



# Material mastery: situating digital library use in university research practices

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## Abstract

In the past several years, researchers in library and information science, computer science and management information systems have claimed that knowledge workers will transform important characteristics of work due to increased access to digital libraries over the Internet. To explore the influence of digital libraries on knowledge work, this study investigated the use of paper and electronic materials by academic researchers in four disciplines at eight US research universities. This study found that at a given point in time, the match between ‘material mastery’ and features of using a particular digital library could explain its use. This paper discusses findings about digital library use, work characteristics and how material mastery explains patterns of digital library use. © 1999 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

In the past several years, researchers in information science, computer science and information systems have claimed that knowledge workers will work in new ways due to greater access to digital library technologies (Vogt, 1995; Guevara & Ord, 1996). The term ‘digital libraries’ refers to a variety of electronic resources and services including the world-wide web, shared databases and bibliographic systems. However, it is difficult to examine the use of any one electronic collection for knowledge work because ‘digital library’ materials are linked in ways that often blur the boundaries between different collections. It is impossible to determine simply from access logs how a subset of users in a particular discipline uses them.

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Therefore, in order to understand how knowledge workers use digital libraries, this study took a more intensive and traditional approach to understanding changes in work: visiting knowledge workers from four academic disciplines in their offices and interviewing them about how they used both paper and electronic materials in the course of different research projects. This paper reports the findings of this study. Results from this study of university researchers in four disciplines indicate that whether knowledge workers use a particular digital library or electronic material depends upon the match between the features of using the particular digital library and what is defined as material mastery.

## 2. Background: material mastery

Material mastery was originally theorized from the integrative diagramming of theoretical concepts in this study using grounded theory methods (see Section 3 and Strauss, 1987). Using grounded theory terminology, material mastery is a ‘core category’ of materials use skills derived from ‘concepts’ identified in the study. Material mastery has two definitions based on attributes of knowledge workers: (1) skilled ways of working with materials from a body of knowledge within specialized work worlds; and (2) Possession of those skills. In order to explain the kinds of knowledge and skills involved in material mastery, this study draws on the following typology of materials use skills for knowledge work. Examples follow each skill category.

### 2.1. General materials use skills

*Basic skills for computer and library use:* typing, operating a computer, and locating materials in a physical library.

*System-specific searching skills:* Using command languages for a particular database, finding help, using specialized features (location guides, batch searches).

*General search strategies:* Citation searching, reference chaining, leafing through a journal run.

### 2.2. Material mastery skills

*Disciplinary search strategy:* Ability to obtain disciplinary materials knowing what materials are available, choosing where and how to find specific disciplinary sources, and knowing how specific sources and materials are displayed and organized.

*Disciplinary materials selection:* Judging the quality, appropriateness and importance of materials in the context of stream of work, differentiating between terms and concepts in different specialties, understanding disciplinary materials, integrating materials into work.

*Field integration:* Relating research findings and programs to the social structure of the discipline, draw upon the origin and development of the discipline, contributing with respect to the scope of the knowledge produced by a discipline or specialty, relating research programs to each other with respect to a discipline or specialty, addressing key funders’ research agenda.

The first three skills in the typology: basic skills, system-specific searching skills and general search strategies are categories of skills that have appeared in the bibliographic instruction literature (Jacobson & Ignacio, 1997; Neuman, 1997). Research on general search strategies includes extensive inquiry into classifying and studying information searching patterns (Bates, 1979a, 1979b, 1989). A traditional approach to understanding digital library use has been: if you can train people in general materials use skills or if you can design systems that are easy for people to use, then they will be able to effectively use the resource. However, more recent work indicates that understanding the context of use (sometimes called 'situated use') is also necessary. Recent attempts to model human factors of scholarly communities using electronic communication (Gaines, Chen & Shaw, 1997) tell us more about the technical aspects of communication systems than the situated factors that influence what they communicate. Although findings indicate that new forms of publication such as electronic journals have not made a large impact on citation practices, it is difficult to ascertain why (Harter, 1998). This work raises questions that are difficult to explore not only because the technology is relatively new to university researchers but also because linking an understanding of research work-life to technical features of scholarly communications systems requires theories that incorporate disparate analytical techniques. The exploration of retrieval approaches based on relevance feedback (Spink, 1997) shows promise for incorporating individual's interaction with electronic materials. The exploration of the skills for judging relevance with respect to social worlds in which materials are used will inform the development of such systems. Moving beyond traditional understandings, this study suggests that digital library use depends on more than general materials use skills; they require a match with discipline-specific skills which arise from work characteristics.

Although the study collected accounts on skills in all areas, this paper focuses primarily on the latter three skills. Material mastery as a theoretical category provides a framework for discussing disciplinary aspects of working with materials beyond the general materials use skills typified in the first three items of the typology. It also extends investigation into the influence of user values (Kuhlthau, 1993) to examine how disciplinary values pervade material mastery skills that the information seeker already possesses. This paper describes material mastery skills as discrete entities and leaves to future work to explicate the relations between them. These skills involve working with documents in various formats (electronic, paper or other media).

Another property of material mastery is the mechanism for gaining possession of material mastery skills. Researchers are initially socialized to aspire to improve their material mastery skills within particular subspecialties through instruction and apprenticeship during doctoral programs and postgraduate preparation. Studies in the anthropology of science examined the social interactions surrounded the use of materials in research settings (Knorr-Cetina, 1981; Latour & Woolgar, 1986). Once researchers attained a working level of what this study calls 'material mastery skill', they increased and sustained it through consumption and publication activities. For instance, faculty researchers' tenure, promotions and raises are usually dependent upon publication, which generates feedback from colleagues via peer review. These colleagues are sometimes called the invisible college (Price, 1963; Crane, 1972). An invisible college is defined as a geographically distributed set of colleagues in a particular research specialty who are the peers that judge and legitimate research contribution and therefore play a major role in material mastery skills development. They train, investigate and sanction

disciplinary search strategies and the disciplinary knowledge of materials. Invisible college members of one research specialty found electronic publication to be a very useful mechanism to disseminate research articles whereas members of other specialties hesitated even to distribute electronic copies of work which appeared in print publications (Kling & Covi, 1995). Peer review provided a key mechanism for authors to receive suggestions from the invisible college about new materials or standards for judgement and thus reinforced material mastery.

This term ‘material mastery’ was derived from a similar term in the study of diffusion of technological innovation (Petrella, 1996). Researchers in diffusion of innovation defined the term ‘social mastery of technology’ to mean the ability of a social group to incorporate technology into its community life. They contrasted this definition with the definition of industrial mastery (a necessary condition for social mastery) which is the ability of a country, society or firm to incorporate technology into its routine operations. Material mastery, as defined in this study, departs from this definition in several ways. First, material mastery skills are socially legitimated individual attributes whereas social mastery describes how material mastery skills are adopted through social participation in a particular work domain. Second, the material mastery category refers to skills for working with documents in a variety of formats rather than exclusively with electronic technologies. Therefore material mastery differs from the conception of the requirement for an individual to have ‘mastery at the information interface’ (Zuboff, 1985).

Several findings from these diffusion of innovation studies are relevant to material mastery. Everett Rogers identified ‘community norms on innovativeness’ as one predictor of adoption patterns (Rogers, 1962). Within one discipline’s specialty, different informants had a variety of stages of awareness, interest, evaluation and experimenting with electronic materials. Regardless, all informants in a particular discipline were aware of the current work characteristics and enumerated several ‘material mastery skills’ common in their discipline. A major difference, however, between use of electronic materials and Rogers’ adoption literature is that the electronic materials and the digital libraries that support them are so malleable that an added step of adaptation often occurs in the diffusion process that may transform the initial innovation into a technology which looks quite different. Because material mastery skills are socially legitimated in each discipline or specialty, they tend to change more slowly than the digital library technology and thus provides an explanation for the initial reception of electronic collections and materials. In fact, future work could investigate the role of Rogers’ factors in changes to what constitutes material mastery.

This study is part of a growing area of research on the ‘social informatics’ of digital libraries (Bishop & Star, 1997). This area investigates the use, design and influence of digital libraries on people. The discovery of material mastery contributes to this discourse by identifying an explanatory mechanism for digital library use on specialized populations of knowledge workers. Related studies in this tradition which specifically examine scholarly communication as a domain include a naturalistic inquiry into the influence of *Thesaurus Linguae Graecae* on Classical Scholarship (Ruhleder, 1995), a citation analysis that examined the influence of electronic journals on scholarly communication (Harter, 1998) and a survey of the use of the JSTOR full text journal collection by university historians and economists (Finholt & Brooks, 1997).

### 3. The study

This paper reports on a study examining 96 faculty member and 28 doctoral students in the advanced stages of their dissertation work from February to June of 1995 (Covi, 1996c). The study investigates university researchers as one set of knowledge workers who were very likely to have access to the skill, electronic resources and print resources which would indicate how other populations might use digital libraries in the future. The study focused on the use of digital libraries and electronic materials for research rather than teaching, service or home life except where digital library use in other areas informed research activities. The research questions included:

- How accurately do researchers perceive availability of electronic materials?
- How much do researchers utilize electronic resources?
- How do electronic resources fit researchers' work characteristics?
- When do researchers prefer electronic to paper formats?
- How do preferences and usage vary between disciplines?

The informants in the study were drawn from a diverse set of 8 Carnegie classified Research I Universities<sup>1</sup> from four disciplines: molecular biology, literary theory, sociology, and computer science. The universities were selected based on three dimensions suggested to us by digital library experts as being germane to the use of electronic resources: 4 public universities and 4 private universities, 4 high library dollars per faculty (\$10,000–37,500), 4 low library dollars per faculty (\$3,000–9,999) and 4 centralized library organizations (0–3 branch libraries) and 4 decentralized library organizations (4–76 branch libraries). Within the 8 universities, purposive samples of faculty who were active researchers ( $N=96$ ) were drawn from research disciplines. Rationale for selecting the eight university is described in greater detail elsewhere (Covi, 1996c).

The sampling decision to select four disciplines reflects a desire to study disciplines where there would be at least some use of electronic communication but also to examine differences between disciplines with different models of research work and holding different values about the use of paper and electronic materials (Lodahl & Gordon, 1972; Becher, 1987). When available, informants from different stages of their career were selected focusing on certain disciplinary specialties (computer networking, social networks, drosophila and comparative literature). These disciplines and specialties were chosen for several reasons. First, a pilot study (Covi & Kling, 1996) showed that researchers in these specialties used one or more electronic collections of materials. Second, disciplines were chosen based on a likelihood for electronic material use. Faculty informants were selected from a list in the most recent graduate program admissions material and then contacted by telephone or electronic mail in order to arrange face-to-face interviews appointments at their campus offices. Twenty-four of the doctoral students were identified during interviews with their advisors and the other four students

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<sup>1</sup> At the time of this study, Carnegie I Research Universities were a set of 88 United States universities awarding 50 or more doctoral degrees and receiving at least \$40 million in federal support each year (Carnegie, 1994).

identified from faculty who were not their advisors. Table 1 lists the informant sample by discipline and rank.

The data collection included a semi-structured interview with each informant for 45–120 min according to a pre-tested interview schedule. The principal investigator, Rob Kling and the author spent at least one week at each university. The author was present at all interviews and the principal investigator attended over 50% of the interviews. The same protocol was followed for each interview but inevitably some informants developed better rapport with one or the other interviewers. In order to compensate for putting the informant at ease, when both interviewers were present, both interviewers asked some questions. There were only three interviews that were markedly shorter in duration because informants would not elaborate on their responses.

In addition to field notes, interviews were tape-recorded unless the informant objected (extensive interview notes were also written and analyzed). During data collection, some informants were prompted late in the interview to validate work characteristics and material mastery skills reported by other informants if they did not mention them. These prompts were necessary to help informants, many of whom thought much more deeply about their research discipline than the specific ways they used scholarly communication, recall work characteristics or material mastery skills that may have seemed too obvious to mention or they simply did not initially mention. The prompts were conducted toward the end of the questioning in order to minimize the risk of biasing informants' reports. On a few occasions, there was contact with informants after the interview to follow up with unanswered questions.

The interview data provides rich insights and illustrative anecdotes about the work habits of these informants. However, like some other self-reporting data collection technique, there are several important limitations. First, aside from the accounts of collaborators, advisors and advisees, it is difficult to verify that the reports of the informants reflect their actual behavior. However, because this data set contains a large number of interviews, there were certain work habits such as finding references from key papers and asking an expert for help that were common to many informants. Another limitation is that data reduction and analysis is not fully replicable to investigators absent from the interviews. In many instances, it would be impossible to reveal the entire meaning of the quote solely by means of listening to the audio-recording. Rather than being the sole source, the audio recordings play a key role in reinstating the context of interpretation for the interviewing and helping the interviewer/coder

Table 1  
Profile of informants

	Doctoral students	Assistant professors	Associate professors	Full professor	Total
Molecular biology	10	6	11	7	34
Literary theory	6	4	6	14	30
Sociology	4	3	9	12	28
Computer science	8	8	6	10	32
Total	28	21	32	43	124

to recall gesture, facial expression and even parting comments recorded only in the interview notes that comprise the informants' account.

The interview protocol included obtaining informant consent and a brief explanation of the general purpose of the study so that the investigators could address any questions. The interview schedule included demographic and contact information but chiefly consisted of working from a 'grand tour question' about materials used in a recent project or manuscript the informant had completed and prompting for journal subscriptions, browsing habits, electronic mail exchange of manuscripts, gopher, world wide web, etc. There were also a few questions about how the informant interacts with his/her research community with respect to paper and electronic materials. The interview schedule and other project materials are available online (Covi, 1996c).

Some of the findings about the research questions mentioned are elaborated and reported elsewhere (Covi, 1995, 1996a, 1996b, 1996c, 1997; Covi & Kling, 1995; Kling & Covi, 1995) but also provide background for understanding the data. In the first 6 months of 1995, researchers had very different levels of familiarity with the electronic materials available to them. For instance, some were thoroughly versed in the resources available at their campuses and were in contact with librarians and computing services personnel who occasionally assisted them. Other researchers primarily relied on graduate students, staff assistants or even resources they accessed as graduate students themselves to meet their ongoing needs for scholarly materials. In general, researchers would utilize materials in new ways primarily at the time when they had a personal need for them (e.g., when updating a syllabus, when journal reviewers required certain changes, etc.). In addition, most informants only used rudimentary features of most systems such as boolean searches unless they used them frequently. The frequency, extent and fit of electronic resource utilization in relation to work characteristics are described below. Certain electronic formats were more popular than paper. Electronic mail was almost ubiquitous at the study campuses and several campus administrations were shifting intra-campus correspondence to electronic formats. Most faculty enjoyed the convenience of electronic mail, though many felt they received too much of it.

Some faculty did not have campus network access in their offices but they could dial-in from the office or at home. Network access at most campuses had become congested due to the increased popularity of electronic mail and electronic campus services. Mosaic and the world wide web had become very visible. Although only a few faculty relied on web searches as a first resort, most were aware of the 'home page' addresses which were starting to appear everywhere, even in academic papers. However, almost all the informants reported that for sustained reading, easiest access and transportability, they still preferred reading from paper rather than from the screen. Faculty considered most electronic materials to provide efficient formats for storage, search and dissemination. Differences of preferences and usage between disciplines are discussed below.

The analysis of these findings was based on a theory evolution approach using grounded theory analysis (Strauss, 1987). Grounded theory focuses the data based on patterns that correspond to established theory (for instance on information seeking and sociological studies of knowledge) and using the data to modify and argue for new theory. Initially open coding of 5 interviews yielded 185 initial concepts, which were organized and reorganized into 20–30 categories as new data was coded and added. The coding was primarily conducted by the

author who was present at all interviews and validated through review with the principal investigator who was present at many interviews. The initial data was then refocused into 3–5 properties of interest in each category depending on what dimensions of these properties provided the most data of greatest interest based on the initial research questions. For example, the concept ‘buys books rather than borrows from library’ was an initial concept that was first grouped under the category ‘traditional library use’. However, this code was subsequently re-grouped under ‘interactions as readers’ when the focus shifted from categorizing the source to categorizing roles in scholarly communication. As the causal conditions for digital library use began to emerge through the analysis, the disciplinary context became more apparent and the core category of ‘material mastery’ (meaning the ways of working with materials in research specialties) became a basis for moving from open coding to selective coding.

The grounded theory approach is constrained by the ability to collect data on which to focus. Grounded theory can be used with a wide variety of data collection methods but its power depends upon having a validated data set for inductive analysis. Another limitations of this approach are that the resource intensity of such analysis limits the amount of data which is affordable or can be collected. This study provides an important descriptive account on early digital library use. However, it is limited by the early phase of the digital library development and use. For example, most informants did not know what the term ‘digital libraries’ meant and some had not even been exposed to some of the newest technologies. A few informants did not even have access to computer networks or a dedicated phone line in their offices. Another limitation of this study is the lack of precision. As an exploratory study, the investigators cast a wide net in order to pinpoint interesting and relevant use areas for comparison and to suggest further study. However, despite these limitations, this approach provides the best strategy to explore a previously unexplored area and provides important empirical evidence on which to build new theory.

#### **4. Findings and discussion: digital library use and material mastery skills**

This section presents and discusses findings about digital libraries and electronic materials use patterns by university researchers in each discipline. The study identified electronic materials and resources in each discipline that were typically used or underutilized as reported by the informants. In order to explain why items appear on each list, the informants’ accounts of typical work disciplinary work practices show that there are clear disciplinary differences as well as differences between subspecialties in certain disciplines that figure strongly in the informants selection of electronic resources and how they are used. Key work characteristics provide the context for analyzing exemplary material mastery skills in each discipline.

##### *4.1. Electronic resources utilization*

The 12 informants in each discipline reported their use of both paper (library and own collection) and electronic resources and services. A list of the typical electronic resources used and not used appears in Table 2. As mentioned above, electronic mail was almost ubiquitous



on the 8 campuses visited, yet only in sociology and computer science did informants mention using electronic mail to request papers. Also, in all disciplines searching the world wide web using search engines to identify home pages was not popular.

Researchers in molecular biology and sociology utilized network-accessible bibliographic databases available through libraries and Internet service providers such as MEDLINE, BIOSIS, SOCIOFILE and ABI/INFORM routinely. Although bibliographic databases such as INSPEC, ABI/INFORM and MLA Bibliography indexed the reported journals of choice for researchers in computer science and literary theory, the researchers did not use them. In literary theory and sociology, however, researchers routinely used the online public access catalog for both home library and remote libraries they would visit or from whom they would order materials. In computer science, one database was commonly mentioned in the human–computer interaction specialty: HCI Bibliography. This database was created by Gary Perlman, a human–computer interaction researcher and was widely distributed and available online. In molecular biology, there were several resources organized around genetic sequencing databases such as GENBANK, PDB and FLYBASE. These resources also provided citations to research literature along with other services such as addresses of researchers and ordering information for genetic material.

With one exception, the Journal of AI Research, electronic journals were not mentioned (except in molecular biology which did not appear to have any). Researchers were aware of several titles and some had even examined them, but they did not routinely read or contribute to them. Researchers in computer science used electronic discussion lists to ask people for references, whereas researchers in other areas either did not routinely participate in general discussion lists in their specialty or would not use the lists in this manner. With the exception

Table 2  
Typical electronic resources used and not used (data collected in 1995)

Discipline	Typical electronic resources used to find research materials	Electronic resources mentioned but not routinely or widely used to find research materials
Molecular biology	MEDLINE, BIOSIS, GENBANK, Protein Database (PDB), FLYBASE	Electronic mail requests, Web Search, Online Public Access Catalogs, Journal Volumes on CD-ROM, Electronic Bulletin Boards
Sociology	Electronic mail requests, Online Public Access Catalogs, SOCIOFILE, ABI/INFORM	Web Search, Electronic Journals, Discussion Lists, Bulletin Boards
Computer science	Electronic mail requests, Journal of AI Research (electronic), HCI Bibliography Private Discussion Lists, Electronic Technical Reports, Electronic Pre-Prints	Web Search Online Public Access Catalogs INSPEC, ABI/INFORM, Electronic Journals, Electronic Bulletin Boards (except doctoral students)
Literary theory	Online Public Access Catalogs	Electronic mail requests, Web Search, MLA Bibliography, ARTFL, Journal of PostModern Culture (electronic), Other Electronic Journals, Discussion Lists

of doctoral students in computer science, who tended to routinely check electronic bulletin boards in their specialty, most researchers did not commonly utilize them. In computer science, pre-prints and technical reports were circulated in electronic and paper formats via an online service or by contacting academic departments or other technical report distributors.

#### 4.2. *Explaining use differences: disciplinary work practices*

In order to understand why some of these resources were more frequently utilized than others, the next findings presented will explain some key work characteristics. The following accounts describe informants' modes of contribution and consumption of scholarly communication. After these key characteristics are presented, the analysis of how the electronic resources fit their work characteristics follows.

The following quotes illustrate the importance of making an original contribution to the field in molecular biology. Note how this consideration influences submission of manuscripts, use of documents for verification of originality and the way scientists read new journal issues arriving at the lab.

In a competitive situation, where three years worth of work may become completely worthless, if you work came out 15 days late,...that happens all the time. Under those circumstances, you try your best to talk it out and see if it wasn't possible to send it to journals in a coordinated kind of way so that things come out at about the same time. So that's a very unpleasant situation usually. Sometimes it can be interesting because you are looking at something from one point of view and someone else is looking at it from a totally different point of view but your points of view coincide at the end and then you do some negotiations to make sure those come out at the same time. [HUMB3]

I was pretty sure nobody had done it...because in a previous publication I stated that it was random and then another publications from another group at the same observation. [TUMB3]

I go through [articles] as the journals come in. I will scan through their indexes to find articles that seem like they're relevant to what we are doing and then I photocopy those abstracts. [BSUMB2]

The work practices described by these scientists are heavily influenced by a concern for getting credit for findings and verifying that their findings were original. In their interviews, they described high stakes in terms of obtaining competitive funding (usually on the order of \$100,000 or more per year), raises and promotion based on priority of discovery. Therefore they expressed a sense of urgency in terms of creating, finding and utilizing materials in a timely manner.

In sociology, researchers described a different concern. Instead of competition for priority of discovery, their work practices were influenced by research projects using multiple approaches and touching several research domains.

The project is this multi-year thing... And it involves several things. It involves simulation of [work groups], using alternate models of human cognition, so it gets you into what extent the model matters. It involved collecting experimental data on [work groups] and relating that back to the simulations, collecting real-world archival data on [work groups] relating that back to the simulations. And we're looking across multiple organizational tasks, from one involving [manufacturing], doing [sales]-type things to this [accounting] task, which is really a categorization task. [TUSOC2]

I was well-trained in both education and family. So I was pretty sure that I knew the literature in both education and family... [However] I have to study a lot of fields that essentially, I'm not interested in: says dentist's office: Is there a class difference in how often kids go to the dentist? [DSUSOC3]

I've also gone to the Math Library [indistinct] has books of graph theory, some of which has [topic] stuff in it. I've also gone to the Business School Library... It's irritating to have it so dispersed, particularly when I have to return books. [RSUSOC3]

TUSOC2 described research on work groups involving experiments, archival research and analysis across different tasks. DSUSOC3 studied literature that she was not really interested because it informed her project. RSUSOC3 complained about the decentralized organization of the print materials he needed for his work in Social Networks. Although a couple of sociologists in the study did work with a predominant approach in one domain, most informants found themselves continually reading and addressing materials in several specialties and sometimes different disciplines. Their work required them to address popular issues, adjacent populations and similar themes from related research in their reading, reference to and search for research materials.

Like molecular biologists, computer scientists work required them to keep up with very current materials. However, priority of discovery was less of an issue for them because there were several possible solutions and implementations for the same problems. Note how inter-organizational aspects of their research projects influenced their work practices.

The key product of our research is developed into protocols — network protocols and these protocols, we usually simulate, software simulation. We evaluate the analytic tools for simulation. And in some cases, we also implement. Now we have a couple of ARPA grants for which we are required to actually implement these protocols to see if they work... We are now part of a tested called [project]. [BSUCS1]

I guess I saw that this paper was coming out and from the title of the paper I knew it was related to what I was doing [which was based on 10-year old work] and I was sort of

anxious — did somebody else just think of the same idea? But no, I wasn't scooped. This other paper was sort of a pretty good improvement on the same basic way that the ten-year-old stuff had done. Interestingly unaware of the ten-year-old stuff as it turned out. [TUCS3]

I follow stuff coming out of [western state university], ...I follow everything coming out of the [specialty] group in [midwest state university]... and the [inter-university ARPA- funded project] work. [The project] work has a mechanism for [following other people's work], — we have a workshop every nine months. Every single person talks and you know what they're doing. And then of course, you have to correspond [via e-mail] with them to get the real details because the talks are only 10 min long. [TUCS1]

These quotes illustrate several aspects of computer science research common to all accounts. In the first quote, BSUCS1 explained how his research was associated both with the government agency, ARPA, which funded many of the projects different informants worked on and also the tested project associated with an industrial sponsor. The second quote provides a useful contrast to the priority of discovery work characteristic found in the molecular biology accounts. TUCS3 described how he briefly worried about competition when he had discovered a paper coming out that looked similar to his work. However, the other author's paper was published without reference to the work TUCS3 had found and simply improved the solution to the problem. The third quote illustrates how many computer scientists followed current work through workshops, meetings and tracking the output of certain related research groups. The funder supported the scholarly communication process and created a forum for research output. In fact, in computer science, current work was valued so much that conference papers could count significantly toward career advancement (more so than in the other three disciplines). For example, molecular biology held invited workshops called 'Gordon conferences' but their purpose was primarily to facilitate agenda setting with respect to funding and research projects and the Gordon conferences never issued publications.

Literary theorists, who were found in comparative literature and English departments, described their work practices in a humanistic tradition. The accounts they provided for their work was very specific in terminology they used to characterize their work activities. Note how language and norms about working with text permeate their accounts of working with materials.

It would probably be a misnomer to say I do research. I mean I do arguments and so I'd be more interested in, informed by what other critics have had to say about this argument. So I read a lot in philosophy, I read a lot in social theory, but I don't do anything resembling research and there's never a point where I would need the standard week in the library to find arcane text... I deal primarily with fairly well known primary texts. [DSULT3]

I'm not really a scholar... I guess I do have a feeling, especially the semester I spent in the Bibliotheque Nationale, it was sort of playing at being a scholar. Going to the library

everyday and reading all these old 19th century books and that was — I knew that was not really me... I was playing that role for a moment... Critic versus scholar is usually is the way we used to speak of it. But I'm not really, not particularly nostalgic for that. [MULT1]

This summer I was at Harvard [rare book room] for a week or so and decided that I didn't quite know what I was doing and [that] the best thing to do might be to poke around and get as many, get 18th century books, kind of get a sense of [topic] 18th century, how it changed. [DSULT1]

Literary theorists worked in a much more individual mode than the researchers in other disciplines. For instance, even the sociologists worked with research assistants and collaborated with graduate students. Collaborative authorship was rare among literary theory informants. DSULT3 characterized research as library work with rare books as opposed to his work, which draws upon contemporary materials he could purchase or borrow. There were literary theory informants in this study who worked in each mode but the subsequent two quotes reveal a little more what happened in the libraries. MULT1 felt like a charlatan working in the library mode and actually preferred to do his reading and writing at home. DSULT1 worked in rare book rooms more routinely. Her project concerned not only the literature, but also the formats of the materials, which made it important that she work with certain editions. Most of the literary theorists collected as many of the books they used as they could afford and wrote their articles and books as a contribution to an ongoing dialogue (criticism, arguments) about the particular genre or period of literature and its theoretic relevance.

The following table (Table 3) summarizes the work characteristics illustrated in the sample quotes from each discipline.

#### *4.3. From disciplinary practice to material mastery*

Given these characteristics of work in each discipline, the next findings describe materials use skills in the context of each discipline to illustrate the analysis of why certain electronic resources were utilized and others were not. Supporting quotes illustrate key points.

Why were computer scientists and sociologists able to share references and papers where literary theorists and molecular biologists were not? Why didn't literary theorists use MLA Bibliography whereas molecular biologists heavily used the comparably comprehensive MEDLINE? These questions arise when examining Table 1 and immediately illuminate key disciplinary differences in behavior. One way to understand or even explain digital library use is to interpret accounts of their use patterns of either paper or electronic material in terms of their disciplinary work characteristics. This process produces examples of each of the three material mastery skills: disciplinary search strategies, disciplinary materials selection and field integration. Matching these skills to the features of the materials or resources helps us understand the use patterns in Table 2.

In molecular biology, one of the most common disciplinary search strategies was browsing new journals as they arrived. Most laboratories subscribed to 4–8 print journal subscriptions

(usually including Nature, Cell, Genes and Development) in addition to what their departmental libraries would archive. Researchers in other disciplines also browsed their own journals in this manner but molecular biologists' initial foci tended to be particular genes or functions. The following account describes how one informant's specialty, cell death, came into being as a topic through increasing awareness through multiple sources of activity in this area.

Cell death as a topic only started to get big in the past 2–3 years. [People realized that] people are starting to study this, let's see if my gene is involved in cell death... I wouldn't say that [the increase of interest in cell death] was driven by an important person, though... So there were a lot of journal [articles], it was talked about at meetings a lot of times and was starting to be reviewed a lot, in Nature, News and Views, things like that. There were starting to be a lot of editorials on cell death and why it was important, reviews about the subject so it developed a life of its own [sic] kind of as a field. [RUMB1]

RUMB1 described here how specific materials: journal articles, meeting discussions, the column 'News and Views' in the weekly journal Nature, editorials and reviews. In disciplines where having access to the most current materials is vital, one would expect researchers to utilize the electronic, print or face-to-face outlets that provide the best access to the most current information in their specialty. However, examining the features of the use of electronic materials reveals a gap in electronic distribution of preprints or tables of contents of the upcoming issue of Nature. In fact, serving as reviewers for journals and attending the invitational Gordon conferences provided an important opportunity for researchers to gain important field integration skills for setting the agenda for their work with respect to similar projects. Social networks of peers and former students working as post-docs in labs doing similar work provided even more information about concurrent research projects. Most molecular biologists spent hours speaking to colleagues on the phone each day. However, if molecular biologists had the funding and incentive to make the best use of digital libraries and electronic materials, why didn't they exchange pre-prints electronically or use more electronic communication?

The mismatch between disciplinary materials selection and features of the use of digital libraries and electronic materials available addresses this question. During the time of the study, several journals were experimenting with providing subscribers CD-ROMs of journal

Table 3  
Work characteristics in four disciplines

Discipline	Work characteristic
Molecular biology	Priority of discovery, coordinating contributions, negotiating with competitors
Sociology	Variety of methodological approaches (modeling, experiments, field work), examining social phenomenon in multiple domains
Computer science	Problem-solving, legitimate conference publishing, support from federal agencies and industry
Literary theory	Writing criticism, creating arguments, reading criticism in other disciplines

volumes. Although this format provided an efficient storage medium, the molecular biologists could not easily print or distribute the electronic articles containing graphics.

Printing capabilities are dismal. And so it's kind of a difficult thing where it's on the disk unless you go to a service bureau or something like that it's not easy to get a good print-out. [BSUMB2]

The laser printers did not have enough resolution for researchers to pick up important details from the diagrams and photographs necessary to determine material selection in certain situations. On the other hand, informants also used the MEDLINE and BIOSIS bibliographic databases for author searches and sometimes even to help them recall authors, citations or abstracts of work they had read previously. Although the bibliographic records did not contain full-text, they matched informant's disciplinary material selection skills. Molecular biologists generally found the databases helpful when they needed to locate or cite a particular finding or method.

Another area in which the molecular biologists made effective use of electronic materials related to disciplinary search strategy for gene sequence matching. Resources that had been originally organized to maintain different kinds of genetic information also contained citations to journal articles describing the findings. Because funding agencies and journal publishers mandated author contribution of found sequences to these sources, they provided a definitive source for related work. molecular biologists had several types of these sequence repositories, for example, GENBANK, FLYBASE and PDB. However, in sociology, there were virtually no electronic materials or citation databases associated with the behavioral data base repositories online. Sociologists have different sets of material mastery skills.

In sociology, there was an important marked difference between disciplinary search strategies when one is familiar versus unfamiliar with a specialty. This posed a particularly challenging problem in sociology where even experts in a particular topic must address multiple approaches or recent developments.

If I'm branching out into some area I know nothing about — if it's an area that I know something about, then I know the area, I know the people. I know about everything that they've done. There are no mysteries. If I looked at Soc Abstracts then, I'd just find an incomplete listing of what I know exists. I use it when I'm completely utterly unfamiliar and don't know much about what's been going on. If I knew something about the area 15 years ago, and I wonder what's been happening since, that's when I use it. [RSUSOC1]

RSUSOC1 characterizes his disciplinary search strategy as looking in Soc abstracts when he is either 'utterly unfamiliar' with the specialty or when he has lost touch with the specialty. However, sociologists must select materials outside their specialty if they address project-related issues.

Given this characterization and the work characteristics of sociology that require addressing a variety of methods and domains, one would expect that sociologists would make intense use of a variety of databases. Indeed, Table 2 reveals that they have. However, how would sociologists who need to become familiar with an area use electronic mail to request materials?

The answer lies in the context in which the sociologist utilizes this electronic service. The following quote sheds some insight on this question:

Right now I'm writing this kind of review article in the [specialty] area and so I'm writing it and I notice that I need references on a couple things. I had known they'd been presented. So I just e-mail the participants at the conference and say hey, can any of you guys send me references, then they e-mail back their references. That's one of the things I've been starting to do lately. It's very helpful. [TUSOC2]

Sociologists asked people for papers and references when they have a hunch that they knew what they were looking for. Knowing who to ask for what kinds of material was an important field integration skill, especially for sociologists who needed to track diverse bodies of knowledge and selection of materials by expert referral which was an important disciplinary materials selection skill. Despite this need, sociologists didn't relish library retrieval.

I hate going to the library... You need an article, you need it now and in the middle of your research, you don't even have the time to go out there and go to the fifth floor and track it down... [HUSOC1]

This sentiment was expressed in other ways by researchers in other disciplines. We would therefore expect that full text databases and electronic resources would be very popular. However, particularly in sociology, there were few publicly available electronic resources at the time of the study. Field integration skills did not include development of electronic resources, forums and digital collections and thus provided little incentive for sociologists to develop digital libraries for other. This aspect of field integration contrasts sharply with computer science where many informants expressed the expectation that colleagues would provide and use electronic materials.

The exchange of electronic materials figured prominently in computer scientist's accounts. For example, the following informant described a typical conference interaction that precedes document retrieval.

Sometimes I meet researchers at conferences — we talk about research topics. Then sometimes they ask me to send them some of my papers and I ask them to send their papers on the topic they're working on. [FSUCS2]

Some informants still sent papers via photocopiers and postal mail. However, most informants were exchanging papers in electronic formats via electronic mail, 'anonymous ftp' file servers, gopher and even a few via the world wide web. Computer scientists tended to expect their colleagues to be able to handle electronic formats and many computer science publication outlets required a particular format for paper submission. Working with electronic materials had become a field integration skill since researchers took pride in using computing technology or at least having assistants around to handle technological tasks. Aside from comprehensive databases such as Perlman's HCI bibliography mentioned above, bibliographic databases and online public access catalogs were rarely used. Timeliness was valued in the computer science research community over the risk of duplication (also see TUCS3 above).



Given that working with electronic materials was already part of material mastery, why wasn't web searching more popular? At the time of this study, the professional organizations who sponsored major publication outlets: the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE) were still developing and publicizing their electronic publications policies. In addition, university computer science departments had traditionally handled requests for pre-prints (technical reports) centrally via postal mail and file servers. The preprint services had been automated and made available on the web via the Networked Computer Science Technical Reference Library (NCSTRL) project. There was little incentive aside from novelty value for researchers to make publications available on the world wide web and few researchers devoted much time or resources to update and maintain home pages for this purpose. The disciplinary materials selection most germane to sharing electronic materials was citation in a refereed journal or conference article.

Several other aspects of the match between material mastery skills and features of electronic materials explain why there was only one major electronic journal in a discipline that valued speedy peer-reviewed publication. The Journal of AI Research (JAIR) was the only electronic journal among all disciplines studied that was regularly read and to which researchers in the AI specialty contributed. The clever design of this journal met disciplinary needs for review, faster turn-around, a legitimate form of publication and a new a new outlet.

The major journal of AI is the AI Journal [AIJ — paper] and it has a 2-year backlog and it takes a year to get papers reviewed... by the time they come out they're not relevant any longer. So [JAIR-electronic] was an attempt to do something [about this problem]... It's not uncommon to try to get the reviews back in 6 weeks. You can get a paper published within two-three months of writing it... The idea [behind using an electronic format that prints like a print journal] is... if your deans are going to say, "Is this an electronic journal?" ...you can show him that it's a real journal, that the people using it can read it [in a print journal format]... I guess I'm not quite sure [if it's 'better' to get into AIJ-paper]. My feeling is that actually the [JAIR-electronic] is better. [AIJ] unfortunately has had the same editor for 20 years and he's been focusing it towards a certain class of research, which is becoming less and less relevant to my own work... [FSUCS1]

JAIR was used because features of its use matched the material mastery skills of its specialty. First, AI researchers could easily obtain and distribute it in electronic and even print collections (disciplinary search strategy). Second, they could use the same judgement skills for selecting materials to use as they would for AIJ (disciplinary materials selection). Finally, it matched the values necessary to integrate JAIR's use into AI research (field integration). In contrast other electronic journals were regarded as less-desirable outlets for CS researchers.

I can't answer [how e-journals figure into merit and promotion decisions] very definitely because I do not know what quality these electronic journals will be. The conviction which we have for the [e-journal for which he is an associate editor] is that it will be fiercely written and so I would have no objections [to having e-journal articles count for tenure] if the evidence is strong that these are not just a sloppy way of getting papers published, you know — half-baked ideas... [MUCS2]

Other implications of electronic journal publishing and scholarly legitimacy are discussed elsewhere (Kling & Covi, 1995).

Similarly computer science researchers preferred private discussion lists to electronic bulletin boards because of their disciplinary search strategies. Like other disciplines, notably literary theory, computer science public forums attracted a diverse cross-section of experts, hobbyists and serious-minded participants. Because computer science researchers chose scholarly communication outlets that minimized irrelevant, time-consuming interactions, these forums were rarely used. However, sometimes doctoral students or researchers wanting to learn more about a new specialty found these forums helpful for developing material mastery skills in a new area. Disciplinary materials selection in literary theory also depended on researchers judging the quality of a specialized dialogue with colleagues who share a certain kind of common interest.

Materials use in literary theory included browsing through books and journal articles in order to keep up with current discourse and interesting materials related to the genre.

In the field of literary theory... where you're trying to keep up, it's not a problem to find out what to read because, in a sense, the field is... so elastic that anything that is read by people outside the field in which it originated, becomes it's own literary theory... you're trying to keep up your reading — what other people are talking about so there you are to some extent following journals or other books. [MULT1]

Strategies for searching for materials and disciplinary materials selection chiefly concerned identifying books and articles via the online public access catalog. However, similar to the sociologists, those who didn't work with rare materials preferred to avoid the library. Literary theorists liked to purchase books.

I use the library more for books I don't like — I don't want to own. Most of the books I respond to, I buy. [DSULT3]

If the disciplinary search strategy was to purchase books that are most relevant (and likable) there would have been little personal motivation, let alone disciplinary reward, for making the books not purchased more electronically accessible. Mismatches between electronic resources and field integration skills help explain other gaps in use of a variety of potentially useful technologies.

For example, one might expect electronic mail between authors to be an excellent means to track and facilitate discourse. Unfortunately, like computer science, public forums have major drawbacks for creating work using field integration skills. The following field notes from an untranscribed interview illustrates this point.

She describes the bulletin boards she uses as 'tempests in teapots' or 'local weather systems' where 'there are no consequences beyond the small'. She is uneasy about them because they are undisciplined and writing is about discipline and censorship. People on these bulletin boards talk about things she thinks and reads about and there is some air of seriousness. However there is also some total frivolity and no self-censorship. She finds this irresponsible because people make statements semi-anonymously. She knows people who use bulletin

boards, but she feels that she is in the majority in lurking rather than participating. [HULT1]

In this example the features of the communication system: its occasional ‘air of frivolity’, ‘lack of censorship’ and undisciplined writing conflict with her values and field integration skills for what constitutes legitimate discourse. Similarly others complained about the time pressure that they feel in responding to electronic mail and the tendency to be overly ‘chatty’ in electronic mail. Although many literary theorists had begun to use electronic mail regularly for a variety of tasks, only a few were able to use it to follow or create discourse in a serious manner. This state of affairs indicates that either more serious, disciplined forums will arise to match the values or literary theorists will continue to value more asynchronous and measured discourse than electronic mail and bulletin boards provided.

Similarly, the lack of use of MLA bibliography initially may be surprising considering it provides a comprehensive collection of diverse materials. The following quote illustrates a common problem with comprehensive databases that contain materials from multiple specialties.

I’ve had research assistants in the summer who I’ve asked to do a search in the MLA bibliography and they always came back with such huge piles of print outs that almost never seemed useful... I suppose it’s true that I tend not to search for articles unless I have reference already. [MULT1]

The comprehensiveness of MLA bibliography did not match the specialized vocabulary and constraints on desired materials literary theories developed for disciplinary materials selection. In fact, doctoral students reported using the MLA bibliography during one critical phase of their program. They used it to explore publications relating to potential dissertation topics. In other words, like TUCS3, they were worried about being scooped! Also like the computer scientists, as they improved the field integration of their work, they tended to recognize the ‘elasticity’ MULT1 mentions above.

Another field integration mismatch involves a set of electronic journals that were beginning to proliferate at the time of the study. The ‘English Server’ at Carnegie-Mellon University provided a set of interesting electronic materials and services that most literary theorists were aware of but few used regularly. One resource of interest was the *Journal of Post-Modern Culture* (JPMC). There was a lot of interest in the implications for discourse in this new media. However most literary theorists continued to rely upon the traditional modes of publication for key source materials. The discipline as a whole had deep ties to traditional forms of publication in its history and many literary theorists were not clear about how to respond with their work. In addition, similar to journals in every other discipline there was the practical matter of disciplinary material selection with respect to paper versus electronic media. The more established prestigious journals were distributed and consumed in paper formats. The accounts of disciplinary material selection were sprinkled with implicit association of electronic journals as newer, untested forums. More discussion of researcher perceptions of adoption patterns are discussed in (Covi, 1997).

Table 4 summarizes the material mastery skills in each of the four disciplines. This

discussion has explained how matching these disciplinary skills with features of using digital libraries and electronic materials can help us understand why particular digital libraries will be utilized.

## **5. Conclusions and implications**

This study identified patterns of document use by university researchers that clearly show the influence of social characteristics of scholarly research activities on digital libraries use patterns. By articulating the emerging theoretical construct called material mastery, this study explains why some disciplines used certain electronic resources more than other disciplines and why researchers within a disciplinary specialty use certain electronic resources more than other colleagues in that discipline. This study identified three characteristic components of material mastery: search strategies; selection skills; and field integration skills, in each of four disciplines that explained the reported use of digital libraries. These results provide both theoretical and practical implications.

This study was informed by and builds upon studies of scholarly communication, electronic journal use and information retrieval. It provides theoretical implications for extending the investigation of ‘user-centered’ searching and the role of ‘relevance’ in searching to incorporate a situated perspective of digital library use. Material mastery allows researchers investigating digital library resources to articulate a situated construct from which to discuss ‘relevance’ and ‘user-centered-ness’ without departing from the work and organizational influences that influence search effectiveness. By identifying specific discipline-specific patterns of working with materials as work practices embedded in social processes rather than retrieval activities apart from related interactions, future work will increase the understanding of the relationships between the social structure of knowledge in a particular discipline and the information use behaviors of those who create that knowledge. In this way, material mastery adds to a body of work related under the rubric of ‘social informatics’ that make theories of social behavior available in the analysis of digital library use (Bishop & Star, 1997).

For practitioners, material mastery helps broaden the definition of ‘access’ to digital library systems and services to include socially situated characteristics. By viewing access this way, practitioners will better recognize that digital libraries will be used only when workers can readily integrate them into social legitimated and legitimate-able ways of working. Providers of digital library technologies and content providers also need to become aware of the material mastery skills in the client populations they serve. In the late 1990s when the United States mass population is becoming familiar with system-specific searching skills for work and recreation on the world wide web, training of general search strategies is not always sufficient to justify the cost of the important but often invisible added value of information mediators. As information resource centers downsize and workloads increase for mediators, it behooves the digital library provider to become well-acquainted with the disciplinary search strategies and disciplinary materials selection behavior of the client population. Subject specialists were available to all the researchers in this study, but few worked closely with them. Instead researchers tended to rely upon apprentices or trained assistants to obtain if not select relevant disciplinary materials. The subject specialist, as a digital library provider, could assess the

Table 4  
Material mastery skills in four disciplines

Discipline	Disciplinary search strategy	Disciplinary materials selection skills	Field integration skills
Molecular biology	Looking through current journals to notice new, popular topics	Using article graphics (photos diagrams) or sequence citation to select relevant materials	Contributing to mandated databases using materials in comprehensive collections
Sociology	Searching database to get an incomplete listing to learn about unfamiliar areas or catch up on previously familiar areas	Selecting by expert referral, selecting materials from disciplinary collections,	Knowing who to ask about what materials, relating relevant outside materials to current work,
Computer science	Requesting papers based on previous knowledge of the research area, tracking specific authors or meeting authors at conferences	Selecting based on relevant to project/ current work, choosing scholarly communication outlet to minimize irrelevance	Publishing in appropriate outlets, valuing timeliness over possible duplication
Literary theory	Browsing journals and books to read in order to keep up with current discourse rather than to seek out new source texts	Selecting books and articles to become part of the owned working collection	Valuing thorough, crafted arguments over timeliness, honoring differences in textual forms

disciplinary search strategies and provide or assist in developing important new resources that would match material mastery skills.

Digital library developers can best use these insights in requirements analysis or user-centered design of electronic resources and services. Designing and adapting system features that address the field integration skills of the users would increase the likelihood of use over the long-term and ease training. Attention to building usable interfaces so that sophisticated search techniques or advanced features would be easily apparent to researchers who are more attentive to their problem than the system interface would also improve the likelihood of use. Also, knowing that material mastery skills change more slowly than the digital library technology they are building can help builders provide adaptable features for an increasing range of disciplinary search strategy skill among the users.

## 6. Future research

Material mastery provides an initial framing concept for examining the adoption and adaptation of new scholarly forms of communication. However, in order to test this concept, future work will investigate how skills and values change over time. One study will revisit the informants in this study to learn how, if at all, their reported scholarly communication practices have changed. Another sub-study will focus data collection on one particular specialty from this study to explore, in greater detail, the range of material mastery skills, how they vary between individuals and how they are developed and maintained over time. These studies will not only provide a greater basis for understanding, but they will also be able to elicit successful innovations in current information retrieval systems, services and their relationship to the work practices of scholars.

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