NOTICE TO READER

This manuscript is a final draft of the article as submitted to the Haworth journal *Science and Technology Libraries* in December 2002. Due to editorial error, Haworth published an earlier draft of this paper instead of the final draft. They declined to rectify this error in the online version of the journal.

Furthermore, the issue and copyright date of the journal as published was 2001 (vol.21 no.3/4) even though the issue containing this article did not actually appear until September 2003, due to ongoing publication delays of this journal.

The reader is advised that the author considers this version to be the definitive final draft that should have been published but was not. Scholars wishing to cite this work should preferably cite this final preprint, rather than the published article.

CONVERSATIONS WITH CHEMISTS:

INFORMATION SEEKING BEHAVIOR OF CHEMISTRY FACULTY IN THE ELECTRONIC AGE

David Flaxbart

SUMMARY: Six faculty members in the Department of Chemistry and Biochemistry at the University of Texas at Austin were interviewed one-on-one to gather information about their information-seeking behavior, favored resources, and opinions about the transition from a print to an electronic information environment. In most cases, these chemistry faculty members have eagerly embraced the enhanced access to chemical information made possible by the steady addition of electronic journals and networked database systems. The most-cited benefits include significant time-saving and convenience as well as access to more journals than ever. As a result, use of the physical library and its printed collections by faculty is declining. Chemistry faculty interviewed expressed a strong self-reliance in their information-seeking skills, and showed sophistication in their choice of tools.

KEYWORDS: Information-seeking behavior, electronic journals, chemists, chemistry faculty

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INTRODUCTION

Understanding how scientists gather and use information in their work is an important first step in developing library collections and services. It involves many facets: index searching, current awareness, reading behavior, communication among faculty and between instructors and students, and the role of the library. The comparatively recent addition of digital formats to the mix makes this topic even more challenging by adding complexity and moving much of the behavior outside the library walls. Electronic access, especially *remote* access, has generally increased the consumption of information, and at the same time provides different avenues for obtaining it.

A good portion of the literature on the "information-seeking behavior" of scientists has focused on the usage of scientific journals. The voluminous work of Donald King and Carol Tenopir is probably best known in this area, and has been extensively cited.[1-2] Research on the behavior of chemists as a specific group is somewhat less plentiful.[3-4] The advent of electronic journals has sparked significant changes both in the way scientists use their literature and in the way it is published.[5-7]

The predominant methodology in user-studies is the survey. Other methodologies used to examine user behavior include citation studies, focus group discussions,[8-9] and one-on-one interviews, the method employed for this article.

User-behavior studies, no matter how well executed, can have a number of inherent drawbacks. First, a user study dates very quickly. The rate of change in information services is currently so rapid that it is difficult to take a meaningful snapshot of it, and that snapshot may soon be of strictly historical interest. Comparison of studies over time, to detect trends and changes, is also difficult because of differing methodologies and subject groups. There is also a tendency in some studies to statistically over-analyze sparse or highly subjective data.

Further, there can be a significant disconnect between the types of questions asked in surveys, the respondents' understanding of those questions, and the investigator's interpretation of the responses. The two groups define terms somewhat differently, and much can be lost in the translation. An interview-based study can circumvent this problem by allowing the interviewer to adjust and adapt a set of questions for each respondent, explain unclear terms on the spot, and ask follow-up questions to elicit more in-depth responses. The drawback is that interviews take much more time, and the number of responses is much smaller than a survey can generate, thus making statistical analysis of results impractical.

Finally, any study that focuses on a single institution's user group is difficult to extrapolate reliably to other populations because of the wide variability in available resources and services among institutions.

So why do this? What can be gained from studying information seeking behavior among faculty? First and foremost, any excuse to sit down with one's faculty and discuss the information landscape is a good one. It helps educate the faculty, inform the librarian, and reduce the distance between them. In this sense individual interviews are much more meaningful than surveys.

Second, gathering details about how the faculty use library services, or don't use them as the case may be, can be useful both in validating the choices that the library has made recently, as well as inform future choices. Not only does this influence the selection (and deselection) of resources, it can also extend to the design of the library web site, and to the development of new services and outreach methods.

Finally, despite the transitory nature of user studies, some general conclusions can be reached that can and do extend beyond the immediate future. Some of them may even contradict common wisdom about what faculty do and how they do it, and break down a few stereotypes about scientists in general and chemists in particular.

CHEMISTS AND THEIR LIBRARIES

Chemistry is a highly collaborative science, whose core functioning unit is the research group. Laboratory work is carried out largely by graduate students and postdoctoral researchers. The professor organizes and directs the work, prepares grant applications, administers the funding, and supervises the workers. Papers to be submitted for publication might be written by the professor, but may also be drafted by the person who has done most of the lab work, who will usually be the lead author of the paper. The graduate students are often engaged in two-pronged workloads: participation in the team's work as a whole and their own research for their dissertations. In general these two directions are intertwined and often cannot be easily separated.

There is frequently collaboration among different research groups, either within the same institution or with others elsewhere. Interdisciplinary collaboration is also of growing importance, and research efforts frequently cross traditional departmental lines. This cross-pollination can be informal, or it may result in new "institutes" or "research centers" that share faculty and resources from several departments to explore cutting-edge fields, without the organizational baggage of established departments and curricula. Much of the most exciting research in universities today takes place within these dynamic groupings.

The work of a chemistry professor is multifaceted and extremely time-consuming. In addition to regular teaching and committee duties, the professor must oversee a group that might be quite large. This administrative role involves obtaining and dispersing funding, purchasing equipment, carrying out myriad administrative tasks, mentoring students, supervising dissertation research, and attending many meetings.

An assistant professor seeking tenure must juggle these jobs -- often without much experience, guidance, or administrative support or funding -- and still find time to excel and make a name for himself or herself in a large and intensely competitive international academic community. This can involve long workweeks and frequent travel. Obligations can pile up because the new professor needs to stay in the good graces of senior colleagues everywhere, making it difficult to say 'no.' And the constant need to secure outside research funding -- the single most important factor in success or failure -- looms over it all. The life of a professor can be very stressful.

Knowing one's way around the scientific literature is crucial to carrying out many of these duties effectively. Staking out a research area, getting funding, getting published, earning recognition from colleagues, and ultimately earning tenure all depend on strong information-seeking skills. A scientist lacking these skills is at a considerable disadvantage, and risks delays, embarrassment, and rejections on many fronts. Many of these skills are learned under duress as a graduate student, at the same time as the "culture" of the discipline is absorbed. Part of that culture is a sense of what information is most important and what publication avenues are most appropriate and advantageous.

If an army travels on its stomach, then chemists surely travel on their journals. The cutting edge and the archival record of chemical research are both found almost exclusively within the realm of peer-reviewed journals. Chemists have never widely adopted other formats such as preprints or conference proceedings. Patents, another major segment of the chemical literature, are not used as intensively by academics as by chemists in industry. Monographs are used for background and overview purposes, but are not regarded as mechanisms for transmitting new research results.

Thus chemists are highly dependent on timely access to the most important journals in their field, which include rapid-communication and letters journals, full paper journals, and review journals.

Most other things in the library -- databases, monographs, conferences, reference books -- are secondary in importance and are used mainly to identify more journal articles. So it should be no surprise that chemists will ultimately judge their library on its journal collection. In the past this meant print journal subscriptions in the library and photocopied articles obtained via interlibrary loan. Today this primarily means on-demand desktop access to electronic journals on the Web. As the availability and acceptance of digital information formats accelerate, user expectations rise accordingly, often challenging a library's ability to keep up both technically and financially.

And keeping up is the name of the game. Before World War II it was possible for a chemist to read and know almost all of the relevant literature in his field plus a fair amount of that outside his immediate area of interest. This is, of course, no longer even remotely possible. Chemists have time only to gather and read the most crucial publications for their research, and the unread ones pile up relentlessly. Yet a person does not become a chemist in order to search for and read about the research of others -- one's own research is what counts. That's why the ability to search and gather the literature quickly and efficiently is so important. Every hour spent reading or photocopying is an hour not spent experimenting and writing.

Much of their professional lives is wrapped up in the *process* of scientific communication: writing and submitting papers, reviewing papers and proposals by others, editing journals, browsing, reading, sharing, and discussing articles, maintaining personal reprint files, and searching databases for still more. The literature can fascinate, annoy, bore, surprise, and inspire. But ultimately it is just a means to an end. That end is the creation of new knowledge, which, as the cycle repeats itself, creates more literature.

THE SETTING

The University of Texas at Austin (UT) is a large public institution (over 52,000 students, over 11,000 of which are graduate students) with major programs in science and engineering. UT is the fourth-largest producer of Ph.D.'s in the United States. It is the flagship campus of the University of Texas System, which has eight other academic campuses and six medical institutions scattered around the state. Due to odd twists of history, the Austin campus has a large College of Pharmacy and a nursing school but does not have a medical school or a medical library. It is the flagship campus of the University of Texas System, which has eight other academic campuses and six medical institutions scattered around the state.

The Department of Chemistry and Biochemistry, a unit of the College of Natural Sciences, has over fifty tenure-track faculty positions and active interdisciplinary collaborations with a number of other academic departments, colleges, and research institutes on the Austin campus. Approximately 270 graduate students were enrolled in the fall of 2002, almost all of whom are on Ph.D. tracks. In addition, the department employs nearly one hundred postdoctoral researchers and other research scientists in various capacities, as well as around fifteen non-tenure-track instructors. There are 700-800 undergraduate chemistry and biochemistry majors; the latter outnumber the former. The Department occupies all of one of the largest buildings on the Austin campus, and also has labs in other facilities nearby. UT-Austin spent over $11 million in chemical R&D funds in 1999.

The Chemistry Library is located in the center of the chemistry building, on the ground floor. It is one of five science branch libraries on the main campus, which are administratively part of the UT General Libraries system. The Chemistry Library is responsible for collecting materials in chemistry, biochemistry, chemical engineering, and human nutrition and food science. While the Chemistry Library serves most of the needs of all chemists on campus, biochemists, medicinal chemists, and physical chemists also make extensive use of other branch libraries that hold materials they need. Founded at the same time as the University, in 1883, the Chemistry Library's collection is deep, with journal holdings extending back into the mid-19th century. Its collection numbers over 88,000 volumes, with over 300 current journal subscriptions. Approximately a quarter of the collection is currently housed in an offsite storage facility. The total annual budget for chemical information is around $700,000, which includes subscriptions to databases such as *SciFinder Scholar*, *Beilstein Crossfire*, and *Chemical Abstracts - Student Edition*.

UT-Austin has invested heavily in the future of online scholarly information. The UT library has subscriptions to several thousand electronic journals, as well as nearly 50,000 electronic books. Due to budgetary necessity, the General Libraries began in 2000 to cancel the print versions of hundreds of journals, especially those from large commercial publishers such as Elsevier, Academic Press, Kluwer, and Wiley. The Chemistry Library has over one hundred such online-only subscriptions at this time. It continues to maintain print subscriptions to core journals from the American Chemical Society, the Royal Society of Chemistry, and the German Chemical Society, among others.

METHODOLOGY

Six faculty members in the Dept. of Chemistry and Biochemistry were selected and asked to participate in a personal interview, which lasted 60-90 minutes. While these professors certainly do not form a scientific or statistical sample, and were not chosen randomly, they were selected with the intent of talking with a suitably representative cross-section of the department. Two interviewees came from each of the three largest subject divisions within the department: Biochemistry, Organic Chemistry, and Physical Chemistry. One from each division was a "senior" tenured faculty member and one was a "junior" tenure-track assistant professor, in order to take into account the generational differences among faculty. The one-on-one interviews were conducted in the faculty members' offices during the summer of 2002.

All faculty interviewed supervise active groups and laboratories containing a number of graduate students, postdocs, and in some cases undergraduate research assistants. The six interviewees and their main research specializations will be designated thusly throughout the article:

- Senior Biochemist: regulation and organization of metabolic pathways
- Junior Biochemist: bioinformatics of protein function and interactions
- Senior Organic Chemist: natural product synthesis and ligand-protein interaction and enzyme mechanism
- Junior Organic Chemist: catalytic processes in natural products synthesis; nanostructured materials design and assembly
- Senior Physical Chemist: photophysical processes in polymers and self-assembling polymers; polymer synthesis and characterization
- Junior Physical Chemist: spectroscopy and microscopy of heterogeneous materials

All interviews were based on a set of prepared questions, although the discussions ranged widely and occasionally went off on various tangents. The questions fell into several distinct categories:

1. Background questions on who within the research group carries out information-gathering tasks
2. Tools that are used for these tasks (database selection and awareness)
3. Tools and techniques used for current awareness
4. The impact of electronic journals on research
5. The future of chemical information and science libraries

The questions were primarily designed with the intent of launching an engaging conversation, and to obtain a glimpse into the world of the working research group.

INTERVIEW RESULTS

Despite the wide range of interests represented in this group, the interviews drew some consistent responses and validated some generalizations about chemical information-gathering practices.

Faculty Roles in Information Seeking

There has often been a vague assumption in libraries that science faculty do not carry out their own literature searching and information gathering -- that others, especially graduate students, do it for them. While this may be true for rote in-library tasks such as retrieving and copying articles, the interviews indicated clearly that faculty do most or all of their own literature searching themselves. All but one indicated that they rely on their own skills to gather necessary information. The senior biochemist stated it best: "I can cast a wider net with the computer [than students can], and use my judgment for the decision on which ones to pursue. That's not left to the students."

The exception was the senior organic chemist, who said that he relies on students to do searches for projects currently underway, while he tends to do searching for the future directions of research. Partly this is due to time constraints, but it is also a pedagogical issue, since he feels students need to learn how to gather information on their own.

Most of this work is done in their offices, during "regular" working hours. (Chemists can keep rather long hours, which frequently include late evenings and weekends.) Work at home is often limited by the quality of equipment and internet connections, which are generally slower than ethernet connections on campus. The fact that major resources such as *SciFinder Scholar* and *Beilstein Crossfire* cannot be proxied for off-campus use via third-party internet providers is also a factor, and thus home use is often limited to downloading and reading journal articles.[10] The junior biochemist said that he frequently downloads article PDFs in his office onto his laptop, then takes them elsewhere to read offline.

Each faculty member was asked to assess his own information-seeking skills on a scale from "expert" to "good" to "adequate" to "needs improvement." While modestly stating that there's always room for improvement, most rated themselves good or expert, and the quality of their responses to other questions largely backed up this assessment. The senior physical chemist said he is "adequate plus." The junior physical chemist stated that he is "pretty good, in comparison to my students, who are borderline adequate." He claims that he can always find a needed paper first, and that this ability involves his knowledge of the field as well as skills in selecting keywords and using databases -- skills that come with experience.

Another question dealt with the flow of information within the research group -- who informs and instructs whom in the availability and use of research tools. Again, most respondents indicated that a top-down model was the norm. Learning about new resources can often be haphazard, given the blizzard of email and paper mail descending on today's scientists. Everyone must set up filters to make it manageable, and sometimes library alerts and news postings do not make it through the first time. Viewing library "What's New" Web pages is a rare occurrence. Students and colleagues can always be sources of tidbits of news and advice, but it seems that faculty rely on their own abilities to stay up with the newest developments, and in turn inform their students.

The junior physical chemist said that students have more of a ‘pinpoint approach’ to finding literature, getting something specific right when they need it, rather than looking at much literature in general, whereas he gets his ideas from the old model of library browsing -- a "just in time" vs. a "just in case" philosophy. The senior organic chemist indicated that he depends more on student assistance than the others do, asking them for help with specific tools when he needs it. His students work more frequently with complex tools like *Beilstein Crossfire*, and he finds it faster to ask them for help than to relearn the details himself.

However, none of the faculty stated that they actively instruct their students in database use. Faculty may be more liable to pass on information in the form of relevant articles, PDF files, and email alerts, but in general database and journal searching skills are self-taught. Students learn from each other or from the library, but self-instruction is the norm, and it usually takes place at the point of need.

The Tools of the Trade

All the interviewees were asked about the primary and secondary tools they use in information gathering: which one is the most important, and why, and what others they also use. The variety of responses here was definitely interesting. Somewhat surprisingly, *SciFinder Scholar* (Chemical Abstracts) is not always the tool of choice for some chemists.

The organic chemists benefit from having two excellent resources at their disposal. Both claimed frequent use of *SciFinder Scholar*, but also of *Beilstein Crossfire*, and said that the type of information need governed the choice between them.[11] The junior organic chemist prefers *Beilstein* for seeking preparation and reaction information, especially for natural product fragments, since this tool's structure searching capabilities are faster and more powerful than *SciFinder*'s. Topical and keyword searches, on the other hand, are much more effectively done in *SciFinder*. He indicated that both tools are used daily. The senior organic chemist likewise said that "*Beilstein* is a better tool for things we typically do," but that *SciFinder* was used slightly more than *Beilstein* because of its author and keyword capabilities.

The junior physical chemist also uses *SciFinder* as his primary tool, because of its good coverage of the physics literature. One drawback he described is *SciFinder*'s inability to do precise multi-field searches up front. (*SciFinder* requires the user to execute a single initial query by topic or author or chemical identifier, then refine or analyze the results after the fact.)

The senior physical chemist was the only one who indicated a preference for *Web of Science*, the public interface to ISI's *Science Citation Index*. He uses this tool daily because "it cuts across things in a unique way and avoids keyword problems by tracking citations and co-citations over time."

The two biochemists described the most sophisticated approaches to using databases to locate pertinent literature. Both biochemists indicated that *Medline* (or its free version, PubMed) is their primary tool for literature searching. This may be the result of individual research emphasis: the senior biochemist categorized himself on the biological, rather than the chemical, end of biochemistry. He described a highly specialized method of searching. His research group relies on EndNote bibliographic management software as a front end to *Medline*, simultaneously building a local database of bibliographic records for subsequent use in writing papers. He said that EndNote is "on all the time" on his computer, and that he searches both *Medline* and his local database several times a day at least.[12]

The junior biochemist, whose specialty involves bioinformatics, called *Medline* the most important tool in his field, and said it was used almost exclusively. While he uses the standard public interfaces to *Medline* (either Ovid or PubMed), his group also licenses the *Medline* database directly and loads it onto a local server. This file is then "mined" using custom-written Unix programs that look for articles reporting highly specific information on protein interactions. These searches primarily target the Abstract fields, rather than MeSH headings, which he characterized as "horrible, arbitrary, and inconsistent." He indicated that more than half of the group's literature retrieval was based on this data-mining technique, and that *Medline* is a very rich database to use for this purpose because of its size and age.

The faculty also described a variety of secondary access tools that are used to complement the primary favorites. The senior organic chemist named *Medline* as an occasional backup to *SciFinder* and *Beilstein*. He also said he does searches within specific publisher e-journal sites, such as the American Chemical Society's Web Editions and Elsevier's *ScienceDirect*, though these searches are usually limited to looking for papers by specific authors. The junior organic chemist indicated *Chemical Abstracts-Student Edition* (via OCLC FirstSearch) as a favorite alternative due to its flexible multi-field searching capabilities. He also uses *Web of Science* when looking for the "state of the art" on a particular topic, especially when he's engaged in writing a paper for publication. Although he doesn't use it nearly as frequently as *SciFinder*, it is equally important at these times. Both physical chemists also listed *Chemical Abstracts-Student Edition* and *Web of Science* as alternatives for the same reasons.

The biochemists again displayed more independence from "traditional" tools to complement *Medline*. The junior biochemist listed resources such as *Faculty of 1000* (Biology Reports Ltd.), *BioMed Central*, and *CiteSeer* (also known as NEC ResearchIndex, for computer science topics), as well as *Web of Science*. The mention of *Faculty of 1000* was particularly interesting as an alternative, peer-recommended approach to the biology literature.[13]

The senior biochemist mentioned tools such as the NIH-NHGRI genome databases, that provide crucial genetic data in the public domain. He noted however that there is currently a tendency to privatize these formerly free tools and charge for access to them, which in most cases means that he no longer bothers with them. (A specific example is the *Yeast Proteome Database*, now owned by InCyte.) He suspects that many of these newly commercialized tools will fail in the near term for lack of subscribers. Academics have their own ingenuity to fall back on: "we're cheap, and we know how to do things ourselves." The senior organic chemist also noted the *Protein Data Bank* (PDB) and various NIH sites as important resources.[14]

Finally, faculty were asked about their knowledge and use of a short list of free Web resources that are often linked to from library web sites. Some of these are literature-based, while others are focused on chemicals or chemical data. Surprisingly, some of these sites tended to be unknown to the faculty interviewed, or known only by name, and rarely if ever used. Table 1 presents a matrix of these sites and the responses to them.

TABLE 1

Use of Selected Web-based Resources

Resource	Sr. Org.	Jr. Org.	Sr. Phys.	Jr. Phys.	Sr. Bio-chem.	Jr. Bio-chem.
ChemWeb	O	N	N	U	N	H
ChemFinder	N	H	N	N	U	N
NIST Chemistry WebBook	N	N	N	U	O	N
BioMed Central	N	H	N	N	H	U
PubMed Central	H	N	N	N	U	U
PubScience (DOE)*	N	N	N	N	N	N
sciBase	N	N	N	N	N	N
arXiv.org (LANL/Cornell)	N	N	N	O	N	N
sigmaaldrich.com	H	O	H	U	U	H

Key: U - uses this resource; O - has used it occasionally but not regularly; H - has heard of it but doesn't use; N - has never used it.
* PubScience was discontinued in November 2002.

Staying Up to Date

One of the most daunting problems facing today's scientists is keeping up with the literature in one's field. As the scientific literature has expanded relentlessly in past decades with more authors publishing more papers in more journals than ever before, the problem is not a minor one. It requires a concerted effort on the part of a scientist to stay abreast of the latest developments in even a highly specialized field, and this leaves little time for reading in "outside" areas.

Brown described preferred methods for staying up to date among chemists and biochemists: scanning current journal issues was far and away the most professed method.[15] While the tools, access methods and formats have all evolved, this is still largely true today. Fernandez conducted a survey that found that faculty still tend to use a wide variety of mechanisms to stay current in their literature, with table-of-contents (TOC) scanning being the most popular.[16]

Publishers have long acknowledged the importance of scanning tables of contents of journal issues, and many have set up free email services that will alert recipients when new issues of specific journals are published. Some messages contain that issue's table of contents; others merely include a URL where the TOC can be found on the Web. A major drawback to this type of service is that many journals are so large that TOCs are of marginal use to chemists looking for highly specific articles. Titles such as *Proceedings of the National Academy of Sciences* and *Journal of Biological Chemistry* are so vast that TOC scanning can be quite time-consuming and often not fruitful. Most of these services originate with the publisher and do not involve the library directly. Some libraries have in turn offered locally-developed alternatives as well.[17]

In the past, scanning journals required regular visits to the library, as well as examining whatever personally subscribed journals came in the mail. Most libraries provide a current periodicals area where new issues are kept for a time. A faculty member who set aside a particular time period each week for browsing there could expect to stay up to date on interesting new developments. This scenario, however, is rapidly becoming obsolete. All but one faculty member interviewed for this article indicated that they rarely if ever visit the library for this reason anymore; some never did in the first place. Only the senior organic chemist expressed a preference for browsing new journal issues in the library. Unfortunately, he can no longer be assured of seeing all the latest issues because the UT library has dropped so many print subscriptions in favor of their online counterparts over the last couple of years. This is a trend that will no doubt continue due to ongoing budgetary constraints.

The junior biochemist subscribes to a number of specific TOC-alerts. The junior physical chemist avoids TOC-alerts because he doesn't want to receive large volumes of unnecessary email. He prefers to search "on the back end" in indexes like *SciFinder* and find new materials that way. He peruses tables-of-contents on occasion, but this is not a priority.

Organic and medicinal chemists are somewhat different in that they are structure-based rather than vocabulary-based. Graphical tables of contents (or graphical abstracts), which have existed in print for many years, are vital for effective journal scanning in organic chemistry: they enable a reader to scan an issue's contents looking not for key terms, but for structural representations of the chemical substances and reactions central to each article. The senior organic chemist, as mentioned above, said he prefers to look at graphical table-of-contents (GTOCs) of journals in the library, and failing that, browses them online when available. The junior organic chemist keeps a meticulous written list of his core journals, marking off each issue as it is examined online, so that he doesn't miss any. He also prefers looking at GTOCs online, which maintains a degree of serendipity that would be lost if he relied on keyword searching in indexes. Major organic journals such as *Journal of Organic Chemistry, Tetrahedron, Tetrahedron Letters,* and *Organic Letters* have incorporated GTOCs into their online versions, with varying degrees of effectiveness. Special current awareness publications such as *Methods in Organic Synthesis* and *Natural Product Updates* (both from the Royal Society of Chemistry) are composed entirely of graphical contents selected from other journals. The *Derwent Journal of Synthetic Methods* similarly abstracts new reactions from core journals and worldwide patents.

Third-party table-of-contents services have existed for many years. ISI's Current Contents and UnCover are probably two of the best known. While the UT Libraries have made use of UnCover (now taken over by Ingenta) and subscribe to its Reveal alerting service, there is little evidence that it is used much by science faculty. UT has not subscribed to any Current Contents databases in the past, so these are not a local option. Furthermore, none of the faculty mentioned using the TOC viewing function within *SciFinder Scholar*. (Since this is a relatively new addition to Scholar, they may not be aware of it, and usage statistics indicate that this option is rarely used at UT.) The commercial version of *SciFinder* provides a "Keep Me Posted" function for registered users, but this is not available in the academic version.

Of the six faculty interviewed, only the senior biochemist indicated that he uses an independent automated TOC service. His group, with two others, shares a subscription to a service called Reference Update (RU), now provided by ISI and similar to Current Contents for the biomedical sciences. Subscribers receive a weekly download of new records covering about 1,100 biomedical journals, that can be searched within special client software supplied by the vendor. (RU does not cover core chemistry topics and journals.) This enables the user to create and store search profiles that are used over and over. Although the service is not cheap, the biochemist said that cost is not a factor: "RU is easily customized as my focus changes. I would happily pay for it all myself, [since] there's no way to keep up with the literature without something like this."[18]

The senior biochemist is also one of the handful of faculty members who still receive an electronic SDI ("Selected Dissemination of Information") via the library. An automated search profile within the STN online interface is run against new records added to the CA file every two weeks, and results are emailed to him. The library picks up the charges for this service. This complements his other regular searching in *Medline* and Reference Update, and retrieves some items of more strictly chemical interest that would otherwise be missed. ~~Due to the costs involved, this is not a service that is widely advertised to faculty.~~

Given the overall difficulties in scanning new journals for articles of interest and the apparent reluctance to use publisher-based or third-party alerting services, do these faculty feel that they're really keeping up to speed with the literature? Their responses to this question varied. The senior biochemist, who has by far the most elaborate literature retrieval setup, feels he is up to speed, despite the steadily increasing volume of literature. The junior biochemist speculates that he "misses a fair bit" and would like to see better alerting services to streamline the process, although time is a limiting factor that will never go away.

Both the junior and senior physical chemists confessed that they miss way too much. The senior one expressed "semi-angst" in admitting that he hasn't been able to keep up for years, though he's generally aware of developments in specific areas. When he moves in a new direction, a "blitzkrieg" of reading is required, especially when a new grant proposal is being written: a failure to cite relevant research can cause delays in the grant review process (as well as potential embarrassment). The junior physical chemist expressed similar tendencies to ratchet up searching and reading during grant- and paper-writing time. He is often shocked by what he has missed, and feels that's just the tip of the iceberg. But "as long as we're not completely scooped, we can continue to make contributions."

In contrast, both organic chemists feel they are up to speed with the literature, though they must be more selective in what they choose to read.

A follow-up question asked the faculty members to estimate whether they now read more or fewer articles, and scan more or fewer journals, than they did in the pre-online past. Again, the responses varied. The junior organic chemist responded that he now reads and scans more than he used to, due to increased availability and convenience. The senior organic chemist, on the other hand, reckons he reads less. As he still relies on print, this is due in part to the cancellation of print of journals he used to scan. The junior physical chemist pointed out that it's much easier to obtain, store, and forward articles in PDF format -- he suspects he has thousands squirreled away on his hard drive -- but no easier to find time to read them all. His reading volume probably hasn't changed much, though he is likely now selecting better things to read. His senior colleague believes he reads and scans more now, and citation tracking leads to new journals and more papers in a given area that he would not find in traditional TOC scanning.

The junior biochemist stated that even though he has access to many more articles, he has "time to look at a lot less." As a specialist in the rapidly expanding fields of genomics and proteomics, where the volume of literature and number of journals are growing quickly, he must scan more titles than he used to. His senior colleague believes he is reading the same number of or more articles, and scanning more journals, due also to the convenience of online access.

Despite the increased access and convenience brought about by electronic journals, it is obvious that the principal limiting factor in the chemist's literature consumption pattern is time. More articles from more journals may ebb and flow across the desktop, and a 100-gigabyte hard drive can absorb a vast number of PDF files, but only a finite number can actually be read and assimilated. Selectivity is crucial: the chemist must now choose only the best and most promising items to read, and these tend to come from a limited number of prestigious "top" journals. While there are thousands of journals published in chemical and biochemical fields, it is very likely that most are rarely read or consulted. Large e-journal package subscriptions such as ScienceDirect, which bundle the good with the mediocre, have widened the availability of lower-tier journals, few of which had wide print distribution. Both citation studies and analysis of consortial e-journal usage statistics show that their usage nevertheless remains low compared to that of top-tier titles. It seems that Bradford's Law, which posits that a small core of journals accounts for the bulk of use, is alive and well.[19-20]

The Changes Brought by Electronic Journals

It is difficult to overstate the impact electronic journals have had on the practice of science. The profound nature of the changes brought about by desktop access to journals makes it difficult to believe that they have only been in existence for less than ten years, in many cases less than five years. The rate of adoption of new formats by both publishers and end-users has outstripped even the most optimistic estimates of the mid-1990s. No matter how one measures it -- by levels of comfort, levels of usage, expressions of satisfaction -- scientists have embraced electronic access with open arms, even though some remain troubled about long-term issues such as archival permanence, economics, and the serendipity factor.

Early pilot projects with online journals, such as the CORE project at Cornell University in the early 1990s, showed chemists voicing concerns about the viability of accessing journals on a computer.[21] Most faculty did not anticipate rapid acceptance of this new format in place of comfortable printed journals that had remained largely unchanged for many decades. Nor did many librarians. The fact that two extraordinarily conservative and cautious cultures -- academic science and scholarly publishing -- adopted electronic formats so quickly is testimony to the power and attraction of digital access. There will be no going back.

The interviews for this article offered the opportunity to hear opinions about electronic journals and their significance. While the interviews covered a variety of subjects, the faculty tended to direct much of the conversation toward this topic, making it clear that much of their thinking on chemical information now revolves around electronic journals.

When asked how electronic journals have affected their work, the faculty interviewed were unanimous in their opinion that e-journals have brought major changes. The change cited most often is the saving of time. The junior organic chemist said it best: "Hours spent in the library are now reduced to seconds online. [It's] that much easier to stay ahead of the curve." The junior biochemist recalled the "miserable success rate" he used to experience in using his university library as a graduate student, and how electronic access has made obtaining articles so much easier and more efficient.

As much as some scientists and librarians like to wax nostalgic about the happy and fruitful hours spent exploring the library stacks, the basic reality is that many scientists (and students) never enjoyed the task: it was something put off as long as possible, delegated to others, or neglected altogether. The hassles and obstacles involved in doing library research in the printed world -- poring through arcane and microscopically-printed indexes, searching for shelving locations, tracking down missing journal volumes, recalling books, fighting malfunctioning photocopiers -- are likely reasons why library users have been so quick to embrace an alternate mode of access. Using any library can be a frustrating -- even maddening -- experience at times, especially if one is in a hurry. This is not to say that the digital library is inherently easier to navigate, or more clearly organized, or more complete -- but it is certainly *faster*. And the ability to explore it and retrieve information without leaving one's office makes up for many other shortcomings as far as users are concerned. You still may not find what you're looking for, but at least you didn't waste four hours trying.

Other questions addressed their current use of the physical library, and how they felt about losing access to many printed journal subscriptions, which are being dropped in favor of online-only formats. All those interviewed reported that they come to the actual library less now than they used to (despite the fact that the Chemistry Library is in the same building as their offices). The junior physical chemist says he still comes to the library fairly often (as it is very close to his office), but rarely can muster the energy to walk to other nearby branches. Almost all of his journal articles come from the online sources, however. Immediate desktop access to articles is to him an important indication of value: the more effort it takes to get a copy, the less likely it will turn out to be worthwhile. The junior organic chemist expressed equal enthusiasm about e-journal access, but said he would seek out what he needed regardless of its format or location.

The senior faculty might be expected to miss printed journals more than their younger colleagues, and this was reflected in their responses. The senior organic chemist was alone in saying that he still uses print journals most of the time. He is still a frequent visitor to the library, but now has fewer printed journals to scan and use due to the cancellations of that format, a fact that clearly distresses him. He is reluctant to migrate to electronic access: "Until it becomes necessary I won't do it." The senior physical chemist expressed some similar sentiments, saying that he missed the serendipity factor of flipping through journal issues: coming across the unexpected may be possible in the online world, but "it doesn't seem to happen much in reality." He too visits the library less nowadays, "because it's easier not to."

The rush to convert libraries to digital formats, while a boon to most researchers, is clearly not applauded by everyone, and librarians must be careful not to assume that it is. It can be tempting to dismiss the arguments of print-lovers as hold-overs of an earlier age, from people unwilling to change. But there are demonstrable drawbacks to an online-only world, particularly visible in the well-documented reluctance of many people, young and old alike, to read anything from computer screens. A paper print-out is still the final destination for most articles, which may explain why PDF formats are still far more popular with users than HTML versions of the same content.[22]

The Future

The concluding set of questions asked the faculty to give an overall impression of today's chemical information landscape, whether they think it is getting better or worse, simpler or more complex, and what they think about the future of science libraries.

The senior organic and physical chemists were ambivalent about the changes they've seen so far, and where they're leading. The latter called the current situation "chaotic" in that there are now so many places a user must remember to look online for pertinent information. He is also concerned that availability of the gray literature will suffer as researchers focus only on journals that are accessible online. (The very term "gray literature" may now be expanding its meaning to include journals that are not online, which must surely be an ominous warning to their publishers.)

The senior organic chemist decried the time it takes to navigate through multiple web pages to reach a desired article -- a task that could be done faster by flipping rapidly through a print journal. He looks forward to increased hypertextual crosslinking among journals and indexes, especially using metadata applied to chemical structures within the text. But he said that overall the situation is "not yet at the point where we need it to be."

The others interviewed were generally enthusiastic about the direction chemical information is taking, and feel that it is now easier to identify and obtain information. The junior physical chemist believes that "it's immensely easier to find stuff now," as well as less time-consuming. He doesn't hesitate to do exploratory literature searches on a whim, just to see what's out there. The rest echoed this opinion.

When asked about what they'd like to see developed in the next few years, faculty mentioned things that are being actively considered as next steps in the online information infrastructure. The junior physical chemist, expressing amazement at how little genuine content is out there on the Web, sees a role for libraries in filtering the gems from the dirt. The junior organic chemist had a desire for more complete journal backfiles online, with more extensive crosslinking among them, as well as electronic versions of key reference works popular among organic chemists.

The theme of seamless linking back and forth from indexes to fulltext was mentioned again and again. This would require greater cooperation among publishers than currently exists, as well as further development of standards such as DOI and OpenURL, and wider implementation of link-servers that bridge the gap between databases and local subscriptions. Ironically, taking advantage of digital-only article features would require users to move away from static PDF versions, which at this time they seem reluctant to do. The portability and printability of the PDF clone still trump the more flexible HMTL/SGML/XML versions. The junior physical chemist admitted that colorful animations and applets in an article are eye-catching, but ultimately they are based on raw data, which is what a scientist really wants to scrutinize.

Some of the faculty are acutely aware of troubling issues facing all the stakeholders in scientific information, particularly the problems of archival permanence and cost. Others are only vaguely aware of these issues, and have not yet given them much thought. The younger faculty tended to be more suspicious of publishers' motives and long-term commitment to access than the older ones, who have worked longer with publishers as editors and reviewers. Electronic journals have a more tenuous quality than printed volumes on library shelves. Entire collections can vanish with the push of a button or the crash of a server. The junior physical chemist went so far as to say he was afraid that libraries might be "scammed" in the future by publishers who threaten to take away access to crucial information if growing money demands can't be met. Libraries need guaranteed permanent access to material they've paid for, and preferably they should only pay once, not over and over, he said. The junior biochemist is equally uncomfortable with commercial publisher control over vital research information. He knows and supports the goals of the Public Library of Science, but must still submit papers to non-conforming journals due to the demands of tenure and promotion.[23]

CONCLUSION

While academic chemists certainly share many similarities, it should be noted that the chemists interviewed for this article are faculty at a large research university, whose main interests are focused on cutting-edge research and publication, and the training of graduate students. They also benefit from having access to a large library system offering subscriptions to thousands of STM journals, fairly comprehensive monograph collections, and many (but certainly not all) of the major database systems now available for campus licensing. Their responses might not coincide neatly with those of faculty at smaller institutions whose primary mission is undergraduate education. The faculty interviewed for this study were chosen to provide a broad representation of research chemists according to seniority and subject specialization.

Chemists are happiest when they feel that their library is making genuine attempts to understand the uniqueness of their information resources and needs, and not lumping them together with other scientists. Chemistry is not like biology or medicine or physics. These fields certainly share similarities, but each has its own unique culture, vocabulary, and scholarly communication system. This caveat extends to the fact that Chemistry itself is not a homogeneous discipline. The same kinds of differences that separate broad disciplines also separate -- to a somewhat lesser extent -- subfields within the discipline.

While one would expect a variety of approaches to information seeking, their remarks provided strong evidence that electronic access is taking over more completely and more rapidly than anyone could have predicted a few years ago. Chemists have largely overcome their initial reluctance to use and depend on electronic journals. Faculty, far from being slow to adapt, are leading the way, continuing to direct their research groups' information-seeking in the new environment. While there is certainly two-way flow in the groups as faculty and graduate students learn from and teach each other in many informal ways, faculty resist depending on others for their information needs. The faculty's level of sophistication in seeking information should not be underestimated. They are creative, canny consumers and searchers. Generational differences, while evident to some extent in this small sample, are not large and should not be overestimated -- most senior faculty are adept at manipulating changing formats and have adapted just as well as their younger counterparts.

It is also clear that, for the most part, faculty are using the physical library much less, even when their offices are nearby. The time-savings and convenience of online journals and databases enable faculty to consume more information in less time. Faculty are supportive of the library, but admit that they will visit the facility less if they don't have to. The key task for librarians in the future will be to ensure that users continue to make the mental connection between the online resources they use and the library, which still must select, pay for, organize, and promote them. The library retains its crucial role of intermediary, and this function is more important than ever as users face a widening array of choices, and a wide variation in content quality on the Web. The faculty interviewed understand that role and express hope that it will continue to grow.

Librarians studying the information-seeking behavior of chemists should avoid focusing too much on particular tools and resources. When choices are available, chemists will choose tools that suit them best, and these vary according to subject specialty, type of need, and personal preference. *SciFinder Scholar* is an extremely broad and useful resource, but it is not the ideal tool for every information need in chemistry. Libraries can get tremendous mileage out of a few well-chosen (but often expensive) resources. Offering a variety of tools is important, along with the knowledge that nobody uses everything, but everybody uses something.

As librarians are already well aware, the process of identifying documents has long since migrated to online database use. Printed indexes and alerting publications are relics of the past. Many academic libraries that have not already dropped subscriptions to the printed *Chemical Abstracts* may choose to do so in the near future. However, the appropriate online replacement for CA, *SciFinder Scholar*, is far from being affordable for many libraries, forcing some to retain printed CA against their preference or better judgment. Many smaller schools, as well as those in developing countries, can afford neither. Access to the tools of chemical information is a necessity, not a luxury, and librarians and faculty together should continue to advocate for affordable access for all educational institutions.

While this study made no attempt to gather quantitative data on e-journal use, the opinions expressed by faculty point to the overwhelming acceptance of digital formats as the *primary* means of viewing the results of chemical research. As a new generation of graduate students moves into the faculty, it is very possible that their attitudes, coupled with market forces, will virtually eliminate the traditional printed scholarly journal from the daily lives of most practicing chemists. Librarians will thus have to reassess the need for maintaining print subscriptions into the future. The gradual conversion of archival backfiles to digital formats will likewise drive a trend of moving to off-site storage or even discarding altogether the printed runs of some journals, further decreasing the use of physical libraries.

This begs the question of the long term fate of science branch libraries, which could face pressure from academic departments to shrink, move, or even close altogether as electronic formats replace print in the hearts and minds of users at all levels. Collections housed in centralized libraries (which are already "remote" as far as many scientists are concerned) will also face pressure to downsize or move to off-site or compact shelving. Librarians will have to plan actively for the evolution of the library from a book-centered shelving facility to a user-centered "information commons."

While the revolution in *access* has been rapid, the revolution in scholarly communication is only half-complete. The myriad capabilities of the digital medium have made few significant inroads into major chemical journals. Features only possible in digital format, such as 3D molecular structures, animations of dynamical processes, raw data files, interactive calculations, applets, metadata, and Chemical Markup Language (CML), are still waiting for wider adoption.[24] Test-beds such as the *Internet Journal of Chemistry* have not yet been very successful in attracting chemists to these technologies.[25-26]

Scientists and editors have welcomed the electronic journal and database for their convenience, power, and speed, but the fundamental design of the scholarly journal and the articles within it has changed very little. The final output is most often a print-out or photocopy that duplicates the original printed page. Is this because the traditional printed article is still an ideal information delivery package, that needs no further bells and whistles? While everyone can see the limitations of the two-dimensional printed page, a migration to more evolved digital artifacts will have to be led by the authors, editors, and readers – who are, after all, the same people. These changes cannot be forced upon them by publishers or libraries.

It remains to be seen whether electronic formats will spark a revolution in scholarly communication as profound as the ongoing revolution in access. Scientists and librarians both have a very large stake in the outcome, and must work together to ensure that it is positive for everyone. To that end, the opinions of academic chemistry faculty matter a great deal, and librarians can benefit enormously from keeping a finger on the pulse of the primary creators and consumers of chemical information.

NOTES

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2. King, Donald W. and Tenopir, Carol. 1999. "Using and reading scholarly literature." *Annual Review of Information Science and Technology (ARIST)* 34:423-77.

3. Williams, Ivor A. 1993. "How chemists use the literature." *Learned Publishing* 6(2):7-14.

4. Brown, Cecilia. 1999. "Information seeking behavior of scientists in the electronic information age: astronomers, chemists, mathematicians, and physicists." *Journal of the American Society for Information Science* 50(10):929-43.

5. Stewart, Linda. 1996. "User acceptance of electronic journals: interviews with chemists at Cornell University." *College & Research Libraries* 57(4):339-49.

6. Stankus, Tony. 1999. "The key trends emerging in the first decade of electronic journals in the sciences." *Science & Technology Libraries* 18(2-3):5-20.

7. Sathe, Nila A., Grady, Jenifer L., and Giuse, Nunzia B. 2002. "Print versus electronic journals: a preliminary investigation into the effect of journal format on research processes." *Journal of the Medical Library Association* 90(2):235-43.

8. Searing, Susan E. and Estabrook, Leigh S. 2001. "The future of scientific publishing on the Web: insights from focus groups of chemists." *portal: Libraries and the Academy* 1(1):77-96.

9. Young, Nancy J. and von Seggern, Marilyn. 2001. "General information seeking in changing times" *Reference & User Services Quarterly* 41(2):159-69.

10. Some institutions have developed technical solutions to the problem of proxying SciFinder Scholar for off-campus use via third-party internet providers, but the author's institution has not yet had the financial capability to explore them.

11. *SciFinder Scholar* is the proprietary academic interface to the Chemical Abstracts suite of databases. These include the CAPLUS file, Chemical Abstracts back to 1907; the Registry file, a database of chemical structures and names containing more than 40 million compound records; the CASREACT file, indexing several million organic reactions back to 1975; and subsidiary files such as CHEMLIST (regulatory information on chemicals) and CHEMCATS (chemical supplier catalogs). The Registry and CASREACT databases are searchable by chemical structure drawing as well as character-string queries. *SciFinder* is a site-licensed product of Chemical Abstracts Service, a division of the American Chemical Society.

    Beilstein Crossfire is a proprietary interface to the *Beilstein* database of organic structure and property information, containing records for over seven million carbon compounds and seven million organic reactions, with associated physicochemical data and literature references. *Beilstein Crossfire* is a product of MDL Information Systems, a subsidiary of Elsevier Science. It is made available for academic site licensing via the *Beilstein* Minerva Consortium in cooperation with the University of

Wisconsin. Both *SciFinder Scholar* and *Beilstein Crossfire* require special client software to be installed on a user's machine.

12. EndNote allows direct connections to Z39.50-compliant databases and provides a generalized search interface to specific files. Records retrieved can be directly imported to a locally-maintained database and then searched later. A number of chemistry graduate students have indicated a preference for this type of searching interface, and express disappointment at the inability to connect to databases such as *Chemical Abstracts Student Edition* (FirstSearch) and *SciFinder*, which are not Z39.50-compliant. The library usually discourages this technique, since it bypasses many of the unique features of native database search interfaces. Records retrieved via native search interfaces can however be imported into bibliographic management software with appropriate filters. EndNote is a product of the Institute for Scientific Information (ISI): *http://www.endnote.com/*

13. Faculty of 1000: *http://www.facultyof1000.com/start.asp* From the home page: "Faculty of 1000 is a new online research tool that highlights the most interesting papers in biology, based on the recommendations of over 1000 leading scientists." It is available via personal or institutional subscription. BioMed Central: *http://www.biomedcentral.com/* CiteSeer: *http://citeseer.nj.nec.com/cs*

14. National Human Genome Research Institute (NIH-NHGRI): *http://www.genome.gov/* InCyte Yeast Proteome Database: *http://www.incyte.com/sequence/proteome/databases/YPD.shtml* Protein Data Bank: *http://www.rcsb.org/pdb/*

15. Brown, "Information seeking behavior of scientists," 931.

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17. Schlembach, Mary C. 2001. "Trends in current awareness services." *Science & Technology Libraries* 20(2-3):121-32.

18. Reference Update: *http://www.isinet.com/isi/products/ru/*

19. Davis, Philip M. 2002. "Patterns in electronic journal usage: challenging the composition of geographic consortia." *College & Research Libraries* 63(6):484-97.

20. Davis, Philip M. 2002. "Where to spend our e-journal money? Defining a university library's core collection through citation analysis." *portal: Libraries and the Academy* 2(1):155-166.

21. Stewart, "User acceptance of electronic journals."

22. In 2001, Austin users downloaded 46,865 articles from the American Chemical Society Web Editions system; 86 percent of these were in PDF format.

23. Public Library of Science: *http://www.publiclibraryofscience.org/.* PLoS started as an open letter signed by thousands of scientists demanding that journals make their archives freely available to the world after a certain time, and calling for authors to boycott journals that did not comply. This demand was generally ignored by publishers, and no boycott resulted. PLoS is now turning to self-publishing

alternatives instead, and in 2003 launched its first open-access journal, *PLoS Biology*.

24. Murray-Rust, Peter, Rzepa, Henry S., and Wright, Michael. 2001. "Development of chemical markup language (CML) as a system for handling complex chemical content." *New Journal of Chemistry* 25(4):618-34.

25. The *Internet Journal of Chemistry* began in 1998 with the laudable goal of demonstrating and promoting the capabilities of Internet technology in chemical communication. But the number of articles published has declined steadily in each successive year: 38 were published in 1998, but only eight appeared in 2002. Available at: *http://www.ijc.com/*

26. Bachrach, Steven M., Burleigh, Darin C., and Krassivine, Anatoli. 1998. "Designing the next-generation chemistry journal: The Internet Journal of Chemistry." *Issues in Science and Technology Librarianship* no.17 (Winter). Available at: *http://www.istl.org/98-winter/article1.html*