Online Systems for Information Access and Retrieval

Carol Tenopir

Abstract

In 1973 F. W. Lancaster published the first textbook about online information retrieval (with E. G. Fayen). That text and his later writings and books on the topics relating to online searching set the precedent for many books to follow. His early work also advocated many changes to the state-of-the-art systems and anticipated many of the characteristics of modern online information retrieval systems. Although the basic underlying structure of modern systems is still similar to what Lancaster wrote about thirty years ago, many of the changes he advocated have occurred. From an era of bibliographic databases on command-driven systems searched by library professionals, online systems have evolved to have friendlier interfaces, include full texts or links to full texts, and are targeted to the end users of the information. The information industry has evolved, as have the online search systems and tools that are so commonplace today.

Introduction and Lancaster's Legacy

Information Retrieval On-Line by Lancaster and E. G. Fayen, published in 1973, set the standard for a multitude of books that appeared throughout the '70s, '80s, and '90s about online searching for information professionals. The winner of the 1974 Best Information Science Book Award, its significance goes far beyond being a catalyst for other textbooks, however.

Ask college students today when online information systems first became available and they are likely to point back only to the 1990s when the Internet and World Wide Web made online content ubiquitous. By the time Lancaster's book on the topic was published twenty years before that, he had already worked for several years to shape the emerging online

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database industry. (The essay by Barbara Rapp describes his influential evaluation work for the National Library of Medicine MEDLARS.) This 1973 book marked the historical moment in time when online systems (the term then still emerging as "on-line") became the standard for information retrieval. First bibliographic databases, then directories, other reference books, full text journal articles, and electronic books, online information systems became the norm for searching and retrieving a wide variety of content. Today it is difficult to imagine scholarly research without online resources, but Lancaster's early works provided readers of the time a first glimpse into a new world.

Although the systems now look different on the surface and include an ever-expanding array of features, many of the tools and techniques that Lancaster and Fayen described in such detail in 1973 still form the basis for online retrieval systems of today. According to coauthor Emily Fayen (who was working with Lancaster at NLM when they wrote the book) "the book's lasting legacy is its vision about what online information retrieval ought to be and how it might be achieved. Although the illustrations of the hardware are now very amusing, most of the systems concepts have not changed."

Bourne and Hahn, in their *History of Online Information Services: 1963–1976* call *Information Retrieval On-Line* "a major milestone in the literature of online systems" and go on to explain that it was "more than just a narrative, it functioned for years as a textbook, handbook, and encyclopedia on all aspects of online retrieval systems" (p. 2). The publication was listed as a milestone in the chronology of the history of information science in a book by Lilley and Trice that traced the growth and development of information science through the contributions of influential individuals (1989).

But it was not the first book on information systems by Lancaster. His 1968 book *Information Retrieval Systems: Characteristics, Testing, and Evaluation* combined with the 1973 online book morphed more into an online retrieval system text with the second edition in 1979. When it was updated and expanded in 1993 with Amy J. Warner as *Information Retrieval Today*, a Lancaster book once again became the standard text for online retrieval and the basis for online searching principles and practices.

Lancaster's online texts never fell into the trap of attempting to be merely a tutorial on the ins and outs of specific online systems. Instead they used real systems such as MEDLARS, Dialog, and BRS to illustrate the fundamentals of all online systems. Boolean logic is clearly described in its practical applications to information systems (ironically, since, Lancaster was not a proponent of Boolean logic for information retrieval, instead advocating a partial match system that would use relevance ranking) (Lancaster, 1972; cited in Bourne & Hahn, 2003, p. 217). His texts go beyond online searching to cover topics of controlled vocabulary develop-

ment, system evaluation, and relevance as covered in more detail in this issue in the articles by Swartz, Rapp, Saracevic, and others.

Another irony is that these books were used by master's students in schools of library and information science, often those who hoped for careers as online search intermediaries. Contrary to the pervasive wisdom of the 1970s, Lancaster was an early advocate of end user searching. The thought of end users doing their own searching was met by scorn or trepidation by many others of the time (Bourne & Hahn, 2003, p. 218), but Lancaster's detailed studies of NLM MEDLARS and other early systems convinced him that researchers should do their own online searching (Lancaster, 1972).

A list of the many online searching textbooks for information professionals that owe much to Lancaster would fill this paper; a selected sampling is included at the end.

Much has happened in the online information world, certainly since the 1973 Lancaster and Fayen book, but even since Lancaster and Warner in 1993. The topics covered in *Information Retrieval On-Line* and *Information Retrieval Today* will form the organization of this article, excluding those topics mentioned above that fall more appropriately in other articles or those topics, such as equipment for online retrieval, that are so outdated as to be of historical interest only. (Topics of historical interest through 1976 are covered in detail in Bourne and Hahn and through 1985 by Lilley and Trice.) Lancaster's influence and an overview of current developments in the following areas are covered here:

- Fundamentals or basics of online information systems
- The existing online information/database industry
- Users and intermediaries
- Future trends

This cannot be an exhaustive treatment of all developments in online systems over the past four decades; instead it provides a snapshot of change by comparing the two decades of the 1970s and the 2000s and Lancaster's influence in the present and future of online information systems.

Fundamentals of Online Information Systems

More than any other topic covered here, the underlying basics of online systems have arguably changed the least over time. Lancaster's overall systems approach, viewing information retrieval as a complex system that can be broken into many separate system components for better understanding, is the approach long favored by researchers who realize that each subsystem must be understood to understand or improve the whole. (Wang & Forgionne, 2006).

While the systems approach remains the preferred way to approach information retrieval system evaluation, the major change in this systems

approach in the last decade is to integrate the human aspects of the system (beyond relevance judging), to focus on the cognitive and behavioral aspects of real users (Harter & Hert, 1997). Information retrieval is now seen as an interactive or social activity with the various situations and aspects of the user influencing overall system performance (Wang & Forgionne, 2006; Saracevic, 1995; Kagolovsky & Moehr, 2004).

Lancaster is a master of clear explanation of concepts that are often unfamiliar or confusing to his readers, including Boolean logic, file structures, evaluation criteria, and vocabulary control. The need for information professionals to know these fundamentals has not changed (Tenopir, 2001), nor has continued reliance on these basics in information retrieval systems.

While the underlying technology of inverted file structure has improved dramatically to provide efficient retrieval of massive full text databases, the importance was established in early online systems (Zobel & Moffat, 2006). Although often criticized and now faced with many alternatives, Boolean logic remains the standard for information retrieval systems (Frants et al., 1999; Sparck Jones & Willets, 1997). The most common criticism of Boolean logic systems throughout the 1980s and 1990s was that end users had trouble understanding Boolean logic and thus query formulation is too difficult (Frants et al., 1999). Lancaster (and others, notably Gerard Salton [Salton & McGill, 1986]) anticipated these concerns as early as the 1960s by recognizing that Boolean systems were difficult for users to understand. Frants, et al. believe that criticism of the difficulty of Boolean query formulation is more criticism of existing operational systems and interfaces, rather than of Boolean logic as the underlying foundation of a system, however.

Lancaster was an early advocate of partial match systems coupled with relevance ranking of partial match results. This allows the user to make the decision of when he or she has found enough relevant documents, rather than presenting results as a complete unranked set that must be examined in total. Although many systems experimented with partial match from the 1960s onward (Frants et al., 1999), it was not until the Web search engines of the past decade when they became the rule rather than the exception in the information industry.

Frants, et al. point out that Boolean logic-based information retrieval systems do not preclude relevance ranking, and, indeed, in 1968 Lancaster described the use of weighted index terms to rank documents from a Boolean query. Many experimental systems that use statistical, linguistic, or other approaches to partial match, however, are more typically associated with relevance ranking (Belkin & Croft, 1987; Kinnucan et al., 1987; Sparck Jones & Willet, 1997).

One thing that had to be changed to make online systems friendlier or easier to use was to improve the interface (Ahmed, McKnight, & Oppen-

heim, 2006). Today's Web search engines have extremely simple interfaces that hide the inner workings of a complex system, and commercial information retrieval systems have improved over the decades, although interfaces for online information retrieval systems are still not considered user-friendly (Resnick & Vaughan, 2006).

Marchionini and Komlodi (1998) trace the development of interfaces for information retrieval systems from the 1970s through the 1990s; from interfaces "designed mostly for users who were highly specialized professionals" to those that "support casual, literate end users (i.e., average educated citizens) to the current emphasis on highly technical areas such as medical and scientific research to now include all areas of human interest" (p. 92). Ten years after Marchionini and Komlodi's descriptions, different interfaces continue to help a wide variety of users navigate and find a wide variety of textual, numeric, and graphical information.

Interface development has paralleled user-centered research and development in information retrieval and the Web. Looking ahead, Marchionini and Komlodi predicted today's ubiquitous access that is "embedded in the larger information activities of life and customizable to individual preferences and abilities" (p. 115).

Best practices for future user interfaces as described by Resnick and Vaughan (2006) include considerations about the structure and metadata of the corpus, automatic vocabulary matching, user control in browsing and searching, search assistance in the interface, and special considerations for mobile devices.

Many of these were considerations even in Lancaster's early work, but even he did not anticipate the ubiquity in his lifetime of mobile information retrieval devices smaller than a deck of cards! Information systems basics have gotten more complex, mingling the components of the past with new structures, features, and design considerations made possible by development in hardware, software, and communications technologies. In turn the information industry itself has gotten more complex.

The Information Industry

In the 1970s and into the 1980s the information industry was a world of secondary publishers of indexes and abstracts who leased their bibliographic databases to third party vendors or large library systems. The bibliographic databases and early search systems served as pointers to primary publications that remained in print containers such as printed journals. Today secondary publishers and third party vendors both still exist, but primary publishers are also electronic publishers and the lines between the three are less sharply drawn. Bibliographic databases pointed to printed content; today's content is most often completely digital.

Linking through technologies such as OpenURL and cooperative initiatives such as CrossRef draws all parties together for a unified search

experience (Grogg, 2006). A library user may search on a bibliographic database such as PsychInfo that is made searchable by a third party vendor such as H. W. Wilson or ProQuest, and click on a "full text" button to be seamlessly taken to a selected article held on a primary publisher's full text e-journals platform.

Major scientific primary publishers, such as Elsevier, Wiley, Springer, etc. all have their own search and retrieval platforms in addition to participating in the search and retrieval systems of others by linking and other agreements. Their articles are likely searchable from their own platform, from various secondary indexes, and by major search engines such as Google with links back to their own repository of articles. The July 2007 issue of *Fulltext Sources Online* lists nearly 35,000 periodical titles available on average from nearly six different e-sources, including aggregators, primary publishers, and other online sources (Glose, Currado, & Orbanus, 2007). The biggest drivers of traffic to e-articles today are Web search engines, but the behind the scenes links to full texts are often a result of library and CrossRef linking (Grogg, 2006).

The growth and ups and downs of the database industry were monitored in detail yearly by Martha E. Williams in her directory of *Computer-Readable Databases*, published from 1976 through 1985, and Cuadra Associates' *Directory of Online Databases* published from 1979 through 1992. In 1987 Gale acquired and consolidated the directories, changing the name in 1993 to the *Gale Directory of Databases* (Williams, 2004). As of 2004, the Gale Directory reported on over 18,000 databases (up from 301 in 1975), made available by nearly 2,000 database vendors. It was conceivable in 1973 for an online searcher to know the characteristics of every available online database; today they may know well just those few in a specific subject area or on selected search services.

While government agencies still produce major databases and search systems (for example, the National Library of Medicine), the database industry now includes a majority of commercial organizations and professional societies. According to Williams:

> In the 1960s and 1970s, the NFP [not for profit] (mostly professional society-based) publishers gained prominence because of their importance and increased use of those databases. Both government and NFP databases continue to be important resources, particularly in the sciences; however, while their numbers have increased a bit, they have a decreasing market share. Government databases decreased as a percentage of all databases [from 56 percent in 1977 to 11 percent in 2003]. NFP/Academe databases also decreased over the same time period, from 22% [in 1977 to 10 percent in 2003]. Commercial databases continue to climb, having increased from 22% in 1977 to [78 percent in 2003]. (p. xxiv)

The lines delineating exactly what is a database and what is a website or a search platform is also somewhat muddy as the lines between vendors

and database producers grows muddier. The LexisNexis system traditionally is counted as a single "database" by the Gale Directory, yet all of the individual full text, bibliographic, or directory files available through the Dialog system are counted as separate databases. This is an untidy information world that was not even conceivable in 1973.

Not only is the number of databases growing, the amount of information within each is growing. By Williams' (2004) calculations, the number of records in databases increased by "a factor of 403" from 1975 to 2003; from a total of 52 million records to nearly 21 billion. There is, of course, much variation in both the number of records in databases and the average size of a record. According to Williams:

> The entities counted as database records vary widely but generally range from 200 to 2,000 words (or, in the case of non-word-oriented records, they require a comparable number of bytes for storage.) Records may be citations, abstracts, news stories, magazine articles, biographical records, unique names of chemicals, unique chemical structures, property data, recipes, time series, software programs, images, or descriptions or listings of virtually anything. (p. xix)

The impressive growth of the information industry does not include the whole of the massive Web and does not begin to touch the annual production of information. Lyman and Varion (2003) estimated that about 5 exabytes of new information was created in 2002 or 800 megabytes for every person on earth. They go on to explain: "*How big is five exabytes?* If digitized with full formatting, the seventeen million books in the Library of Congress contain about 136 terabytes of information; five exabytes of information is equivalent in size to the information contained in 37,000 new libraries the size of the Library of Congress book collections."

General trends and issues in the database industry have been reported annually since 1996 in *Library Journal*'s annual Database Marketplace Survey (see, for example, Tenopir et al, 2006, 2007). Major recent trends include the continued consolidation of the information industry within a handful of major commercial players that are responsible for primary journal and book publications (Tenopir et al., 2007) and an acceleration of innovative search features, automatic indexing and abstracting tools, search platforms, and other software tools. Personal files, as envisioned by Lancaster, are now a reality, with a number of software tools that help researchers download and maintain personal files (Tenopir et al., 2006).

Databases of today often have millions of records and extensive full texts. Visualization and clustering of search results help searchers cope when they retrieve thousands or tens of thousands of potentially relevant items. Many commercial online systems have added clustering or visualization techniques to their system displays recently after years of testing and development (Zhu & Hsinchun, 2005). Add to that RSS feeds, podcasting, multimedia content and links to other software tools such as

spreadsheets, bibliography management software, etc. and online systems are at last beginning to go beyond the search and retrieval systems of the past decades (Tenopir et al., 2006).

Users and Intermediaries

Lancaster's belief that end users could do their own searching was not a commonly held belief in the 1970s (by librarians or many end users alike.) Except for some discipline-based notable exceptions, such as law, the movement for end user hands-on searching did not pick up steam until widespread availability of personal computers starting in the early 1980s. It was further advanced by CD-ROM databases in the mid-1980s, which helped change the common method of charging for online searching by the time spent online (Misho & Lee, 1987). In 1985 and 1992, online searching texts by Goldmann were among the first to target squarely the end user researcher and make it clear that intermediaries are not long for this world. Alex Meystel, in the foreword to Goldmann's 1992 text explains that "Goldmann warns against the use of an intermediary: they lose information because they do not understand the inquiry and because they cannot transform the inquiry into the procedure of search. As a result you lose vitally important information" (p. xv). Numerous researchers have demonstrated that searching is an essential part of the iterative research process (see for example, Ellis & Haugan, 1997; Beaulieu, 2000; Kuhlthau, 1991).

Marydee Ojala (1986) (editor of ONLINE magazine) described online searching in the decade of the 1970s as "strictly for librarians and the term end user applied to people for whom librarians did searches" (p. 197). Even by the mid-1980s it was a new and still controversial topic.

While nearly everyone does at least his or her own Web search engine searching today, the controversy comparing the effectiveness and efficiency of end user vs. professional searching has not gone away. Because now, except in some special library settings, it is expected that end users will do their own searching, the focus of concern has turned to improving reference encounters, more effective education or training sessions, and the design of better systems. A problem-solving approach to reference encounters is one suggested improvement (Cottrell & Eisenberg, 2001), as is using the latest technologies to improve the reference interaction (Curry, 2001). Systems are still viewed as too difficult, however, especially when compared with familiar general search engines and must be improved to improve the search experience for novices (Xie, 2003).

In the meantime, online system training has become a major focus of reference librarians and more training materials for users substitute for easier systems (Tenopir & Innes, 2001). Libraries use both face-to-face and computer assisted instruction to help their users become more proficient in online searching of a variety of systems for specialized and

general users (Tenopir & Innes, 2001). Although most systems provide tutorials and help functions, evidence suggests that they are rarely used (Tenopir, Baker, & Grogg, 2007).

Lancaster's focus on user needs foreshadowed the research focus on individual differences and the human side of information retrieval that got momentum in the 1990s (Kuhlthau, 1991; Wang, 1999; Sugar, 1995). Kuhlthau's work that demonstrated both the cognitive and affective elements of human behavior influenced the entire research process helping to initiate a vigorous user-focused research agenda and the realization of the importance of the individual user in the ultimate success of an online system (Wang, 1999; Tenopir, 2003).

Future Trends in Online Information Retrieval Systems

Never one to avoid controversy, Lancaster and Fayen (1973) made fourteen predictions of what the future of online systems might be. They recognized the danger of predicting the future and that "we may be just beginning to scratch the surface on the possibilities of applying technological advances to problems of information transfer" (p. 416). Danger aside, they were remarkably prescient in their predictions, which included (p. 412–416):

- a great increase in the number of information services that can be accessed from around the world, including large general purpose systems and systems for specialized subjects;
- specialized systems will be more "user oriented," easily accessible, and require "comparatively little effort" to use;
- systems will exploit the interactive, heuristic, and browsing powers of the online computer more fully for practitioners in a field, rather than information professionals;
- they should be oriented to natural language rather than controlled vocabularies;
- vocabulary search aids at the time of searching will be incorporated, bringing together synonyms and semantically related terms;
- computer aided instruction should be incorporated into systems;
- systems should be capable of being searched by techniques other than formal Boolean expressions (including English language input, relevance ranking, fractional retrieval (partial match);
- "On-line retrieval systems must certainly permit the ranking of output";
- "Future on-line systems must require less effort to use. They should adapt to the user rather than expecting the user to adapt to them";
- online systems and the equipment to use them must be more widely accessible;

- systems will provide online support to personal files;
- "Ultimately, on-line systems must interface with systems capable of retrieving and displaying complete text";
- informal channels of communication will remain important and new communications technologies will "facilitate the transfer of information among scientists";
- online systems will interface with other systems, such as statistical packages, text editing programs, etc.

None of these predictions is controversial anymore; indeed, for those developments that are still only partially achieved, most researchers would wonder why progress has not been swifter. The Internet, developments in computing and telecommunications technology, and great leaps forward in software, standards, and digitization, have made the online information world of today remarkably similar to Lancaster's predictions, as described in these pages. Emily Fayen agreed in a 2007 interview, when she said "for the most part, we got it right. In some ways, we didn't go far enough—but who could have predicted the Internet in 1972–3?" One thing she believes they got wrong is "where we said that controlled vocabularies would be used for searching, but not for indexing. This is just about the inverse of what has happened, namely that professional indexers still use controlled vocabularies, but searchers almost never do." And the projection "in which we advocated the use of natural language should have included the need for multi-lingual capabilities."

Stephen Arnold, an information industry thought-leader, remarked in his keynote address to an online meeting in 2005, "Much of what is 'hot' or trendy in search is only slightly new. A bit of poking under the marketing promises, one finds string matching, thesauri, statistical relevance ranking, and algorithms that run more quickly on today's fast, cheap hardware." Many of the present developments in online systems build on ideas of the past, with hardware, software, and telecommunications advances making all of Lancaster's predictions at last possible.

Of course not every development in today's online systems was predicted. The domination of large commercial Web search engines is changing user expectations and leading the way for system developments on an unexpected scale. Social networking, expectations of online interaction, and collaborative tools drive user experiences in new directions (Abrams; Casey & Savastinuk, 2007), although these phenomena are just beginning to influence "serious" information retrieval systems. For twenty-first-century visionaries such as Abrams, these developments are a natural outcome of a generation that has always had the power of online search systems in their own hands.

Joining people and the power of online communication can merge the formal and informal information networks in ways that are just begin-

ning. Physicist Paul Ginsparg (2000), founder of the physics e-print server now at arXiv.org, articulates the future vision of a "global knowledge network." He prefers this term to "electronic publishing," which connotes cloning a paper-based world rather than inventing a new way to communicate. In 2000 Ginsparg predicted: "In the next 10 to 20 years, it is likely that many research communities will move to some form of global unified archive system, without the current partitioning and access restrictions familiar from the paper medium, for the simple reason that it is the best way to communicate knowledge and hence to create new knowledge." This vision incorporates many elements that Lancaster foresaw nearly thirty years previously.

Summary and Conclusions

Lancaster, with several different coauthors, was an early visionary and teacher in the practical aspects of online search and retrieval systems. From the earliest days of commercial online systems in the late 1960s and early 1970s he advocated better systems that would make online searching easier and more effective for those who have the information need.

It took over three decades for online systems to begin to fully live up to the expectations described by Lancaster and Fayen and another decade for systems to begin to move into realms and ideas that expand on their expectations. The underlying structure and content of online searching laid in the 1960s and 1970s (and before) still serve online systems today. But this underlying structure, coupled with great advances in hardware, software, and telecommunications, is allowing growth of online systems into much more than the systems described by Lancaster in 1973. End users not only have their hands on today's systems, their needs and experiences are driving developments and the future of information creation and retrieval as never before. All of these factors are leading the world of online search and retrieval closer to Lancaster's visions of 1973—it just took over thirty years to get there.

References

Abrams, S. (2007). Stephen's lighthouse. Blog. Retrieved on August 15, 2007, from http://stephenslighthouse.sirsi.com.

Ahmed, S. M. Z., McKnight, C., & Oppenheim, C. (2006). A user-centered design and evaluation of IR interfaces. *Journal of Librarianship and Information Science, 38*(3), 157–172.

Arnold, S. E. (2005). Envisioning the future of search: Keynote speech for the information today online meeting, New York, 2005. Retrieved July 21, 2007, from http://www.arnoldit.com/speeches/nysept28.pdf.

Belkin, N. J., & Croft, W. B. (1987). Retrieval techniques. *Annual Review of Information Science and Technology, 22*, 109–145.

Beaulieu, M. (2000). Interaction in information searching and retrieval. *Journal of Documentation, 56* (4), 431–439.

Bourne, C. P., & Hahn, T. B. (2003). *A history of online information services: 1963– 1976.* Cambridge, Massachusetts: MIT Press.

Casey, M. E., & Savastinuk, L. C. (2007). *Library 2.0: A guide to participatory library services.* Medford, NJ: Information Today, Inc.

Cottrell, J. R., & Eisenberg, M. B. (2001). Applying an information problem- solving model to academic reference work: Findings and implications. *College and Research Libraries, 62* (4), 334–347.

Curry, E. L. (2001). Technological advances in reference: A paradigm shift? Introduction. *Library Trends, 50*(2), 165–167.

Ellis, D., & Haugan, M. (1997). Modelling the information seeking patterns of engineers and research scientists in an industrial environment. *Journal of Documentation, 53*(4), 384–403.

Fayen, E. Personal correspondence with Tenopir, November 21, 2007.

Frants, V. I., Shapiro, J., Taksa, I., & Voiskunskii, V. G. (1999). Boolean search: Current state and perspectives. *Journal of the American Society for Information Science, 50*(1), 86–95.

Ginsparg, P. (2000). Creating a global knowledge network. *BMC News and Views 1* (9). Retrieved August 12, 2007, from Biomed Central http://www.biomedcentral .com/1471–8219/1/9.

Glose, M. B., Currado, T. D., & Orbanus, C. (Eds.). (2007). *Fulltext sources online.* Medford, NJ: Information Today.

Grogg, J. (2006). Linking and the open URL. *Library Technology Reports, 42*(1).

Harter, S. P., & Hert, C. A. (1997). Evaluation of information retrieval systems: Approaches, issues, and methods. *Annual Review of Information Science and Technology, 32*, 3–94.

Kagolovsky, Y., & Moehr, J. R. (2004). A new look at information retrieval evaluation: Proposal for solutions. *Journal of Medical Systems, 28*(1), 103–116.

Kinnucan, M. T., Nelson, M. J., & Allen, B. L. (1987). Statistical methods in information science research. *Annual Review of Information Science and Technology, 22*, 147–178.

Kuhlthau, C. C. (1991). Inside the search process: Information seeking from the user's perspective. *Journal of the American Society for Information Science, 42*(5), 361–371.

Lancaster, F. W. (1968). *Information retrieval systems: Characteristics, testing, and evaluation.* New York: Wiley.

Lancaster, F. W. (1972). *Evaluation of on-line searching in MEDLARS (AIM- TWX) by biomedical practitioners* (Occasional Papers series, no. 101). Urbana- Champaign: University of Illinois, Graduate School of Library Science. (ERIC No. ED 062 989).

Lancaster, F. W. (1979). *Information retrieval systems: Characteristics, testing, and evaluation* (2nd ed.). New York: Wiley.

Lancaster, F. W., & Fayen, E. G. (1973). *Information retrieval on-line.* Los Angeles: Melville Publishing.

Lancaster, F. W., & Owen, J. (1976). Information retrieval by computer. In D.P. Hammer (Ed.), *The information age: Its development and impact* (pp. 1–33). Metuchen, NJ: Scarecrow Press.

Lancaster, F. W., & Warner, A. J. (1993). *Information retrieval today*: *Revised, retitled, and expanded edition* (originally published as *Information Retrieval Systems: Characteristics, Testing and Evaluation*). Arlington, VA: Information Resources Press.

Lilley, D. B., & Trice, R.W. (1989). *A history of information science: 1945–1985.* San Diego: Academic Press.

Lyman, P., & Varion, H. (2003). How much information? 2003. University of California, Berkeley, School of Information Management and Systems. Retrieved July 17, 2007, from http:// www2.sims.berkeley.edu/research/projects/how-much-info-2003.

Marchionini, G., & Komlodi, A. (1998). Design of interfaces for information seeking. *Annual Review of Information Science and Technology, 33*, 89–130.

Meystel, A. (1992). Foreword. In N. Goldmann, *Online information hunting* (pp. xiv– xvi). Blue Ridge Summit, PA: Windcrest/McGraw-Hill.

Mischo, W. H., & Lee, J. (1987). End-user searching of bibliographic databases. *Annual Review of Information Science and Technology, 22*, 227–263.

Ojala, M. (1986). Views on end-user searching. *Journal of the American Society for Information Science, 37*(4), 197–203.

Resnick, M. L., & Vaughn W. V. (2006). Best practices and future visions for search user interfaces. *Journal of the American Society for Information Science, 57*(6), 781–787.

Salton, G., & McGill, M. (1986). *Introduction to modern information retrieval.* New York: McGraw Hill.

Saracevic, T. (1995). Evaluation of evaluation in information retrieval. *Proceedings of the 18th*

Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, 138–146.
Sparck Jones, K., & Willett, P. (Eds.). (1997). *Readings in Information Retrieval.* San Francisco: Morgan Kaufmann.
Sugar, W. (1995). User-centered perspective of information retrieval research and analysis methods. *Annual Review of Information Science and Technology, 30,* 77–109.
Tenopir, C. (2001, May 1). Why I still teach dialog. *Library Journal, 126,* 36, 38.
Tenopir, C. (2003). *Use and Users of Electronic Library Resources: An Overview and Analysis of Recent Research Studies.* Washington, DC: Council on Library
Resources. Retrieved May 16, 2008, from http://www.clir.org/pubs/execsum/sum120.html.
Tenopir, C., Baker, G., & Grogg, J. (2007, May 15).The database marketplace 2007: Not your family farm. *Library Journal, 132, 34–40, 42*+.
Tenopir, C., Baker, G., Robinson, W., & Grogg, J. (2006, May 15). The database marketplace 2006: Renovating this old house. *Library Journal, 131, 32–36.*
Tenopir, C., & Ennes, L. (2001). Reference services in the new millennium. *Online, 25*(4), 40–45.
Tenopir, C., Wang, P., Zhang, Y., Simmons, B., & Pollard, R. (2006 December, online; 2007, in press). Academic users' interaction with science direct in search tasks: Affective and cognitive behaviors. *Information Processing and Management.*
Wang, P. (1999). Methodologies and methods for user behavior research. *Annual Review of Information Science and Technology, 34,* 53–99.
Wang, Y. D., & Forgionne, G. (2006). A decision-theoretic approach to the evaluation of information retrieval systems. *Information Processing and Management, 42*(4), 863–874.
Williams, J. G., Sochats, K. M., & Morse, E. (1995). Visualization. *Annual Review of Information Science and Technology, 30,* 161–207.
Williams, M. E. (2004). The state of databases today: 2004. *Gale Directory of Databases 2004, 1* (1). (Alan Hedblad, Ed.). Detroit: Thomson Gale.
Xie, H. (2003). Supporting ease-of-use and user control: Desired features and structure of Web-based online IR systems. *Information Processing and Management, 39*(6), 899–922.
Zhu, B., & Hsinchun, C. (2005). Information visualization. *Annual Review of Information Science and Technology, 39* (1), 139–177.
Zobel, J., & Moffat, A. (2006). Inverted files for text search engines. *ACM Computing Surveys (CSUR), 38*(2), Article 6.

Selected Online Retrieval Texts by others that Followed Lancaster and Fayen

Bell, S. S. (2006). *Librarian's guide to online searching.* Westport, CT: Libraries Unlimited.
Borgman, C. L., Moghdam, D., & Corbett, P. (1984). *Effective online searching: A basic text.* New York: Marcel Dekker.
Chen, C., & Schweizer, S. (1981). *Online bibliographic searching: A learning manual.* New York: Neal-Schuman.
Convey, J. (1977). *Online information retrieval: An introductory manual to principles and practice.* London: Library Association Publishing.
Convey, J. (1984). *Online information retrieval: An introductory manual to principles and practice* (2nd ed.). London: Library Association Publishing.
Convey, J. (1989). *Online information retrieval: An introductory manual to principles and practice* (3rd ed.). London: Library Association Publishing.
Convey, J. (1992). *Online information retrieval: An introductory manual to principles and practice* (4th ed.). London: Library Association Publishing.
Fenichel, C. H., & Hogan, T. H. (1981). *Online searching: A primer.* Marlton, NJ: Learned Information.
Fenichel, C. H., & Hogan, T. H. (1984). *Online searching: A primer* (2nd ed.). Marlton, NJ: Learned Information.
Gerrie, Brenda (1983). *Online information systems: Use and operating characteristics, limitations, and design alternatives.* With a foreword by F. Wilfrid Lancaster. Arlington, VA: Information Resources Press.
Gilreath, C. L. (1984). *Computerized literature searching: Research strategies and databases.* Boulder, CO: Westview Press.

Harter, S. P. (1986). Online information retrieval: Concepts, principles, and techniques. *Library and Information Science Series.* Orlando: Academic Press.
Li, T. (1985). An introduction to online searching. *Contributions in Librarianship and Information Science 50.* Westport, CT: Greenwood Press.
Maloney, J. J. (1983). *Online searching technique and management.* Chicago: ALA.
Meadow, C. T., & Cochrane, P. (1981). *Basics of online searching.* New York: Wiley.
Palmer, R. C. (1983). *Online reference and information retrieval.* Library Science Text Series. Littleton, CO: Libraries Unlimited.
Palmer, R. C. (1987). *Online reference and information retrieval* (2nd ed.). Library Science Text Series. Littleton, CO: Libraries Unlimited.
Walker, G., & Janes, J. (1993). *Online retrieval: Dialogue of theory and practice.* Database Searching Series. Englewood, CO: Libraries Unlimited.
Walker, G., & Janes, J. (1999). *Online retrieval: Dialogue of theory and practice* (2nd ed.). Database Searching Series. Englewood, CO: Libraries Unlimited.

Carol Tenopir is a professor at the School of Information Sciences at the University of Tennessee, Knoxville; director of research for the College of Communication and Information; and director of the Center for Information and Communication Studies. Her areas of teaching and research include: information access and retrieval, electronic publishing, the information industry, online resources, and the impact of technology on reference librarians and scientists. She is the author of five books, including, *Communication Patterns of Engineers,* (IEEE/Wiley InterScience, 2004) with Donald W. King. Dr. Tenopir has published over two hundred journal articles, is a frequent speaker at professional conferences, and since 1983 has written the "Online Databases" column for *Library Journal.* She is the recipient of the 1993 Outstanding Information Science Teacher Award from the American Society for Information Science/Institute for Scientific Information and the 2000 ALISE Award for Teaching Excellence. She also received the 2002 American Society for Information Science & Technology Research Award and the 2004 International Information Industry Lifetime Achievement Award. Dr. Tenopir holds a PhD degree in Library and Information Science from the University of Illinois.