# Material culture and the shaping of e-science

Christine Hine

Department of Sociology, University of Surrey, UK

c.hine@surrey.ac.uk

**Abstract.** This paper explores aspects of the material culture of scientific disciplines that may shape their response to information and communication technologies (ICTs). A case study is used to identify salient aspects of culture that may vary across disciplines, and thus may result in the emergence of quite different virtual cultures. The topic of the case study is biological systematics (taxonomy), the field responsible for the classification and naming of organisms. This discipline has been quick to identify ICTs as promising for resolving some of the perceived problems of the discipline. Current use of ICTs focuses on development of publicly available distributed databases of names, of specimen collections and of biodiversity information, and there has been prominent policy attention and a proliferation of new initiatives and agencies. Analysis of the case study demonstrates that the use of ICTs has been shaped by and is consistent with the existing material culture and political context of the discipline. In this field we have a well-established example of the adoption and interpretation of ICTs for scientific work, raising some important issues about the varying status of virtual objects and working practices, and providing some general messages which will transfer to e-science sensu stricto.

## Introduction

Efforts within the e-science and e-social science communities have latterly focused on developing demonstrator projects, which develop applications within a specific domain. These demonstrations “explore the potential” of e-science, and are intended to show what the potential pay-off of new large-scale computing facilities and data infrastructures might be. Demonstrator projects have an inherent specificity, in that they show what can be achieved in a particular problem domain. They have also a generality, in that they are intended to illuminate the wider phenomenon and offer suggestions of what the same technologies could achieve in other areas. Demonstrator projects are flag bearers for the technology. In addition to this emphasis on recruitment of support for e-science through specific demonstrations, there has also been a focus on development of generic or transferable solutions. An emerging toolkit of Grid based technologies, for example as promoted by the Open Middleware Infrastructure Institute in the UK, enhances the image of the Grid as a general technology with broad applications. The very concept of the Grid, and the idea of a generic form of middleware to make this Grid seamlessly available to users, suggests a generalisability to the form of the research relationships and activities forged through the Grid. In addition to these proposed functional and technological dimensions to the generality of e-science and the Grid, there is also a rhetorical aspect. It is arguable to what extent e-science as practiced is a coherent phenomenon, but its presentation as a singular concept with many of the qualities of a computerization movement (Hine, forthcoming) plays up generality at the expense of specificity and heterogeneity.

In this paper I suggest that it would be useful to examine the specificity of e-science solutions from a sociological perspective, as a contribution to the ongoing identification of fruitful areas for exploration, and as a corrective to a tendency to assume generality without supporting evidence. As a part of this quest for specificity, I suggest that it is useful not just to focus on scientific cultures that operate under the explicit label of e-science, but also to examine other areas where use of ICTs is expanding. Analysing experiences outside of e-science offers the possibility of separating out the analysis from the influence of the expectations surrounding that movement. Case studies of this kind offer the chance to learn about the constraints and motivations surrounding use of ICTs outside of the specific funding initiatives focused on e-science and the sets of expectations about what is to be done and how it is to be achieved that these initiatives generate. There is, after all, a rich heritage of attempts to use ICTs in sciences in novel and ambitious fashion, and it would seem appropriate for e-science to learn from this experience rather than separating itself artificially from it.

This paper draws particularly upon a field which has a lengthy heritage of studying the detail and specificity of scientific cultures, namely the sociology of scientific knowledge. Ethnographic studies have established a view of science as comprising a locally situated and culturally specific domain, enacted through distinctive literary and material cultural practices. Viewed against this backdrop, claims about the generalisability of e-science solutions raise some caution, suggesting a need to identify aspects of scientific cultures that may be salient in determining whether general solutions prove indeed to be generalisable. This paper advances a case study intended to demonstrate the potential capabilities of these approaches to illuminate e-science. As a “demonstrator ethnography”, it aims both to contribute to a specific domain, by describing the culture of a scientific discipline coming to grips with extended use of ICTs, and to propose a general applicability, by using an ethnography of scientific culture to identify aspects of other cultures likely to be disturbed or enhanced by ICTs.

The paper begins with an introduction to some literature on the heterogeneity of science and the diversity of the material cultures which underlie scientific practice. From this foundation positioning science as specific and diverse cultural practice, the paper then moves to exploration of a case study. The domain of concern, biological systematics, is introduced and salient aspects of its material and political culture described. It is argued that aspects of the material culture provided an easy resonance with understandings of ICTs, prompting the field to explore ways in which a virtual culture could supplement and extend that existing material culture. This has occasioned debate of some troubling issues, but even these can often be viewed as consistent with the existing traditions of developing standard practices. At the same time, aspects of the political context have suffused the ways in which assessments of these new technologies were made, predisposing individuals and institutions to see and explore resonances. The field of biological systematics has thus proved to be ripe for adoption of ICTs, but the history and heritage of the discipline and the prevalent concerns about its future shaped its reactions in specific ways. In a final discussion section the paper explores the extent to which these observations may transfer to other disciplines, using this as a basis to speculate on the likely extent and form which uptake might present in other disciplines.

# Scientific disciplines and material culture

Within the sociology of scientific knowledge, laboratory ethnographies have been prominent in establishing the possibility of viewing science as a form of social practice (for reviews see Pickering, 1992; Lynch, 1993; and more recently Sismondo, 2004). The initial swathe of laboratory ethnographies (notably Knorr-Cetina, 1981; Zenzen and Restivo, 1982; Collins, 1985; Lynch, 1985; Latour and Woolgar, 1986; and Traweek, 1988) sustained an argument for detailed attention to the micro practices of scientific work, formulated as a response to philosophical attempts to specify the basis of scientific enquiry. Rather than studying what scientists said they did or what commentators claimed that they did, it was suggested that we could usefully pay attention to the detail of what they did. In the contemporary context of e-science, aiming directly to re-shape scientific endeavours and provide new infrastructures to support them, this goal of studying the detail of actual practice takes on a new significance. In particular, the sociological perspective can add an attention to the ways that scientists work with objects both material and virtual, and an understanding of the way that fields of science differ.

A number of authors have chosen the diversity of science as their focus. One of the more systematic attempts, by Whitley (1984), identified two dimensions along which scientific disciplines varied: the extent of predictability of outcomes; and the levels of dependency between scientists working in the field. This gave Whitely a basis for understanding the way that academic disciplines varied in their behaviour and social organization. Fry (2004) has subsequently suggested that Whitley's framework offers a basis for understanding the different information infrastructures that disciplines have developed. There are, however, some limitations to the systematic approach, notably the extent to which it neglects the instability of disciplines and the emergent nature of their understanding of the job at hand. Similar points could be made about Nentwich's (2003) comprehensive review of cyberscience. His analysis of the prospects for intensive use of ICTs in various fields is based on factors such as their size, the pressures to publish, the amount of collaboration and the existing communication conventions. Whilst compelling in its comprehensive and systematic coverage, this analysis too risks reifying aspects of scientific fields which participants may experience in a more dynamic fashion.

Ethnographic perspectives on the diversity of science take a more fluid approach to the qualities of scientific disciplines, anticipating that the nature of the work to be done and the identity of the group engaged in it will emerge in practice and be subject to change both over time and in the different circumstances in which they are presented. One influential articulation of the diversity of scientific practice has been provided by Knorr-

Cetina (1999) in her description of epistemic cultures. Each epistemic culture consists of a distinctive arrangement of working practices, institutional arrangements, roles and hierarchies, and technologies. Each site of scientific work assembles a ‘machinery of knowledge construction’ made up of the empirical, the social and the technological: each plays its part in contributing to a unique epistemic culture, within which the scientist is produced as a particular kind of epistemic subject. Viewed from this perspective, the scientific endeavour becomes more dynamic than the systematic analyses of Whitley and Nentwich allow and the diversity of science becomes less predictable.

Knorr-Cetina’s ethnographic perspective describes science as comprised of distinctive epistemic cultures. These cultures do not necessarily map onto disciplines. Galison (1997) found that even within microphysics he could find separate subcultures, each with their own sets of instruments, skills, theories and working practices. Ethnographic perspectives on the diversity of science take a broad view of the cultural components that may be of interest: attention to the social hierarchy and institutional form is combined with a concern for the form that the objects of scientific analysis take and the technologies that are used to manipulate them. An analysis of scientific practice on this basis would have, it seems, an appeal for informing e-science work. Already we have studies that suggest adoption of electronic communications by scientists may be culturally specific (Merz, 1998), that new data sharing infrastructures can be problematic to make culturally acceptable (Wouters and Schröder, 2003) and that the introduction of new forms of data storage can occasion new perspectives on objectivity and the quality of data (Beaulieu, 2001). Drawing on the sociology of infrastructure perspective (Bowker and Star, 1999), Bowker (2000) has suggested that the development of infrastructures for biodiversity data sharing involves decisions which seem technical but can also be viewed as political in their shaping of constituencies and future actions. The applicability of this kind of insight to e-science operates on more than one level: to promote design of infrastructures which accommodate the diversity of practice, and to occasion reflection on the prospects for success and potential consequences of the overall endeavour.

The current paper makes a modest contribution along the lines outlined above, deploying a historico-ethnographic view to explore one scientific field’s response to ICTs. The topic of the case study is biological systematics (taxonomy), the field responsible for the classification and naming of organisms. This discipline has been quick to identify ICTs as promising for resolving some of the perceived problems of the discipline. Current attention focuses on development of publicly available distributed databases of names, of specimen collections and of biodiversity information, and there has been both prominent policy attention and a proliferation of new initiatives and agencies. In the next section of the paper I will outline aspects of the material culture within which this burgeoning virtual culture has arisen, and discuss how the developing virtual culture both supplements and troubles that existing material culture.

# Material culture and ICTs in systematics

## The distributed systematic instrument

Any scientific field depends on its instruments to manipulate the objects which it is concerned to know about, making them amenable to observation and, as appropriate to the field, experimentation. Scientific instruments from microscopes to particle accelerator/detector complexes provide ways in which the natural world is brought under the remit of sciences and made available for study. Systematics founds itself on the study of the diversity of living things. The required instrument is therefore a means of making this diversity practically available for an individual systematist to work with. The main way in which this is achieved is through specimens, collected in the field, labelled with information about their origin and assembled in large collections. Careful practices of preservation and storage maintain the quality of specimens, allowing them to remain usable for centuries at a time. Natural history museums and herbaria house what can be vast collections of these specimens, which then provide the basis for systematists to conduct comparisons, construct classifications and arrive at hypotheses about evolutionary descent.

Common metaphors for the specimen collection include the "library of nature" or, latterly, a database of life. In an introductory text on plant taxonomy, Jeffrey (1982: 31) explained the function of the herbarium in this way:

> The herbarium is, therefore, a data store in which information about plants is stored mainly in the form of dried plant specimens and their accompanying field notes.

The collection allows the systematist to transcend time and space, studying historic and geographic variations. As Cronquist (1968: 18) put it "In the herbarium one can travel from Maine to Alaska and California and back again in five minutes". Certain kinds of specimen have a special significance according to the nomenclatural practices of systematics: these are the "type specimens" upon which the description of a group is based. This specimen becomes the one to which any future decisions about the application of names will refer back, and it is therefore almost inevitable that a systematist seeking to review the classification of a group will need to view the type specimen. There are well established agreements that specimens will be lent between institutions, and that institutions will welcome visitors to examine specimens such as the types which they may not wish to trust to loan.

There is thus an extent to which the existing material culture of systematics, realised through the specimen collections of systematics institutions, represents a distributed scientific instrument for exploring natural variation. The major systematics institutions act as nodes in a network, sharing duplicate specimens, providing loans and distributing information about specimens. To the existing practices of loan and visiting, online databases have latterly been added, allowing for systematists to explore the collections of other institutions remotely. It is as yet not clear how far meaningful systematic work could be carried out using online images of specimens, and most examinations of material online would need to be followed up by loan request or visit where features of interest were found. Nonetheless, it is fair to say that the growing virtual culture of online databases fits well with this existing material culture, supplementing the existing distributed instrument. This is not to say that the virtual developments have been achieved without effort, nor that they have been achieved without tensions and contradictions. Some of these issues are examined in the next section.

## The qualities of virtual specimens

The development of online database of specimens has brought to the fore a variety of issues not previously addressed to a great extent by systematists. At the same time as the properties and potential of virtual specimens are being explored, so too are the qualities of their material counterparts being defined. Virtual specimens have often been described, publicly at least, as having valuable qualities that material specimens lack: they are readily available unlike the hard to access material specimen collections, and they are robust and available in multiple copies, unlike the fragile and unique material specimens. The Keeper of the Herbarium at the Royal Botanic Gardens, Kew, mapped out a possible future based on these qualities:

> The imaging of herbarium specimens could lead to a revolution beyond that of greater and faster access to the image and its associated data. Herbaria of the future could include specimens held in underground bunkers filled with inert gas (nitrogen, carbon dioxide), and kept at a low temperature with humidity control to reduce the risks of fire and the ravages of destructive insects. Most scientific work would be carried out on electronically held data and images, and rarely might the actual specimen be required. These bunkers could be monitored constantly and if specimens needed to be seen they could be collected, delivered and returned by robots. (Owens, 2003: 27)

The availability of virtual specimens has, however, also created some concerns, highlighting previously unnoticed virtues of the material specimen collections. These concerns revolve around the audience who might access the online collection, and their competence to interpret what they see.

One sense in which online specimens are troubling is the concern that unscrupulous collectors might use databases to locate populations of rare species. The availability of an online database, without controls over the audience for that availability, raises the potential for deviant use. Another dimension of availability that has been troubling relates to the highly formalised rules for publishing new nomenclatural information. Within a herbarium, it has historically been the practice for a systematist examining specimens when preparing a revision to write an opinion on the herbarium sheet itself. These opinions are written "for the record" but with little expectation that anyone would be reading them in the foreseeable future: the next revision of a group might reasonably be expected to be a generation away. Some comments may even give new species names, even if the author never actually managed to publish the name for the formal record. Tucked away in a herbarium cupboard these comments do little damage, and the only anticipated audience would be another expert in the group, who would of course be well versed in nomenclatural practices and aware of the state of accepted knowledge of the group. When the same information is published in remotely available databases the audience becomes less easy to predict, introducing potential disruptions in established and carefully guarded naming practices. An uncomfortable light is cast upon the practices of the past, a situation described by Guala (2000) as “All ghosts come out of the closet”.

Databasing can require matters previously left unexamined or ambiguous to be explicitly specified and this, as much as the basic effort of data entry, may become the most labour intensive step in the process. Whilst the actual circumstance in which a databasing decision inadvertently publicizes a previously unpublished name might be rare, the specific example raises a more general issue concerning the competence of the audience. Placing information in an uncontrolled public domain such as an online database raises the question as to who is accountable for the information provided. Systematics institutions have had to consider whether they should be relatively conservative, making decisions on behalf of the audience and thus protecting them from potentially misleading information, or whether they should adopt an open policy that places the onus on the audience to use information in a responsible manner. Whilst solutions will vary between communities, the broad issue of audience, including judgments about competence and accountability, is likely to arise for many communities instituting new data sharing infrastructures.

The growth in online databases has brought other issues to the fore for systematics, most notably the question of ownership and copyright. Whilst previously the ownership of specimen collections was rarely a topic of concern, latterly institutions have been prompted to think more specifically than ever before about the extent to which they see themselves as having rights over the specimens they hold and the information associated with them (Owens and Prior, 2000). This point is particularly pertinent in the context of increasing moves in the area to link databases together, producing virtual collections which span institutions and ultimately aiming to provide seamless access to specimen data wherever it might be held. It might be predictable that this would prompt discussion of standards for data storage, and protocols for the provision of search results in standard form, as has indeed been the case in pan-European collaborative projects (Scoble, 2003). Less obvious is the realization that developments in digitisation prompt institutions to realise that there are things about the status of their material collections, such as copyright, that they never knew in the first place.

Although virtual specimens have some troubling aspects, there is also an extent to which troubling debates themselves have a heritage that fits in with the discipline’s view of itself. Where the discussions about the qualities of virtual specimens are concerned, it is worth noting that this is the latest in a long history of interest in modes of representation, for example on whether photography or hand drawing provides the most accurate portrayal of a specimen for systematic purposes. It is certainly not obvious in this field that digital representations will be seen as better. Current moves towards standards setting should also be seen not in isolation, but as the latest move for a discipline well used to discussing appropriate standards and procedures in nomenclatural matters.

One final point of great concern to systematics institutions is worth noting: the labour of producing virtual collections. The size of collections and the historical backlog in digitising is such that major systematics institutions often have no complete database of their collections. Programmes of digitisation have been inaugurated, but anticipated completion times are far in the future even when substantial proportions of existing curatorial staffing are diverted into the effort. Historically systematics institutions have viewed themselves as being under-funded for their role, as acknowledged in the UK by the House of Lords Select Committee on Science and Technology (Select Committee on Science and Technology, 1991; Select Committee on Science and Technology, 2002). The expectation that collections be digitised has often been experienced as an addition to the core business of the institution, without specific funding being made available. Where there is funding, this involves prioritisation of collections viewed as being particularly fundable in some way, either through economic or conservation-related importance, or due to a particular aesthetic or historical appeal. Systematics institutions have been at pains to highlight the laborious nature of digitisation, in order to maintain access to what limit funds there are. At the same time there has been a concern to point out that digital specimens do not make their material counterparts redundant. As Wheeler (2004: 578) puts it “There is something deeply significant about being in the presence of the actual object”. In both aspects it has been important to argue that virtual practices supplement, rather than replacing their material predecessors (Woolgar, 2002). This raises a further dimension of the growing virtual culture of systematics: it is experienced by those concerned as an intensely political domain.

## Political contexts and concerns about use

Thus far I have argued that the development of a virtual culture in systematics was consistent with the existing material culture and that the forms of debate which it has occasioned, whilst apparently novel, also have their roots in established disciplinary practice. Nonetheless, transferring practices to the virtual format has brought some new tensions to the fore. The virtual culture can thus also be viewed as a disruption to the material culture that it supplemented. Virtual culture has offered systematics both an opportunity and a burden. The opportunity lies in the potential to impress new audiences with the worth of the discipline, to explore new sources of funding and to address some of the global inequalities of which many within the systematics community and beyond have become conscious. The burden lies in the prevailing expectation that systematics will make use of new technologies, and the increasing political prominence that means that it has to be seen to do so in a particular fashion.

The backdrop to recent developments in systematics is provided by the Convention on Biological Diversity, signed at the Rio Earth Summit in 1992. This convention committed its signatories to a range of actions aimed at safeguarding biodiversity, amongst which was a requirement to share systematic expertise and resources. Systematics was enshrined as a fundamental discipline for the conservation of biodiversity, providing systematics institutions with a greater then ever before prominence, nationally and internationally. This took place against a backdrop of geographical inequalities in the systematic discipline, in terms of the distribution of expertise and the location of systematics collections. The history of the discipline is in large part a colonial history, and the collections tend to remain with the former colonisers, while the former colonies lack both expertise and raw material, in terms of a heritage of specimen collections, to seize control of their of biodiversity conservation. In this context the sharing of systematics data has become thoroughly politicised. This observation then begins to make sense of the recent moves towards publicly available online databases. Data sharing (sometimes called data repatriation) has become the solution of choice for addressing the lack of access to resources. There is a sense of obligation to digitise in the discipline which over-rides many concerns for detailed user analysis that would otherwise be expected. Systematics has become suffused over a short period of time with the expectation that data will be made available in digital form. This has led to a broad swathe of related developments, often experimental in nature and aimed at open accessibility.

A further incentive to exploit the possibilities of the Internet comes from the much-lamented low status and under-funding of the discipline, which accompanies the global political significance stemming from international initiatives on biodiversity conservation. The discipline is at once under siege and in the public eye. There has been considerable commentary from outside the discipline on what practitioners should be doing to advance their work and make its products available. ICTs, and particularly distributed Internet-accessible databases, have become the solution of choice proposed from outside the discipline. This pressure is experienced across the discipline, filtered and transformed through the priorities of various funding bodies, and balanced by concerns within institutions to develop products that appropriately reflect their identity and interests. ICTs have been symbolic as much as functional for the discipline. In the House of Lords Select Committee on Science and Technology's 2002 review of the state of systematics in Britain considerable prominence was given to the role of ICTs in improving the image of the discipline. The point was made clear in the summary of the Committee's report:

> We highlight the importance of digitizing the systematic biology collections, which will both increase accessibility of these data and help to update the archaic image of systematic biology. (Select Committee on Science and Technology, 2002: 5).

On grounds of international politics, and of concerns about the status of the discipline informed by a reading of contemporary cultural norms, systematics was predisposed to find the use of ICTs appealing. The implementation is often difficult, and has become as much a burden as a blessing, but in many senses the systematics institutions could not afford not to participate. Systematics has found resonances between its own problems and the solutions that ICTs offered, but various aspects of its political context and its concerns about status predisposed it to find those resonances.

# Discussion

A single case study is obviously not a sound basis from which to extrapolate about the likely response of other disciplines. Systematics is an unusual discipline in several regards, including the extent of its material culture and its orientation towards archives, its heritage of community-wide formal agreements on practice, and its distinctive political significance. To this extent the descriptions offered here are not generalisable. It is, however, possible to argue on the basis of the details presented here that there is likely to be a consistency between the existing material culture of a discipline and the ways in which it makes use of ICTs. There is enough evidence that these material cultures can vary quite markedly between disciplines for form grounds on which to expect a similar variation in the uptake and interpretation of ICTs. Knorr-Cetina (Knorr-Cetina, 1999) provides a basis for understanding these variations as constituted in distinctive epistemic cultures. One aspect of epistemic culture is the communication regimes which sustain it (Hilgartner and Brandt Rauf, 1994; Hilgartner, 1995). Data sharing is often likely to raise considerable questions about what is to count as data and how it is to be specified and made available. The extent to which knowledge is specifiable in a formal sense is an enduring question in the sociology of scientific knowledge (Collins, 2001). In e-science the question takes on a new significance, as ontologies are negotiated (Ribes and Bowker, forthcoming) and data sharing formats instilled in infrastructures (Beaulieu, 2003). With its online databases systematics is developing new communication regimes, and needing to work out the associated expectations about ownership and accessibility in real time as well as the standards for representing what it needs to know. Systematics has been dealing with these issues in distinctive ways that fit with its own institutional structures and with its understanding of itself as a historically situated community. Concerns about audience, ownership, representation and labour will recur in other communities. It may be helpful for information about the conception of problems and the possible resolutions to be made available between communities, to enrich debate and pre-empt reinvention of solutions. It is important, however, that e-science and e-social science frameworks should not instill too rigid a notion of problems and their specification in advance.

A study of the material and virtual cultures of contemporary systematics therefore offers some prospect to inform reflection on the prospects for e-science and e-social science. It is clear that use of ICTs arises as a situated response, shaped by aspects of the existing material culture, by the political and policy environment in which the discipline operates and by the institutional dynamics through which the discipline is constituted. The direction of influence is not wholly one-way: ICTs in turn have provided occasions for reflection on and changes to the practices of material culture, policy context and institutions. E-science and e-social science initiatives can usefully learn from this kind of experience, since many communities adopting Grid technologies will face similar issues. It is likely, however, that they will both arrive at quite different solutions and have quite different ways of arriving at those solutions. My rendition of the systematics case is intended to demonstrate that the specificity of e-science solutions goes beyond the technicalities of requirements, and extends into the ways in which requirements are arrived at and evaluated. Some communities will find more resonance between e-science solutions and their own concerns than others. Some will also be more minded to find those resonances than others. A discipline which sees little need to enhance status or satisfy political pressures is less likely to be predisposed to look to e-science for solutions.

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