of the study of ecosystems, their expertise differs broadly according to their objects and methods of research (phytoplankton, penguins, nutrient flows, etc.).

The archiving of research data is one of the Network's priorities since its inception because the aggregation of large quantities of data (from the field notably) is an important characteristic of the environmental sciences today. Thus, a position is dedicated to the management of research data at each site.[1] An "information manager" (sometimes called "data manager"), most often trained in or familiar with both information technology and environmental sciences), occupies this function (alone or part of a team at some sites). Nearly a third of the information managers possess doctoral degrees in science (computer or natural sciences) while the rest have Bachelors

[1] This position has been provided for in the Network's budget since its creation.

or Masters degrees. Most information managers with a doctorate are active in research projects either in the Network or in other research communities.

With a wide geographical distribution[2], information managers are a *de facto* community. They meet each year for a network annual conference where they participate in discussions, presentations, workshops, demonstrations, etc. Formal working groups and informal monthly meetings (by tele- or videoconference) together with their own information newsletter allows them frequent opportunities for communication and collaboration. Although it brings together many different profiles, a strong and stable identity in the long term helps distinguish the information manager community within the Network. In terms of organization, formal recognition as a committee (Information Management Committee) and a representative on the Network's administrative council provide the group representation.

Information managers are in charge of all the research data produced at their sites. They ensure the coordination of all tasks connected to the production, manipulation, archiving, and, in certain cases, the exploitation of data: collection in the field, treatment, quality verification, stocking??, analysis, web site and database publication, etc. Concretely, once data have been collected in the field, the "brute" data are given to the information managers who then digitize them (if it has not already been done) by inscribing the metadata (literally the "data about the data") in a way that conserves the data's context of production.

Documenting the data consists of indicating general information such as the research project title or the names of researchers and more detailed information about sampling techniques, instruments, measuring units, etc. Generally, a part of this information is recorded at the site of data collection itself, on paper or electronic tablets, by researchers and their teams. This information will then be greatly elaborated (completed and verified) by the information managers during organization of the data in the laboratory and the database recording (registration and ingestion). Data documentation carries special importance within the Network since the latter has, since the 2000s, made public data produced at its 26 research sites.[3] In other words, each researcher's and each site's data in the Network must be available online to be shared and reused not only within the Network but also outside it. This implies, first of all, that the documentation of data is sufficiently complete and detailed to be able to leave the laboratory's walls – and the disciplinary traditions – in which they were produced. This documentation corresponds to what Vinck (2011) calls the equipping, or the addition of a thing to an object which modifies its status and proprieties and which, notably, inscribes it into a space of exchange and circulation. For example, a series of chemical measurements on water in a given aquatic milieu can only be compared to another if the details regarding collection conditions (date, geographic localization, instrument type, depth level, analytical technique…) are also present. Metadata documentation constitutes the *sine qua non* condition for the mobility of scientific data. For the remainder of this article, I will focus on the task of documenting, a process that sometimes is called data contextualization or metadata production.

---

[2] The 26 sites and research states in the Network are spread across the United States, Antarctica, and the Arctic.

[3] The sites have a maximum delay of three years from the moment they are collected to put their data online. This expectation is integrated into the evaluation of each site's scientific production which takes place every six years and determines the continuation of research funding.

Data documentation currently constitutes an important activity, if not the most important, in the work of information managers in the Network. It is important to specify that the Network's policy regarding the free circulation of research data is rooted in the project of developing a very large database based on a process of standardizing data documentation procedures. In fact, the free circulation of data in the Network rapidly encountered a large diversity of systems, technical architectures, modes of classification and data documentation. A common descriptive standard for data (or metadata standard[4]) was adopted (in 2001) to give uniformity to the operations spread among the 26 sites (figure 1 presents an example of standardized metadata). The "cyberinfrastructure" project (a term utilized by the Network for its very large database project) targets not only the publication of data for dissemination among researchers but also online detailed analyses of large quantities of interdisciplinary data, which requires a carefully refined level of data documentation.

```
<geographicCoverage>
        <geographicDescription>Ficity, FI, metropolitan area,
                USA</geographicDescription>
        <boundingCoordinates>
                <westBoundingCoordinate>-112.373614</westBoundingCoordinate>
                <eastBoundingCoordinate>-111.612936</eastBoundingCoordinate>
                <northBoundingCoordinate>33.708829</northBoundingCoordinate>
                <southBoundingCoordinate>33.298975</southBoundingCoordinate>
                <boundingAltitudes>
                        <altitudeMinimum>300</altitudeMinimum>
                        <altitudeMaximum>600</altitudeMaximum>
                        <altitudeUnits>meter</altitudeUnits>
                </boundingAltitudes>
        </boundingCoordinates>
</geographicCoverage>
<temporalCoverage>
        <rangeOfDates>
                <beginDate>
                        <calendarDate>1998-11-12</calendarDate>
                </beginDate>
                <endDate>
                        <calendarDate>2003-12-31</calendarDate>
                </endDate>
        </rangeOfDates>
</temporalCoverage>
```

Figure I. Description of geographical and temporal coordinates in the metadata standard language.

In practice, the implementation of a common standard for describing data which constitutes the cornerstone of the very large database project was an extremely complex and laborious process

[4] The standard, called "Ecological Metadata Language," is a standardized language of data description specially developed for ecology.

that was marked by the confrontation of "data cultures" proper to different research teams.[5] In 2007, six years after the adaptation of the common standard, barely half of the sites had succeeded in documenting their data according to the standards and it was not until 2009 that all the sites generated properly documented data sets. As I write these lines, the large database project is still being developed.

In my ethnographic study, I followed this database project paying special attention to attempts to standardize the process of data documentation. Following Bowker's (1994) principle of "infrastructural inversion," I observed the development work on a technical infrastructure (decisions and choices regarding architecture and technical standards, etc) and its contents (types of data, represented disciplinary fields, etc.), work in which information managers were, in practice, at the forefront and which redefined their work through processes of becoming visible and invisible. The inquiry rests on participant observation techniques, interviews with the actors, document analysis (technical documentation, reports, etc.) and artifacts (databases, prototypes, etc.) over a period of two years (from 2004 to 2006). I was based at the university institution where two of the 26 research sites are established. I was able to observe, *in situ*, and on a daily basis, the work of researchers, students, research professionals, technicians, paying particular attention to information managers. I observed these sites by participating in the activities and events that occurred there: work situations, scientific conferences, meetings, teleconferences, design sessions, hallway conversations, etc.

MAKING WORK VISIBLE/INVISIBLE

Scientific Data Documentation: The Work of Small Hands

Susan is an information manager at one of the Network's 26 sites where she works with two program technicians to administer research data. The site's research team brings together a dozen researchers, primarily oceanographers, to study the effects of climate change on marine ecosystems; around twenty students and post-docs as well as about ten field technicians complete the team. My description of the work of data documentation comes from an example of data collection that occurred during a scientific mission at sea.

The measurement of biomass (the mass of living organisms in a given milieu) is the main focus of the research conducted by the site's team in order to measure change in the ecosystem. Measurements are done at sea during regular missions lasting several days or weeks aboard a scientific vessel. Before each mission, Susan prepares the data documentation forms on which the researchers will record the information relating to the measurements taken out at sea. Researchers, students, and technicians, all of whom take turns on deck manipulating the instruments and collecting samples and in the ship's mini-labs conducting preliminary analyses, fill out the forms. As for Susan, she remains on land in the laboratory. Explaining the details of this collection process to measure biomass[6], she says:

---

[5] On this point see Baker and Millerand (2010).
[6] The measurement of the concentration level of chlorophyll is used here as an indicator of the quantity of vegetal plankton in an aquatic zone, which corresponds to the biomass (or the mass of the living organisms in a zone).

> First, we have the fluorometer, it's the instrument used to measure the biomass or actually the chlorophyll at sea. So after calibrating the instrument, we bring it out to sea. At sea, the sampling bottles are lowered over the side so that water can be taken at different depths, they are brought back up in large 15L bottles, and then we use small 200mL bottles to take sub-samples. After we take a bottle of each one and bring it to the lab where there is a filtering system in which we insert a certain sized filter and pour in our sample. All the plankton contained in the chlorophyll remains trapped by the filter. Next we take this filter and put it in the freezer for 24 hours so that the cells are separated, then we take these frozen samples and put them in acetone to extract the chlorophyll from the cells (…) we get a liquid that we then put in the fluorometer (…) that'll allow us to say that the fluorescence will be proportional to the chlorophyll.

Summarized in this way, the collection protocol appears relatively simple: salt-water samples are taken using bottles at different depths, their contents are then filtered and analyzed with a device called a fluorometer. Although this manipulation is relatively common in plankton biology, a whole host of questions arise in relation to the documentation of the data collected, here chlorophyll concentrations: in which context were the data collected (for which research project, on which date, by which team, etc.)? which sampling technique was used (what size bottles? at which depth, etc.)? with which extraction technique (filtering, which type, size, etc.)? which method of analysis (fluorescence, pigments, etc.)? Each response to these questions can represent a large amount of information that is generally greater than the data themselves.

The data documentation process doesn't begin when the team leaves land (or the ship), but at sea, at the moment the instruments are deployed and the initial analyses in the mini-lab are conducted:

> First, when you collect your samples, you begin to use the paper, and you write the depth, the station, latitude, longitude, etc. so that the samples have labels to indicate the context of their collection. After, when you use the fluorometer, for each reading, you write on the appropriate line on the paper, the fluorescence, let's say the read is done in units of fluorescence. (…) We also write the characteristics of the measurement instrument (…). You have to write also how much water was filtered, etc.

The first data recorded on the form help to document the context of the data collection in time and space (date, geographic location, depth, researcher's name, etc.). These are the first level of metadata. Next, the volumes of the analyzed samples, the values measured, the characteristics of the instrument of measurement all will be indicated; this information constitutes a second level of metadata. First-level metadata is essentially used to identify data clusters for, for example, a search on the subject (ex.: biomass), while second-level metadata allow for their interpretation and analysis. Without the details of the method of analysis, for instance, the data would have little interest for a researcher wishing to use them.

> The notes from these notepads are then entered into Excel. In this case they do the calculations out at sea or wait and enter the data at the lab, sometimes it's just a text file, not Excel, it depends. (…) when the data arrive, the phytoplankton team will work a bit on the data and then they'll send us the file, usually by mail.

The filled-out forms are then transferred into digital format and passed from the research team's hands to those of the information manager. These forms play a particularly important role in the coordination of the research team's work. Created by the information manager, they are brought with the material on-board the ship where they circulate between the bridge, sampling stations, and the mini-lab, passing from hand to hand before returning to the information manager. By circulating among the different research activity sites (at sea on-board the ship and on land in the laboratory) and among the different actors (researchers, students, technicians, information managers), they resemble the boundary-objects described by Star and Griesemer (1989) that support the coordination between different social worlds. More precisely, the form acts here as a "standardized form," that is both a method of communication between different actors and an information depository in the service of preserving data.

Paying attention to the circulation of the forms reveals the distributed nature of the data documentation process that is accomplished in reality by several categories of actors. Moreover, the documents that are used are intermediary documents destined to be transformed and to disappear (the paper form becomes an electronic file which itself is then integrated into a model form). The activity's layout and the ephemeral nature of the support material make it difficult to conserve traces, on the one hand, and, on the other, to identify clearly delineated roles, both of which contribute to the invisibility of these tasks in the overall research process.

> Once we have the file, we have to put it into the pattern "model" form. Because sometimes [out at sea] they change the order of the columns because it's easier for them to fill them out, sometimes they add columns, so we need to check them. For example, they'll have recorded latitude in degrees, minutes, seconds, that's generally how we do it because it's the easiest to understand. So we have to convert these three columns into decimal degrees because that's how the data can be inter-operated. So, for example, if they sent us the chlorophyll data with three decimal points, we know that it's actually one decimal point, the three points are from the instrument because it's digital, so we check with them but make the changes. (…) After, once we've finished the metadata, we pass the data from our production environment [the site's protected database] on to the public sphere, we just change the privileges and it becomes public and consultable.

From the Excel file, the information manager's work consists thus in revising its contents and, most of all, in standardizing the documentation that is produced, by for example using predefined model forms. The work discussed here is one of translation (personal formats are converted into standard formats) as well as one of correction (columns are reordered, values adjusted, decimal numbers set, etc). In other words, the work effaces the traces of the particular contexts in which the data were collected (what Latour and Woolgar (1979) called, in a different context, the erasure of modalities) making way for purified data without the idiosyncrasies of any one individual or laboratory. Information managers thus polish the data to make them mobile and independent of the environment from which they were produced, yet full of precious documentary information that allows one to resituate the data in their original contexts.

In this process, information managers play a key role because they directly affect the quality of the data by enabling their interoperability (and therefore their comparison with other data), by correcting errors, checking anomalies or artifacts introduced by the procedures, and by adding to the field data the precious contextual information that will enable their interpretation. Their level of scientific research expertise is at stake in the quality of data and documents they produce. As Susan explains, "the problem is that information managers are translators and so they could take that literally (…) the researches know this and make the corrections in their head (or so one hopes)." This is an important question within the Network because the information manager cannot be trained in every method used by researchers at his or her site.

Looking in particular at the work of documenting scientific data better reveals the nature of the work of information managers which largely resembles "articulation" work (Strauss, 1988).

> "One cannot do things that figure among the evaluation criteria that the community valorizes. One does not write grant applications for ten million. One does not publish billions of paper every year. One is too busy just *so that the work gets done.* Thus, on the basis of the criteria traditionally used by most of the scientific community, one is simply *invisible*" (my emphasis).[7]

"So that the work gets done" describes precisely what is at the heart of the articulation work that characterizes certain types of work inside organizations. It is work done in the background, generally misunderstood, non-formalized and difficult to formalize; work that is strictly speaking *invisible* but that allows the work to be done and individuals and collectives to work together and cooperate.

In his study on the organization of medical work in a hospital (Stauss et al., 1985), Strauss and colleagues show how nurses are tasked with combining the perspectives of different actors (doctors, patients, families, etc.), a job that also requires the supervision and coordination that are fundamental to administering care but which remain misunderstood, ignored, or undervalued. Similarly, information managers are at the center of collaboration between different categories of actors (researchers, personnel, students…) and different scientific communities in which they conduct the invisible work of coordination and mediation. As the above excerpt illustrates, information managers are also invisible to researchers because their work corresponds little to what the scientific community values and because it cannot be measured or quantified according to the scientific community's traditional evaluation criteria (number of publications or amount of grants).

That being said, the work of information managers is characterized as well by a series of activities of *bricolage* (distinguished by situated knowledge), of *translation* (between technical and scientific domains and between social worlds), and *deletion* (of the activity's traces) which equally contribute to their invisibility.

Lévi-Strauss opposed the bricoleur, a sort of handyman whose competence and knowledge are generally applied according to the situation, to the engineer whose tools and aptitudes are put to use for specific projects. In many ways, information managers are bricoleurs. They learn the rudiments of the profession on the go, they must demonstrate versatility and improvisation on a

---

[7] Citation taken, with the authors' permission, from an ethnographic study conducted in 2004 by Karasti and Baker within the Network. See Karasti and Baker (2004).

daily basis. The work of data documentation itself even resembles bricolage. Thus, a data manager from an affiliated program recounts how several years before the adoption of the standard, he had created from scratch a data documentation format evocatively titled “Everybody Happy Format, EHF” to satisfy the needs of his community. Taking into account the technical computational constraints (concern about interoperability and maintenance), scientific constraints (compatibility with other functioning documentation formats in related disciplines), and the expectations of each of the researchers at his site (about the types of data to describe), he “bricoled” a “home-made” format that, at the time, satisfied the main concerned parties.

Information managers are also translators insofar as they carry out operations of translations between technical and scientific aspects as well as between social worlds. The first dimension of translation is without a doubt the most tangible and corresponds to the very function of a technician, a specialist in a particular technical domain. Information managers convert “raw” research data into readable and interpretable formats for researchers. The second dimension relates to operations of translations between social worlds. Information managers are at the heart of a network of relations that traverse multiple disciplinary, organizational, and institutional domains. If the researchers at the site of which the information manager is a part constitute the latter’s principal interlocutors, he or she will collaborate with the rest of the researchers in the Network, with other research communities, and with the general public (to the extent that the data is available on the internet). In so doing, information managers constantly cross disciplinary or institutional borders (for instance when they publish data from the Network in the institutional archive of a specific university).

Finally, the very nature of the information manager’s work consists of erasing all its traces and make it “transparent.” Information managers work very hard to mask the disorganized, poorly presented, artifact-ridden jumble of data with which they work and to confine the boring work of “clean-up,” organization, and classification of data inside the system. For this is precisely an important aspect of the work of technicians, as Orr (1996) demonstrates in his ethnography of copy machine service technicians who take care to remove any powder trace that could testify to their presence or Suchman (1995) in her study on documentary technicians in legal offices whose work must be presented in court. The work of information managers in the data documentation process may rarely be read or watched: the paper documentation forms researchers bring with them constitute those rare visible documents of the process. Once transferred to electronic media, they are placed into a system of classification and put into the architecture of a database that for the most part will remain invisible to its users.

Making Information Managers Visible: The Recognition of a New Role

The work of standardizing, verifying, and completing the documentation of scientific data is central to the work of information managers examined in this article. In its decision to adopt a common standard for metadata for its very large database project, the Network has taken this process of standardization to a new level. No longer are data documentation standardized solely by research teams at the same site but by the rest of the Network and even the larger research community of ecologists.

Adopting the standard targets two major changes in the practice of data documentation. On the one hand, the documentation must henceforth respect the language and structure of the standard, which implies that the sites must adopt new ways of operating. On the other hand, the researchers are pre-supposed to be the principal actors of this process, taking on now the task of data documentation themselves.

In reality, the production of standardized metadata proves to be an extremely laborious process and, confronted with such a complex task, researchers almost immediately rejected this new role, which was assigned to information managers. In so doing, the complexity of documentation, and those who were primarily responsible for it, in other words the information managers, were given a certain degree of "visibility."

The Dirty Work

When the Network adopted the standard in 2001, the presumed or "configured" users (to borrow the term of Woolgar, 1991) were researchers. At this stage, no other category of actors (technicians or information managers, for example) is mentioned in the documents relating to the standard, destined to "improve the sharing of data among researchers" able to benefit from this new standard representing "the state-of-the-art of metadata standards."[8] One might expect researchers, who are most familiar with their data, to document them and publish them directly in the established database.

However the researchers in the network refused from the start the task, on the one hand, because of the quantity (and complexity) of work that was implicated and, on the other hand, because it seemed like data management work in the broadest sense, which is typically done by information managers.

> "The quantity of metadata to produce is ten times more important than the size of data collected! So researchers aren't going to even try … They would prefer to do their research."

If, as this information manager suggests, the weight of the task discourages researchers from the start, it involves activities that researchers generally try to avoid, or wish not even to *see.*

> "You know, deep down, it's because they don't want to have to deal with it, so they are very happy that I can take it off their hands."

With researchers having refused the role assigned to them in the database project's "script" (Akrich, 1992), the task was rapidly and almost "naturally" given to information managers (to use an informant's own words). Delegating work in this way to information managers resembles what Hughes (1996) called the delegation of dirty work in the health care field, in this case from doctors to nurses. He remarked that, when a profession delegated tasks, they were often tasks considered to be at the bottom of the scale of social values, tedious or even degrading, and that the delegation aimed generally to reaffirm the hierarchy of competency in order to preserve prestige. As for information managers, the researchers in the Network quickly found in the

[8] Internal document, my emphasis.

person of the information manager at their site a way to rid themselves of the problem and the justification was already there since this person already took care of data management work.

Information managers begin the work by converting existing documentation at first and next of producing standardized documentation. However, like the multidisciplinarity that characterizes the Network, documentation practices are extremely disparate and "resistant" to efforts of standardization that have been undertaken. Firstly, the standard proves to be complex; appropriating this new way of describing data is literally to appropriate a new language (in the format of the XML language) with which one must "code" data. Yet information managers have neither the expertise nor the capacity to find the necessary additional resources (even if only in terms of available time). They encounter moreover a flagrant lack of support within the Network, as this manager suggests:

> "One of my greatest frustrations is that they ask us to do it without giving us additional financing even though it requires enormous resources."

In this context, those who succeed in recruiting additional personnel (an intern for instance) are rare. The majority had no other choice but to train themselves on the go. In any case, the experience was difficult: they felt unprepared, "incompetent," or "under qualified" (in the words of an informant). Secondly, the technical tools destined to facilitate the implementation of the standard (notably the automated tools for converting existing documentation into standard documentation) as well as the provided guidance (in terms of training) proved to be useless or inappropriate. The tools created important problems of compatibility within a site's existing data environment and the training provided was not aligned with the needs of sites (learning curves vary as a function of information managers' prior training). Thirdly, and this is where the difficulties are the most advanced, the standard created fundamental problems that exceeded the information managers' responsibilities by broaching epistemic aspects of research data. Very rapidly, managers realized that changing the way they document data came with important consequences for how data are recorded, archived, or even produced. For example, when the systems of classification are unique to one laboratory or researcher, should they be corrected? If not, how can one make them conform to the predefined categories of the standard?

Shaping categories

> "We use a lot of personalized units (*unités*) in our projects that we have created ourselves. (…) These units are not equivalent with the standard, so we have to put them in bulk in the 'method' field … deep down it is not very useful."

In the citation, the information manager mentions an absence, in this case of a missing category for "personalized units," for which she is "obliged to put them in bulk in the 'method' field." This "is not very useful" because the "method" category is a sort of catchall drawer in which methods are described in the form of text. The level of precision and completeness of these descriptions can vary considerably since it is left to the author's discretion to make sure that all the important information is recorded there. Under such circumstances, the quality of the information is highly variable.

In their work on systems of classification, Bowker and Star (1999) show the invisible and constraining force of categories in the production of a social order, which can contribute to privileging certain points of view or, on the contrary, to reducing them to silence. The problem of the lack of equivalency for the personalized units evoked in the above citation reflects the tension between two dominant disciplinary traditions inside the Network, between physical science-based disciplines (ex. climatology) and biology-based disciplines (ex. marine biology), both of which rely on very different types of data.[9] Physical data use standard units of measure (ex.: degrees Celsius for temperature, meters for depth, etc.) while biological data use, in addition to standard units, "personalized" units, created for the particular needs of each project (ex.: "the number of leaves on the lower branches of a plant," "the proportion of live eggs to dead," etc.). Yet it so happens that the standard adopted by the Network incorporated units from the physical science models, and, thus, it is possible to document easily only physical units.[10] In the case of biological data, it is necessary either to "twist" the existing categories or to create new ones.

The work of shaping new categories occupied information managers at all sites and provoked several modifications to the standard. Susan and her team, for instance, created, in the end, a whole collection of new sub-categories destined to structure the "method" field for their site that allows them to capture the diversity of sampling techniques and analytical protocols. By allowing them to specify methodologies, these new categories will also allow them to complete documentation in a way that interprets data correctly, which directly reflects upon the question of the quality of research data.

> For example, are samples treated by extraction or pigmentation? If it's by extraction, how big is the filter? … If we don't have the type of filter or its size, it's a real problem because, if you take datasets and regroup them while, in one case, it's one type of filter and in another, a different type, you introduce major errors into the analysis, and that is what happens…

In the citation, the omission of the filter type used in the extraction technique can cause erroneous data amalgams and lead to invalid results.

> I know that Margaret often uses the HA filter and Rob the GFF and that both usually use these specific filters without thinking to indicate it and that they don't specify the size because they forget and often they only use one size so they forget there are several (…) when I don't know I go and see them about it and they are dumbfounded because they never ask themselves that question.

The work of documentation introduces new constraints that directly affect the way researchers and research teams, even entire laboratory cultures, operate. Margaret does not specify the details of the equipment she uses (name and filter type) because it's implicit knowledge (she only uses one type of filter). The task of information managers resembles then a veritable process of

[9] In the scientific field, ecology belongs to the biological sciences. However, it calls upon several disciplines in the physical sciences, notably physical geography, geology, pedology, etc.
[10] This aspect and more broadly the political stakes of databases are discussed in Millerand and Bowker (2008, 2009).

elicitation of knowledge to make sampling techniques, methods of analysis, units of measure, etc. more explicit. This knowledge is situated and intimately linked to epistemic cultures. Shaping the categories of the standard forces knowledge to be rendered explicit, the choice of conventions discussed, and tends to formalize tacit tasks. Thus, a new type of exchange begins between information managers and researchers in which they discuss the choices of denomination, classification, organization, and presentation of data. The exercise makes the difficulties with which information managers are confronted and the actual work of elaborating content from the standard to become visible to researchers in particular.

A New Role

At the annual meeting of information managers when standardization efforts had entered their fourth year, information managers were given the role of "co-developers" of the standard (Millerand and Baker, 2010). For the first time, their name appeared along with the standard. Information managers were recognized not only within the Network but more broadly within the scientific community of ecologists. They became visible:

> "[The standard] is defined and revised in the context of a continual effort in the scientific community in which the Network's information managers in particular participate."[11]

This recognition comes in the wake of a series of polls about the progress of the process of standardization at the sites and following a memorable meeting between the Network's information managers and the developers of the standard that took the form of a workshop at the annual meeting in 2005. These two events constituted the mechanisms of making the information managers' work visible. On the one hand, the polls revealed the scope and complexity of the task by revealing notably the delays in the process of standardization. In so doing, they contributed to casting the process of standardization as a phenomenon (Igo, 2007), here a complex and laborious process. On the other hand, the workshop was the occasion for information managers to show the inherent flaws and limits inherent in the standard and, most importantly, the "corrections" they provided. During this occasion, they offered demos, presented their tools, discussed different solutions, etc. The workshop led to the publication of a report in the quarterly bulletin of the Network's information managers co-authored by representatives of the two parties (managers and authors of the standard). Information managers' role as co-developers of the standard was now institutionally recognized.

Making Information Managers Invisible: Denying the Recognition of Processes of Work

The institutional recognition of information managers happened however at the expense of the recognition of certain processes, which are fundamental to the work of data documentation yet remain invisible.

The visibility or invisibility of a work activity generally rests on the methods of inscribing and formalizing tasks, which Voirol (2005) has called "formal visibility" in the work environment. In this way, strategies for formalizing an activity are employed to make it "visible," for example a description of tasks associated with a title, level of salary, responsibilities, etc. Writing plays here

[11] Internal document.

a leading role. Information managers developed a series of tools and additions to the standard, among which figured a list of "Best Practices" to encourage the production of standardized metadata. The document, conceived as a practical guide to facilitate the work of data documentation, is also mainly an attempt to formalize new work procedures via writing. However, it was rejected by the authors of the standard and ignored by the Network's managers, seen as an administrative tool during review of site data practices. The practical activity of producing standardized data documentation thus remains without any recognized written traces.

The writing of the document began in 2003 when a handful of information managers suggested creating a common document that would explain in a simple way the contents of the standard. After some months of work, the document, which had transited around most of the Network's sites, brought together, among other things, a series of definitions and explications on what a given metadata field could and could not include. For example, each data set must be linked to a "project" just as it is associated with the name of a researcher or a laboratory. In spite of its apparent universality, the category "project" proved to have different meanings in the disciplinary context of each site.

> "I remember asking myself: is 'project' a '[scientific] cruise' (*expedition*), which, for us in our system, is 'study' or is it the name of the 'site'? This can be interpreted in several different ways, for example at Rob's site, let's assume they are working on mushrooms right now, and so for them, 'project' will be the name of the project: 'Mushroom Project 2002-2004.' But if we did that with our cruises, since we have more than one in the same project, we'd have several projects: 'Jan01-Study,' 'March01-Study,' even though they are for the same larger study. So that caused some problems because the data can't be compared if they aren't organized in the same way."

The example here reflects modes of classification and organization of data that are intimately tied to traditions of research. Univocal and unproblematic in vegetal biology in which it is easy to associate a collection of data to a research project, the collection of data in oceanography makes their classification otherwise more complex. The scientific cruises (the expeditions) are most often the occasion to collect data for several projects (for the logistical reason of cost), thus combining chemical, biological or physical measurements. These data then form their own collection (ex. "Jan01-Study') where each expedition is defined as an entity: "each cruise is its own story" (in the words of an informant). One can understand how such differences may constitute an obstacle to sharing these data, notably in a database. These differences and their consequences on the creation of standardized documentation are precisely what the document on best practices addresses. To return to the cited examples, in the context of multidisciplinary research with oceanographic datasets, it was decided, for precision, that the latter should be associated first with the team and the research site that yielded them and then with one or several research projects.

The "Best Practices" written by the information managers are more than a series of technical recommendations, they are also the expression of a process of formalizing work that attributes roles to different categories of actors (ex.: the information manager is responsible for verifying metadata with the author of the data), the ordering of task (ex. : follow the field guide for the stages of conversion), which translate the responsibilities or negligence of certain responsibilities, for example here a document that fails to respect the standard regarding multidisciplinary data. In addition, the document addresses all the work of interpretation and shaping of categories done by information managers.

Seeing in this effort of formalization the tangible proof of their contribution to the improvement of the standard and with the idea that other communities could benefit from their experience, the information managers proposed to include their "Best Practices" in the documentation that comes with the standard. But the standard's authors disqualified these practices from the start, judging their contents too "provincial" (in the word's of an informant). Considered too "amateur" and too linked to the local particularities of their sites. In other words, the "Best Practices" written by the information managers conflict with the universal vocation of the standard. One developer explains:

> "The Best Practices could have been included with the documentation of the standard if they had been more general since we wish to serve the largest possible part of the ecological community."

By rejecting the idea to integrate the document with the standard, the work of the information managers is made invisible. More precisely, what is made invisible is the local, situated, diversified work of fabricating standardized documentation, in other words the work of interpreting and shaping categories to fit different laboratory and disciplinary cultures and traditions. Non-formalized, this knowledge about the making of documentation, the shaping of categories, etc., will likely not be the object of the process of accumulation, and other communities will have no choice but to take the same route as the Network's information managers. But it is necessary to say as well that choosing to recognize the work of 'little hands' would disrupt the universal character of the standard and, thereby, call into question the logic of top-down development of the National Research Center that created a standard as a solution to the problem of documenting data from all ecological research communities. In the end, the work of little hands in data documentation must constantly be remade and reinvented.

Conclusion

Current trends in the development of large databases for scientific collaboration bring to light new formalizations of research practices and call for a better understanding of the role of actors behind the scenes of the production of scientific data. The analysis of mechanisms for making visible or invisible processes of work and workers in the context of a large database project within a scientific community reveals certain facets of how one category of actors' work, information managers, is brought to light or ignored. In this way, we witness the process of "invisibilization" (Denis, 2009) that is not only the result of the disappearance of the traces of work but also a devalorization of the activity as such.

That being said, if, like technicians, "their work forms an easily erasable layer of the palimpsest of science" (Timmermans, 2003, p. 198), the information managers could see their role gain new importance when large database projects begin to multiply. Straddling technical sciences and environmental sciences, these invisible workers possess the savoir-faire and knowledge that are an indispensible link in the production and circulation of scientific knowledge, most importantly via digital networks. In an era of initiatives of "network science," foregoing the "small-hands" work of information managers will lead to a poorer understanding of contemporary scientific practices.

Acknowledgments
I would like to thank Karen Baker for her precious collaboration as well as the editors of this issue and the anonymous readers who contributed greatly the improvement of this article. I would also like to thank the members of the Network for having accepted to participate in this study and the Social Science and Humanities Research Council of Canada for having financed it.

References

Akrich M. (1992). The de-scription of technical objects. In W. E. Bijker & J. Law (Eds.), Shaping technology/Building Society. Studies in Sociotechnical Change. Cambridge, MA: MIT Press, pp. 259-263.

Baker, K. S., & Millerand, F. (2010). Infrastructuring ecology: New challenges for data sharing. In J. Parker, N. Vermeulen & B. Penders (Eds.), Collaboration in the new life sciences. Surrey. Burlington: Ashgate, pp. 111-138.

Barley S. R. & Bechky B. A. (1994). In the Backrooms of Science: The Work of Technicians in Science Labs. Work and Occupations: An International Sociological Journal, 21 (1), 85-126

Bowker G. C. (2006). Memory Practices in the Sciences. Cambridge, MA: MIT Press.

Bowker G. C. (2000). Biodiversity Datadiversity. Social Studies of Science, 30 (5), 643-684.

Bowker G. C. (1994). Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920-1940. Cambridge, MA: MIT Press.

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

Bowker G. C. Timmerman S., & Star S. L. (1995). Infrastructure and organizational transformation: classifying nurses' work. In W. Orlikowski, G. Walsham, M. R. Jones, & J. I. DeGross (Eds.), Information technology and changes in organizational work. London: Chapman & Hall, pp. 344-370.

Cambrosio A. & Keating P. (1988). "Going Monoclonal": Art, Science, and Magic in the Day-to-Day Use of Hybridoma Technology. Social Problems, Special Issue: The Sociology of Science and Technology, 35 (3), 244-260.

Collins H. M. (1974). The TEA Set: Tacit Knowledge and Scientific Networks. Science Studies, 4, 165-186.

Denis J. (2009). Le travail invisible de l'information. In C. Licoppe (Ed.), L'évolution des cultures numériques, de la mutation du lien social à l'organisation du travail. Paris: FYP, pp. 117- 123.

Desrosières A. & Thévenot, L. (1988). Les catégories socioprofessionnelles. Paris: La Découverte.

Epstein S. (1995). The construction of lay expertise: AIDS activism and the forging of credibility in the reform of clinical trials. Science, Technology & Human Values, 20 (4), 408- 413.

Forsythe D. E. (1993). Engineering Knowledge: The Construction of Knowledge in Artificial Intelligence. Social Studies of Science, 23 (3), 445-477.

Garforth L. & Kerr A. (2010). Let's Get Organised: Practicing and Valuing Scientific Work Inside and Outside the Laboratory. Sociological Research Online, 15 (2), <http://www.

socresonline.org.uk/15/12/11.html>
Goodwin C. (1995). Seeing in Depth. Social Studies of Science, 25, 237-274.
Goody J. (1979). La raison graphique. La domestication de la pensée sauvage. Paris : Éditions de Minuit.
Honneth A. (2005). Invisibilité : sur l'épistémologie de la « reconnaissance ». Réseaux, 1 (129/130), 39-57.
Hughes E.-C. (1996). Le regard sociologique. Essais choisis. Paris : Éditions de l'EHESS. Igo S. E. (2007). The Averaged American: Surveys, Citizens, and the Making of a Mass Public.
Cambridge-London: Harvard University Press.
Karasti H. & Baker K. S. (2004). The Long-Term Information Management Trajectory: Working to Support Data, Science and Technology. Scripps Institution of Oceanography Technical Report: University of California San Diego.
Knorr-Cetina, K. (1981). The manufacture of knowledge. An essay on the constructivist and contextual nature of science. Oxford: Pergamon Press.
Knorr-Cetina K. (1999). Epistemic Cultures. How the Sciences Make Knowledge. Cambridge: Harvard University Press.
Knorr-Cetina K. (2001). Laboratory Studies: Historical Perspectives. In N. J. Smelser & P. B. Baltes (Eds.), International Encyclopedia of the Social and Behavioral Sciences. Amsterdam- New York: Elsevier, pp. 8232-8238.
Latour B. (1987). Science in action: how to follow scientists and engineers through society. Cambridge, Mass.: Harvard University Press.
Latour B. & Woolgar S. (1979). Laboratory Life: The Social Construction of Scientific Facts. Los Angeles, CA: Sage.
Law J. (1994). Organizing Modernity. Oxford: Blackwell. Lynch M. (1985). Art and artifact in laboratory science: a study of shop work and shop talk in a
research laboratory. London: Routledge & Kegan Paul. Lynch M. (1982). Technical Work and Critical Inquiry: Investigations in a Scientific
Laboratory. Social Studies of Science, 12 (4), 499-534. Meyer M. (2009). Objet-frontière ou Projet-frontière ? Construction, (non-)utilisationpolitique d'une banque de données. Revue d'anthropologie des connaissances, 3(1), 128-148.
Millerand F. & Bowker, G. C. (2009). Metadata Standards. Trajectories and Enactment in the Life of an Ontology. In S. L. Star & M. Lampland (Eds.), Standards and Their Stories. Cornell University Press, pp. 149-165.
Millerand F. & Bowker G. C. (2008). Metadata, trajectoires« énaction ». In C. Rosental (Ed.), La cognition au prisme des sciences sociales. Paris : Éditions des Archives contemporaines, pp. 277-303.
Mukerji C. (2009). Impossible engineering: technology and territoriality on the Canal du Midi. Princeton, NJ: Princeton University Press.
Nardi B. A. & Engeström Y. (1999). A Web on the Wind: The Structure of Invisible Work. Computer Supported Cooperative Work, 8 (1/2), 1-8.
Orr J. E. (1996). Talking about Machines: An Ethnography of a Modern Job. New York, NY: Cornell University Press.
Roth W. M. & Bowen G. M. (2001). Of disciplined minds and disciplined bodies: On becoming an ecologist. Qualitative Sociology, 24 (4), 459-481.
Shapin S. (1989). The Invisible Technician. American Scientist, 77, 554-563. Star S. L. (1999). The Ethnography of Infrastructure. American Behavioral Scientist (43), 377-391.
Star S. L. (Ed.) (1995). Ecologies of Knowledge. Work and Politics in Science and Technology. Albany, NY: State University of New York.
Star S. L. (1991a). The sociology of the Invisible: The primacy of work in the writings of Anselm Strauss. In D. R. Maines (Ed.), Social Organization and Social Process. New York: Aldine de Gruyter, pp.

265-283.
Star S. L. (1991b). Power, Technologies and the Phenomenology of Standards: On Being Allergic to Onions. In J. Law (Ed.), A Sociology of Monsters? Power, Technology and the Modern World. London: Routledge, pp. 27-57.
Star S. L. (1989). The Structure of Ill-Structured Solutions: Heterogeneous Problem- Solving, Boundary Objects and Distributed Artificial Intelligence. In M. Huhns, L. Gasser (Eds.), Distributed Artificial Intelligence. Menlo Park: Morgan Kauffmann, pp. 37-54.
Star S. L. & Griesemer J. (1989). Institutional Ecology, 'Translations,' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-1939. Social Studies of Science, 19, 387-420.
Star S. L. & Ruhleder K. (1996). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. Informations Systems Research, 7 (1), 111-134. Version française dans Revue d'Anthropologie des Connaissances, 4(1), 114-161, 2010.
Star S. L. & Strauss A. (1999). Layers of Silence, Arenas of Voice: The Ecology of Visible and Invisible Work. JCSCW, 8 (1/2), 9-30.
Strauss A. (1985). Work and the Division of Labor. The Sociological Quarterly, 26, 1-19.
Strauss A. (1988). The Articulation of Project Work: An Organizational Process. The Sociological Quarterly, 29 (2), 163-178. Strauss A. (1992). La trame de la négociation. Sociologie qualitative et interactionnisme. Paris : L'Harmattan.
Strauss A., Fagerhaugh S., Suczek B., & Wiener, C. (1985). Social Organization of Medical Work. Chicago, IL: University of Chicago Press. Suchman L. A. (1995). Making Work Visible. Communications of the ACM: Special Issue on Representations of Work, 38 (9), 56-64.
Thévenot L. (1986). Les investissements de forme. In L. Thévenot (Ed.), Conventions économiques. Paris : Presses universitaires de France (Cahiers de Centre d'Étude de l'Emploi), pp. 21-71.
Timmermans S. (2003). A Black Technician and Blue Babies. Social Studies of Science, 33 (2), 197-229.
Traweek S. (1988). Beamtimes and lifetimes: the world of high energy physicists. Cambridge, MA: Harvard University Press.
Vinck D. (2011), Taking intermediary objects and equipping work into account in the study of engineering practices, Engineering Studies, 3 (1), 25-44.
Vinck D. (2009). De l'objet intermédiaire à l'objet-frontière. Vers la prise en compte du travail d'équipement. Revue d'anthropologie des connaissances, 3 (1), 51-72.
Vinck D. (2006). L'équipement du chercheur : comme si la technique était déterminante. ethnographiques.org [en ligne], 9, http://www.ethnographiques.org/documents/article/ArVinck.html.
Voirol O. (2005). Présentation. Visibilité et invisibilité : une introduction. Réseaux, 1 (129/130), 9-36.
Waterton C. (2010). Experimenting with the Archive: STS-ers As Analysts and Co- constructors of Databases and Other Archival Forms. Science, Technology & Human Values, 35 (5), 645-676.
Woolgar S. (1991). Configuring the user: the case of usability trials. In S. Law (Ed.), A Sociology of Monsters: Essays on Power, Technology and Domination. London: Routlege, pp. 57-99.