Chemical Information Instruction of the Undergraduate: A Review and Analysis

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Surveys of literature instruction activities over the past 50 years show trends in the number of courses taught, the individuals who do the teaching, and the content of the instruction. Influences of the American Chemical Society and the viewpoint of industrial spokespersons on the nature and extent of information instruction activities are reviewed. Topics examined from historical and current perspectives include course instructors, course alternatives, degree of faculty support, curricular aids including library exercises, availability of major reference sources, and computer searching. Suggestions are made for future improvements in this area.

INTRODUCTION

Chemical information instruction is a vital part of every chemistry student's education. Where does undergraduate information instruction stand today, and what have we learned about it over the past 50 years? Does academic information instruction meet industry's needs? What role can the Americal Chemical Society play in supporting information instruction? What problems face chemistry departments today in providing such instruction? These and other questions and topics will be examined from both a historical and a current perspective, with a glance at future prospects.

SURVEYS OF INFORMATION INSTRUCTION ACTIVITIES

The extent of information instruction activities has been identified through a number of surveys that began in 1932 and increased in frequency during the late 1970s and early 1980s.

Although the surveys have varied in their focus and the groups of institutions examined, each has sought to determine if a course was taught (Table I.)[1–9] In several cases, the survey authors indicated a strong belief that adequate instruction could only be accomplished through a course. Courses appeared in curricula most often in the 1953 and 1960 surveys, with approximately 53% of the Ph.D.-granting institutions offering courses.[2,3] By 1969, the number of these institutions that provided a course had dropped to 39%,[4] with the percentage remaining in the 30s in all but one of the subsequent surveys.[4–9] However, M.S. and B.S. degree-granding schools have provided courses to a greater extent, as is shown by the 56%,[4] 41%,[5] and 59%[8] in the 1960s, 1971, and 1982b surveys, respectively. When courses have been offered, they usually carried one or two credits and were available largely to junior or senior students. The course was required for graduation by 57% and 66% of the schools in 1969[4] and 1984,[9] the only surveys that asked about degree requirements. In 1969, an additional 19% of schools recommended that students take the course. Chemistry professors have traditionally taught the literature course (Table II), especially in non-Ph.D.-granting institutions,[4] which are more likely to lack chemically trained librarians. However, this pattern has changed in the 1980s, as evidenced by the 1982a and 1984 surveys.[7,9] The increased participation of librarians has been attributed to librarians' increased subject expertise, with 55% holding B.S./B.A. or higher degrees in chemistry in 1982a,[7] and to the inclusion of computer searching into the curricula.[8]

In contrast to their focus on courses, few surveys have inquired about instruction provided without a formal course, despite the fact that this method has been preferred by the majority of institutions since 1960, regardless of highest level of degree granted. Such instruction may occur within the framework of courses, as the 64% (161) of schools noted in 1984. Informal dissemination by faculty was cited by 41% (103) of the respondents to the 1984 survey.[9] This process

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was cited by schools that also offered courses or incorporated instruction into courses and may be seen as a natural outgrowth of student–faculty interaction in laboratories.

The nature of information instruction was explored by several surveys. Lectures, library problems, and occasional papers have dominated the teaching techniques, with the primary focus on periodicals, indexes, and monographs.[3–6] The 1971 survey of small institutions noted that the uses of newer sources (such as *Science Citation Index*) and major reference sources from related fields of science (*Physics Abstracts*, *Biological Abstracts*, and *Index Medicus*) are taught considerably less frequently (30–45%) than *Chemical Abstracts* (100%) and *Beilstein* (95%).[5] This lack of emphasis on newer sources, as well as search techniques, was confirmed by the 1979 survey.[6] *Science Citation Index* was taught in detail by only 31% of the schools, *Current Contents* by 20%, and on-line searching by 17%. Although almost all schools mentioned

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Table I. Courses Offered

survey	Ph.D.		M.S.		institutions not granting Ph.D.'s		B.S.		no distinction between institutions	
year	no./total	%	no./total	%	no./total	%	no./total	%	no./total	%
1932[1]									20/100	20.0
1953[2]	32/60	53.0								
1960[3]	42/79	53.2			92/251	36.6				
1960s[4]	60/157	38.9	33/75	56.0						
1969[4]	47/157	30.0	27/75	36.0						
1971[5]							20/49	40.8		
1979[6]									27/106	25.0
1982a[7]									58/175	33.2
1982b[8]	37/102	36.0	38/64	59.0			38/118	32.2		
1984[9]	47/148	32.0	18/45	40.0			27/89	30.0	92/282	33.0

Table II. Instructors

survey	faculty		faculty/librarian		other subject faculty		librarian		librarian–occasional lecture		no response	
year	no./total	%	no./total	%	no./total	%	no./total	%	no./total	%	no./total	%
1953	24/32	75.0					8/32	25.0	11/32	34.0		
1969	84/93	90.0			1/93	1.0	8/93	8.0				
1982a	38/58	65.5	8/58	13.8			11/58	19.0			1/58	1.7
1982b							increasing					
1984	71/103	69.0	17/103	16.5			15/103	14.5				

Table III. Detailed Instruction for All Sources

	% of academic individuals who *used* the sources	% of schools teaching in depth	% of industrial chemists who *used* the sources
Chemical Abstracts	95	76	90
Beilstein	42	45	52
Science Citation Index	45	31	38
Current Contents	35	20	43
Current Abstracts of Chemistry and Index Chemicus	16	15	29
on-line searching	31	17	59

Chemical Abstracts (CA) and *Beilstein*, only 76% taught CA in depth and 45% *Beilstein* in depth. The percentage of detailed instruction for all sources was considerably less than the amount of use that the respondents indicated they made of these sources (Table III). A unique contribution of this 1979 survey was the effort to represent the perspective of industrial chemists. Although only 29% (19) of the bench chemists responded, their responses are helpful in identifying information skills required of chemists in industry. Their use of the sources far exceeded the in-depth teaching and exceeded the use by academics of newer sources. The high cost of many major reference sources and the subsequent cancellation of subscriptions were postulated as a hindrance to in-depth instruction in their use.[7] Only 96.6% of the graduate schools that responded to the 1982a survey subscribed to *Chemical Abstracts*, 78% to *Beilstein*, 87% to *Gmelin*, and 57.5% to *Landolt-Boernstein*.[7] This lack of funds for subscriptions to major reference sources was confirmed by the 1984 survey. Twenty-five percent (63) noted this lack of funds as an overall concern, with the following breakdown by title: 16% (39), *Beilstein* and *Gmelin*; 11% (28), *Science Citation Index*; 10% (26), *Current Abstracts of Chemistry* and *Index Chemicus*; 4% (9) *Chemical Abstracts*.[9]

The 1982b and 1984 surveys inquired further about the teaching of computer searching. In 1982, 38% (28) of Ph.D.-granting schools indicated they provided either formal or informal instruction on how to use chemical literature in computerized form. For M.S./M.A.-granting schools, the response was 40% (25), and for B.S./B.A. schools, it was 29% (15).[8] By 1984, 44% (108) of all schools incorporated information about computer searching into the curriculum, and 22% (55) claimed the students had "hands-on" practice time. However, 44% (108) indicated that they lacked funds to teach computer searching adequately, especially student on-line practice [38% (93)].[9] The effect of American Chemical Society (ACS) curricula approval on the nature of information instruction was a major objective of the 1971 survey of 50 small schools. No significant difference existed in the number of courses offered (11 in approved and 9 in those not approved), but a significantly higher number of approved programs required the course for graduation. ACS-approved curricula included a term paper more often than nonapproved (72.8% vs. 55.5%). The only other discernible difference was that nonapproved curricula included major reference sources from related science fields more often. The authors of this survey noted that ACS Committee on Professional Training (CPT) guidelines did not require information instruction.[5]

AMERICAN CHEMICAL SOCIETY GUIDELINES

An examination of the ACS Committee on Professional Training (CPT) guidelines over the past 25 years shows a slowly increasing emphasis on library resources and information instruction. Only a perfunctory few sentences refer to providing "adequate library facilities" in the 1960 and 1962 guidelines.[10] By 1965, the guidelines were more specific and stated that "the library should carry *Beilstein* and *Chemical Abstracts*" and major journals.[11] In 1972 and 1977 guidelines declared that "if library holdings do not include *Beilstein* and, particularly, *Chemical Abstracts*, the Committee will seek concrete evidence"[12,13] that "the students learn how to use these important references."[13] The 1977 guidelines noted that the "relative need for *Chemical Abstracts*, *Beilstein*, and other reference materials should determine their availability in the library." The alternative of searching computerized files instead of printed CA was first proposed in 1977. Both faculty and chemical information specialists from academia and industry contributed to the next revision, and the 1983 guidelines include the most significant advances in support of chemical information. Subscriptions to *Chemical Abstracts* are expected with at least volume indexes, except in rare cases, and then the "Committee requires evidence that students have ready access to it at neighboring institutions or industrial laboratories" (p 19). The core curriculum should include "systematic use of the chemical literature" (p 10). A new section discusses chemical literature and information retrieval and for the first time calls for formal instruction "imparted either through a specific course or through coordinated instruction integrated into courses" (p 13). Adequate teaching of the use of major sources such as *Chemical Abstracts*, *Beilstein*, *Gmelin*, and *Science Citation Indexes* "will generally require formal lectures." Development of computer searching skills for bibliographic and numeric data bases was considered "highly desirable", with opportunities for students to gain some experience with on-line computer files. The need for students to understand the organization and use of printed sources in order to use computer searching to best advantage was listed as essential.[14] The appendix to the 1983 CPT guidelines appeared several months later and included a chemical information retrieval section that lists the competencies that students should master during their undergraduate years. These skills provide the criteria for developing an information component and evaluating the effectiveness of instruction. Students should acquire a demonstrable, basic understanding of *Chemical Abstracts*, other major secondary works such as *Science Citation Index* and *Beilstein*, standard reference works such as *Mellor* and *Landolt-Boernstein*, primary literature sources, and the organization of the chemistry library. In addition, students should achieve the following competencies: identify the CAS registry number of a compound; efficiently locate chemical and physical properties of substances, including spectra; efficiently locate references for the synthesis or reactions of desired compounds or classes of compounds; efficiently locate references to a desired type of chemical transformation; complete a comprehensive subject search; compile a complete bibliography of an author's publications; locate review articles on a subject; utilize a variety of methods to stay up to date on a subject; utilize footnote references and citation tracking when studying a subject; know the importance of patents and be able to search for patents on a subject; know about the availability and contents of relevant computerized databases (bibliographic, numeric, and full text) and understand the techniques (and benefits/limitations) of on-line searching.[14]

The necessity for formal training was repeated in the 1984 report of the ACS Task Force for the Study of Chemistry Education in the United States. The discussion of the approved curriculum in chemistry noted that information instruction is needed because

> "every professional chemist must use a variety of complex printed sources as well as an increasing number of computerized databases. Further, the pace of change in information systems is greater than can be accommodated by self-help efforts" (p 45).

The task force therefore recommended that ACS "sponsor symposia and carefully defined and designed studies" to examine a number of specific curricular problems, including chemical information retrieval. "These studies should generate resource materials and position papers to provide advice and guidance to college and university faculty members on ways to improve or include appropriate instruction..." (p 45). The increased necessity for instruction and practice in the "burgeoning area of information" was reinforced in the Information Management section, which emphasized the role of computers in increasing the complexity of information retrieval and the need for technical libraries to change from a "collection point" to a "center of manifold information gathering and management activities" (p 48).[15]

THE INDUSTRIAL PERSPECTIVE

Although the ACS CPT guidelines for approved curriculum did not specify formal instruction until 1983, industrial representatives have stressed the importance of a thorough understanding of literature sources as long ago as 1917. In that year, the industrial laboratories subcommittee of the Committee of One Hundred on Scientific Research of the American Association for the Advancement of Science addressed this concern in some detail. The subcommittee agreed that graduates did not receive "adequate and systematic instruction in chemical literature." The solution, they saw, was a course for seniors that would impart a "systematic, working knowledge of chemical bibliography."[16] No further proposals were offered until 1943, when Connolly stressed the need to initiate research programs with a thorough survey of the literature, because it saved time and money and ensured the most thorough patent application.[17] Twenty-three years later, a 1966 editorial in the *Journal of Chemical Education* noted the exponential growth of literature and the increase in interdisciplinary research, which required that students learn firsthand what is available in their libraries and what systems and services are available beyond their own libraries.[18] Paul, in a 1970 National Research Council paper, emphasized the importance of chemical information and described ways for chemistry faculty to become aware of rapid changes in modern chemical information systems.[19] Schwartz (1971) lamented the lack of guidelines and standards for a literature course and suggested contents for a course that would meet the needs of professional chemists. Alternatively, he saw a correspondence course, developed by the ACS Division of Chemical Literature, as an attractive option.[20] The bench chemists surveyed in 1979 stated that they learned their information retrieval skills on the job or were self-taught. They all felt that knowledge of information searching was important to their professional success.[6] Two speakers at a 1982 symposium presented the industrial chemist and librarian's viewpoints. A key factor, the chemist Hendrickson felt, in achieving project goals was a solid foundation in literature. He described how applied research in industry changes literature searching techniques because it (1) requires broader coverage of topics, which necessitates use of reference sources beyond the basic chemistry titles, (2) involves rapid changes in research direction, which results in frequent retrospective searches on different topics and less emphasis on current awareness techniques, (3) requires greater attention to time factors, and (4) places higher importance on patents.[21] Allen, the librarian, described the information short course established to remedy literature searching deficiencies among bench chemists. Further, she suggested that academic instruction discuss such categories of publication as U.S. and foreign patents, specialty reports, internal publications, trade publications, and environmental and safety information. She also stressed the importance of graduates acquiring knowledge of the proliferating computer databases and recognizing time and profit constraints.[22]

Although the industrial perspective has seldom been articulated, the strong consensus among those who expressed their views is that efficient chemical information search techniques are essential to achieve success as professional chemists. Despite this consensus and the on-going instruction efforts in academia, a great need still exists to improve graduates' information retrieval skills.

PRACTICAL APPLICATIONS

Strong proponents of information instruction have shared their experiences and resources with the chemistry and library communities over many years, both in print and at conferences. The ACS Divisions of Chemical Education and Chemical Literature (later Chemical Information) have sponsored symposiums at National Conferences, with occasional contributions from the ACS Society Committee on Education, the ACS Division on Computers in Chemistry, and the Special Libraries

Association's Chemistry Division. Most of these symposiums have occurred since 1969. Although journal articles appeared as early as 1932, they have been more frequent since 1968 and especially since 1979, which reflects to some extent the emphasis on information instruction at conferences.

Courses. Prior to 1968, all but one article described courses, the primary teaching method in earlier years (Soule in 1932,[1] Meldrum in 1943,[23] Van Patten in 1950,[24] and Watters in 1958[25]). Although a course was briefly described in 1971 by Fanta,[26] it was not until the 1980s that articles discussing courses appeared again. At a Special Libraries Association Conference, Wiggins described the three courses taught within the Indiana University Chemistry Department for chemistry undergraduate and graduate students and library school students. The required first course covers the traditional printed sources, an elective course is devoted to computer-assisted techniques where students get "hands-on" practice, and another elective course is devoted to manual and computer-assisted research projects. Two appendixes list the texts used for the courses and reading assignments.[27] Both Kozlowski and Graybeal described courses for upper level students. Kozlowski's course is a comprehensive survey including segments on patents, government documents, and computer searching.[28] Graybeal's course is a one-credit–one-quarter course that covers the major reference sources but lacks time to teach the use of patents, documents, and some major sources in depth.[29] Bohning's literature course includes a segment on the history of chemistry, which he feels is an important component.[30] Wolman described the process through which the current information course evolved at the Hebrew University. The course stresses literature exercises for such topics and techniques as numerical data, chemical reactions, structure searching, current awareness, and computer searching.[31] Gorin also stressed the importance of library exercises in his semester course, which he described in detail.[32] A course that combines writing and literature searching has supporters, such as Melhado, who in 1980 described his chemistry course at the University of Illinois.[33]

Texts and Bibliographies. Chemists and information specialists have published texts that serve both courses and instruction integrated into a variety of courses. Chemical literature texts have a long tradition, as evidenced by such early standards such as Soule (1938),[34] Dyson (1951), and Crane and Patterson (1957).[35] Increased publication occurred in the 1970s and 1980s, with three texts issued in 1979 and four during 1982–1983. Gorin's 1982 paper provides a succinct analysis of a number of texts, which differ widely in scope and content. Some are largely an enumeration of books, journals, and other sources (e.g., Antony).[36] Others deal more or less extensively with ways in which literature is utilized (Bottle,[37] Mellon,[38] and Woodburn[39]), while still others focus more specifically on the process through which information is found (Burman[40] and Maizell[41]).[42] Gorin's 1982 workbook stresses the importance of making library exercises the "principal vehicle" by which chemical information is introduced to undergraduate students. It provides a library exercise for each topic, which ranges from abstracts to patents to computer searching.[43] Wolman's 1983 book emphasizes real search problems and their solutions. He identifies specific types of questions that arise in research laboratories, such as chemical and synthetic reactions, crystallographic data, and physical properties data.[44] Except for Gorin, Wolman, and Mellon, the texts lack library exercises. Skolnik's 1982 book lists and describes monograph and reference sources by subject, encyclopedias, numeric data sources, and publications of major abstract services. He also provides a historical overview of chemical literature.[45]

Audio courses have been developed to augment or provide alternatives to traditional texts and courses. Comprehensive audio courses were developed in 1969 by Ramsay[46] and in 1978 by Wilen for the American Chemical Society.[47] Both courses cover general-reference books and major reference sources, specialized reference titles for subfields of chemistry, data sources, current-awareness sources, and primary sources. Both authors see as advantages the ease of use on a self-study basis and the opportunity to teach about sources not owned in the home library. Wilen's audiocassette course includes a workbook, as well as a textbook that describes the sources, shows how to use them, and explains how to develop search strategies. Other audio courses cover one research tool or topic, such as *Chemical Abstracts*, *Beilstein's Handbook*, *Gmelin*, and spectra.[48]

Some authors sought to aid information instruction by publishing articles that describe the literature of a particular subdiscipline of chemistry. Although now out of date, the three-part series of organic sources by Hancock in 1968 provides a comprehensive bibliography grouped by subject (i.e., natural products), by type of information (i.e., review articles, collection of data), and by type of publication (i.e., abstracts, patents, government reports).[49] This effort was praised by Woodburn, who stated that "Hancock did a highly creditable job of establishing guidelines for the novice faced with the necessity of tracking down" organic chemistry information. Woodburn's observation introduced his own 1972 review of inorganic chemistry sources.[50] An extensive guide to the organometallic chemistry of main-group elements was published by Smith and Walton in 1975,[51] while Katritzky provided the second part of a survey of heterocyclic literature[52] and Huheey included an appendix on the literature of inorganic chemistry in his 1983 general text.[53] Literature sources needed for organic laboratory work are reviewed in several laboratory texts, such as Pasto and Johnson[54] and Streitweiser and Heathcock,[55] while other chapters on literature sources appear in such books as *Guide for the Perplexed Organic Experimentalist*.[56]

Some authors have provided general bibliographies, such as the extensive 1979 annotated list of sources by Malley on "Education in the Use of Libraries and Information in Chemistry".[57] Antony's bibliography included references on the science journal and computer searching,[58] while Douville (1983) compiled a two-part bibliography of audiovisual materials available for teaching chemical literature.[59] A comprehensive bibliography of published chemical literature guides and aids was compiled by Wiggins (1984) for the ACS Chemical Information Division's (CINF) Education Committee, which in turn distributes it to all interested faculty and librarians.[60]

Another category of helpful published guides is produced by publishers of major reference sources and is often available free or for a nominal charge. Each guide often describes one source, such as *Beilstein* or *Chemical Abstracts*, in detail and explains how to use it.[61] Other guides describe the family or group of sources from a publisher, such as Chemical Abstracts Service's *Printed Access Tools Workbook*.[62] Other approaches used by publishers and authors include journal articles on such topics as how to use *Beilstein*[63] and *Chemical Abstracts* and traveling lecturers from the Institute for Scientific Information and Chemical Abstracts Service.

Integration into Courses. The integration of information components into a variety of courses has been developed at schools where a course was not possible. An early proponent of this approach was Sampey,[64] who in 1938 suggested that "parallel" reading assignments in analytical, organic, and physical chemistry courses would extend students' knowledge of chemical techniques. Not until 1974, however, did Aylward offer a detailed description of integration into each of the four years. During the first year, students were introduced to the library and a simple index tool, with retrieval of chemical data covered in the second year. The third-year analytical chemistry course required a review and state of the art report; computer searching was introduced in the fourth year.[65] McElroy and Somerville, both speaking at the Fall 1979 ACS Conference, described their programs at a liberal arts college and a small research university, respectively. Most of McElroy's information instruction is integrated into laboratories during all 4 years, beginning with the use of handbooks for physical data in the first year and progressing through organic, physical, advanced inorganic, research seminar, and honor's thesis. Students search for property data, plan independent lab projects, give oral reports, write papers, and do current-awareness searches. During the senior year, the students help plan a computer search.[66] Somerville's program also incorporates most instruction into laboratories, beginning with organic chemistry laboratories where students learn to use physical properties and spectra sources, *Chemical Abstracts*, and *Beilstein* and to maintain a literature searching log. The junior advanced laboratory provides opportunities to learn the following: *Science Citation Index*; the literature sources for organic, inorganic/organometallic, and physical chemistry; sources of property data; patents; translations; sources of addresses; current-awareness techniques; outside sources of documents. The guides to literature sources identify the types of literature questions from each major subdivision of chemistry and list the optimum or representative sources to answer the questions. The students in the structure determination course receive in-depth instruction in spectra sources and search techniques. The senior year emphasizes "hands-on" practice for searching computerized databases.[67] Powell has described the library-centered instruction at Drew University. In addition to the chemical bibliography course, library assignments are integrated into parts of the first year chemistry courses, organic chemistry, and advanced courses.[68] Wolman relies on a 10-hour elective course but extends the instruction to all who take the advanced synthetic organic course. An introductory lecture reviews information about the library and the role of journal articles; in addition, extensive use is made of major sources relevant to the laboratory, such as *Houben-Weyl* and Theilheimer's *Synthetic Methods of Organic Chemistry*.[31] The 1984 survey confirmed that instruction integrated within courses is preferred by many schools—63% (179). Forty-six percent (75) of these 161 are Ph.D. Universities and 35% (57) are B.S. degree colleges.[9]

Upper level, course-related library experiences have been described by Heath for inorganic chemistry,[69] by Parker for instrumental analysis,[70] by Gorin for biochemistry,[71] and by Krakower for senior research.[72] According to the 1984 survey, a wide variety of advanced courses incorporate information instruction.[9] Hostettler (1984) proposed use of a brief introduction to literature sources that is sufficiently flexible to apply at the beginning of a laboratory course, at the start of an independent search project, or at the beginning of a literature course. CLEAR (Chemical Literature Exercises and Resources) includes three exercises to locate specific chemical information about substances and information on a chemical topic and to learn to use *Chemical Abstracts*.[73]

Although most course-related instruction occurs in the junior and senior years, several authors in recent years have stressed the value of stimulating lower level students to develop good literature habits. Some faculty suggest that the freshman chemistry laboratory is a good time to introduce students to the library and to basic handbooks (Bramley, O'Malley, and Young).[74] Others suggest ways to introduce freshmen and sophomores to literature searching (Kline and Scott).[75] Kline argues that the ability to use handbooks and other reference books should be a minimum requirement for all freshmen. The sophomore laboratory opportunities have been highlighted by Kline, Kozlowski, and Wubbels.[76] Epling suggests an individually tailored search project for large organic laboratory classes.[77]

Computer Searching Instruction. As computer searching of bibliographic and numeric databases has become a major search technique, forward-looking schools have recognized the importance of teaching students about this additional method. Drum (1979) and Antony (1980) described the computer-searching component of their chemical literature courses.[78] Drum noted that the objective was to make students aware of a computerized system's capabilities, not to train the students to search. Each student is asked to develop a search strategy to be executed on *Chemical Abstracts* by the instructor. Howard spoke at a 1980 ACS conference on her institution's experiment in teaching students to use on-line bibliographic databases in their early undergraduate years. Their premise was that students who *begin* with an on-line search are stimulated to acquire skills in the use of other library materials.[79] Gaus, on the other hand, considers it essential to begin with a good working understanding of the organization of a major source, such as *Chemical Abstracts*, and therefore requires a manual search prior to teaching students to search CA online. Gaus' teaching of CA by using the Dialog ONTAP files extends back to 1978, and he has developed student practice questions at three levels of difficulty.[80] Coutts described his teaching the use of printed and computerized *Chemical Abstracts* in 1980.[81] Jenkins' teaching of the computerized *Chemical Abstracts*, using SDC's practice file and the CAS substructure file, to undergraduates at a liberal arts college was described in 1984 and updated in 1985. Students learn the basic search techniques and have "hands-on" practice.[82] Somerville's program of teaching senior chemistry majors to search computerized databases was described in detail in 1982. All seniors learn to search CA, while in the advanced organic and inorganic classes they learn to search the mass spectra, ^{13}C nuclear magnetic resonance, and X-ray crystallographic files on the NIH/EPA Chemical Information System.[83] Later in 1982 Somerville expanded on the elements common to teaching students to search computerized databases. These include development of a special manual to isolate the most important system commands, to demonstrate how to search for typical and frequent questions, and to present the instruction from the chemists' perspective. In addition, all practice sessions are tutored on a one-to-one basis to accomplish the most efficient learning.[84] In 1984 Wiggins described more fully the computer-oriented elective course in on-line searching, which seeks to expose students to as many relevant computer-based sources and techniques as possible. The students prepare search strategies for current awareness searches from Chemical Abstracts Service, learn to search SDC's *Chemical Abstracts* and CHEMDEX files, and have opportunities to search other science files available with SDC instructional passwords.[85] Respondents to the 1984 survey indicated that 42% (106) of schools include information about computer searching in their instruction programs. Fifty-five percent (58) of these schools offer Ph.D. degrees, while bachelor degree colleges constitute 38% (40).[9]

Most instructors have relied on manuals provided by vendors (BRS, CAS Online, DARC, DIALOG, NIH/EPA CIS, SDC) or publishers (CAS, Derwent, etc.). DIALOG has been especially responsive to the chemical community by developing a specialized manual tailored to the needs of chemists[86] and by scheduling training sessions at ACS conferences. Both DIALOG and SDC have recently expanded the CA training files. BRS offers a training file for *Chemical Abstracts*, and

CAS Online plans to add Learning Files for the CA and Registry Files before the end of 1985. In 1980, Chemical Abstracts Service developed manuals for searching CA on BRS, DIALOG, and SDC[87] and now has a 1984 manual for searching CA (STN International System) tailored to the needs of chemists.[88]

On-line instruction has occurred at two levels to date—lecturing about searching or providing students with on-line practice time accompanied by more detailed lectures. The second approach requires considerably more time of both the instructor and student, but those instructors who have pursued this method consider that "hands-on" practice is the more effective way for students to become thoroughly familiar with the benefits and limitations of searching computerized databases.

Teaching Others To Teach. Little information is available about efforts to teach potential instructors how to teach. Three such attempts have targeted the library community. In the late 1960s, Allard et al. conducted a workshop for regional librarians on how to teach *Chemical Abstracts*.[89] This effort was followed several years later by another workshop for area librarians on how to teach the use of science reference sources, including *Chemical Abstracts*.[90] The Association for College and Research Libraries has recognized the need to help librarians without strong science backgrounds teach students to use science reference sources. The course, titled "Teaching How to Teach *Science* Reference Materials" and taught by Thomas Kirk, is offered prior to American Library Association conferences and covers major sources, including *Chemical Abstracts*.

WHERE DO WE STAND NOW? WHERE DO WE GO FROM HERE?

The objectives of a quality information instruction program should be to provide systematic, comprehensive instruction in the efficient use of a wide variety of printed and computerized sources and to have students realize that information searching is an expected and critically important phase in the design and execution of all research projects. Development of effective information searching skills requires practice solving realistic library exercises.

Courses. The number of academic institutions that offer a course has stabilized at 33%, with approximately half of these schools requiring the course for graduation. While a few schools indicated that they planned in 1984 to add an information course, their number is offset by others that are dropping the course.[9] Some schools feel they have few or no problems in providing the course, but most respondents to the 1984 survey noted some difficulties.

Instructors. Faculty taught 69% of the courses in 1984, with faculty/librarian teams teaching 16.5% and librarians teaching 14.5%. With the rapid changes in computer-searching capabilities, the frequent changes in printed sources, and the initiation of new titles, faculty find it increasingly difficult to stay current and to incorporate these changes into courses, especially in areas outside their primary teaching and research interests. The lack of "experts" among faculty has been noted by Kirschner[91] and Skolnik.[92] To help faculty stay current concerning changes in reference sources, short workshops could be offered at ACS conferences and regional or local meetings, to be jointly sponsored by publishers and the ACS Division of Chemical Information. Publishers could provide packets that describe new features, along with examples of how typical questions are answered.

Librarians have become increasingly involved in teaching chemical information courses over the past 5 years, as well as with course-related instruction. This is especially true for Ph.D.-granting institutions, which are more likely to have a chemically knowledgeable librarian. Kobelski noted the increased chemical background of librarians in chemistry libraries.[7] Yet in 1984, 57 institutions had librarians who were too busy to teach (8), did not feel qualified to teach (19), or were unavailable for teaching (30). Twenty-six of these institutions grant Ph.D.'s. Another difficulty faced by 85 institutions is the lack of a librarian with primary responsibility for working with the chemistry department. Thirty of these schools grant Ph.D.'s.[9] It is extremely important that schools that offer Ph.D.'s be served by chemically knowledgeable librarians, so the librarians can work as professional peers with faculty and participate in literature instruction. Historically, few chemistry faculty have worked with knowledgeable science librarians who offered strong information service programs, so faculty have developed low expectations of library support. However, chemistry departments with Ph.D. programs should make clear to library administrators that a science librarian who understands and actively serves the information needs of their department is of vital importance to their teaching and research programs. Librarians with responsibility for working with chemistry departments but who lack chemical backgrounds should be encouraged by their supervisors to develop subject expertise. As new chemistry librarians are hired, library administrators should require a chemistry background and meet competition from industry for technically knowledgeable librarians with reasonably competitive salaries. To help librarians who feel unprepared to participate in chemical literature instruction, workshops should be scheduled at library conferences to discuss chemists' research and teaching activities that require information searching, the kinds of information questions they have and the best ways to answer these questions, and how to teach students to use information sources from the chemist's perspective.

Faculty Support. Information instruction often lacks a critical mass of faculty support (Skolnik).[92] Twenty-five percent (64) of the responding schools to the 1984 survey indicated the information instruction has low faculty priority, and (35%) 88 of the schools noted that faculty were too busy with research and other teaching responsibilities.[9] Some faculty feel that students will learn to use information sources when they need them from fellow students or in research seminars.

ACS guidelines, which emphasize minimum levels of information instruction in approved curricula, can be the basis for justifying additional resources and raising the consciousness of academic administrators. Workshops designed to inform and stimulate reluctant faculty could demonstrate how effective information searching can facilitate research and reduce costs, demonstrate why formal instruction is necessary, and offer possible ways to include information instruction with up to date and relevant curricular materials. Several ACS groups, such as the Divisions of Chemical Information and Chemical Education, could sponsor such workshops, as could other divisions as appropriate.

Place in Curricula. Crowded curricula, with additional constraints as the result of core requirements, limit the possibility of offering courses in many schools. The 1984 survey showed that 55% (140) of the schools felt that the curriculum was too crowded.[9] The pressing need to add courses in newer areas of chemistry is often seen as more important than an information course. Reluctance to establish or maintain a course may be due to some faculty's opinions that a stand-alone course creates an artificial situation, because it lacks direct application to laboratory activities. Additionally, it can be difficult to make students recognize the value of such a course, which they may regard as dull and irrelevant. Proponents of courses, however, consider a separate course as the only way to ensure comprehensive and coordinated coverage of the topic.

Integration into Courses. Integration of information instruction into a variety of courses, particularly laboratories and seminars, has increased in popularity in recent years, and 63% (179) of the institutions preferred this method in the 1984 survey.[9] Proponents see that this approach enables the students to apply information searching as an integral part of course work, so the information work is relevant to their success in laboratories and courses and the work is seen as an important and integral part of research. Some chemists and information specialists have questioned the comprehensiveness of this dispersed instruction, as well as the possibility of effective coordination, and consider that the quality and subjects covered often reflect the experience of instructor, which in itself may vary in quality. Ever-increasing amounts of material to cover in courses has made it difficult to find time for information segments. This concern was expressed by 26% (65) schools in the 1984 survey.[9] While this is an understandable concern, many schools have found that this approach works well. The ACS Chemical Information Division's (CINF) Education Committee could coordinate the sharing of successful models. Integrated instruction should be reviewed annually to ensure that the material is relevant to the course and presented at an appropriate time. Small group discussions with students and faculty can be effective in identifying the timing and content of information activities, because students can be quite candid about such opportunities. Student evaluations often support the need for more effective instruction, such as improving the timing and suggesting more practice questions. This integrated instruction requires coordination to ensure comprehensiveness and to avoid redundancy. Such coordination can be accomplished by one person or a small group. An effective approach is for a librarian, whose primary responsibilities revolve around information, either to serve as the coordinator or to work jointly with a professor. In institutions that do not have a librarian assigned to work with the chemistry department, interested faculty members should be asked to handle this coordination. Again, because these faculty coordinators have other major responsibilities, the chemical information community should provide relevant and up to date curricular aids and maintain a guest lecturer roster.

Yet another difficulty arises when chemistry departments feel that the curriculum is too crowded *and* there is no time available in courses. This was true for approximately 18% (45) of the schools that responded to the 1984 survey.[9] This is probably a misconception, because the author's experience has been that incorporation of an information component is a natural feature of a number of laboratory and lecture courses and contributes to their pedagogic value. Consciousness raising through workshops, publicity, examples of model programs, and persuasion from ACS can facilitate acceptance of this concept.

Availability of Appropriate Instructional Materials. The need for instructional aids has been voiced by faculty and librarians (Kirschner[91] and Wilen;[93] 1984 survey[9]). Texts and audio courses are outdated rapidly and rarely include library exercises. In addition, texts too often contain insufficient information on when and how to use the major secondary literature sources. Descriptions in texts of computer searching are especially inadequate.[93]

Development of modular curricular material may provide the flexibility needed to ensure ease of updating both text and exercises. ACS could publish the modules, for which an annual subscription would guarantee receipt of new materials. Such material should be highly relevant and avoid pedantic writing, so readers can enjoy and benefit from them. The ACS CINF Education Committee and other interested groups and individuals could provide the material. Specific modules should incorporate topics needed by professional chemists but often lacking in many information programs, such as patents, technical reports, major sources from related science fields, and internal company publications. In addition, a pool of industrial information specialists and academic librarians should be available to speak to students about the use of information sources in industrial and academic laboratories. Such speaker rosters could be coordinated by the ACS Division of Chemical Information and augmented by members of such other information societies as the American Society for Information Science and the Special Libraries Association. Self-paced learning methods should be explored as supplements to group instruction. These might include self-paced workbooks or computer-assisted instruction units for microcomputers. The latter could be devoted to how to use major reference sources, how to search for categories of information (such as spectral data), or how to conduct computer searches.

Assignment of Library Exercises. Respondents to the 1984 survey confirmed Wilen's concern about the lack of appropriate problem sets. Approximately 30% (76) noted that they lacked library exercises, while many specifically addressed this concern in their comments.[9] Effective problem sets and other assignments have the following characteristics: they are realistic, individualized, and relevant to course content; they reflect up to date format and indexing policies; they do not require excessive time of students to complete or of instructor to correct; they are revised occasionally to avoid overuse. In addition, the questions must be feasible to ensure that answers can be found. Development of such assignments is extremely time consuming, especially for large classes. Most texts do not include library exercises, and only the Gorin workbook lists multiple options for exercises. Curricular modules should include problem sets that incorporate the characteristics listed above. A variety of type of questions are needed for use in different subdisciplines of chemistry, and both applied and research-oriented questions should be provided. Different levels of difficulty are useful, especially for computer-searching practice, and questions must be answerable within the scope of computerized training files.

Availability of Major Reference Sources. Many chemistry departments lack easy access to some major reference sources due to high subscription cost and the dispersal of sources on campus.[93] This unavailability was confirmed by the 1984 survey. Some small colleges even find the graduated scale for *Chemical Abstracts* subscriptions difficult to finance. Cost sharing between the chemistry department and library might alleviate some difficulties. Reduced rates for colleges are also available for *Science Citation Index* and *Index Chemicus*, but may not be sufficient to overcome budget limitations. Similar reductions would be helpful for subscriptions to other major sources, such as *Beilstein* and *Landolt-Boernstein*.

Computer Searching. Most proponents of information instruction agree that it is essential to learn to use printed sources prior to mastering computer searching. However, computerized databases should not be ignored, for an ever-increasing number and variety of files will emerge in the future—bibliographic, numeric and handbook data, and the complete text of articles. Several obstacles must be surmounted before on-line searching is integrated effectively into curricula. The rapid changes in current systems and databases, as well as creation of new systems and new databases, make it very difficult to learn and retain proficiency. Inexperienced faculty and librarians must first be trained to search effectively by using teaching techniques relevant to the chemists' perspective. All publishers of major sources, in conjunction with existing vendor companies, should develop training programs aimed at the chemistry community. Alternatively, chemistry librarians can also contribute by training students at their institutions. The ACS CINF Division's Education Committee is developing training programs that can be used by faculty and librarians to teach students. An overview of searching, applicable to a variety of systems and many subdisciplines of chemistry, will be available in response to needs expressed in the 1984 survey. In 1985 Chemical Abstracts Service initiated a "train the trainer" program, in which local trainers are taught to serve as instructors and provided with teaching aids. Other curricular needs are on-line practice questions. Chemistry librarians and industrial information specialists are available under the auspices of the ACS CINF Division as guest lecturers on the value and use of on-line searching for scientific research. The cost of teaching searching, especially for on-line practice, is another major difficulty for many schools. Reduced rates of training files are helpful and necessary, but some important databases, such as patents and the *Journal of Synthetic Methods*, lack training files. However, even with the reduced costs, some schools with large chemistry enrollments find the price too high. All publishers and vendors should provide training files and educational programs for use with these files. Close working relationships should be developed and actively maintained between instructors, librarians, publishers, and vendors to ensure the ingredients needed for effective online instruction.

CONCLUSIONS

Opportunities for developing information instruction programs exist today to a greater extent than they have in the past, while at the same time the rapidly changing information environment poses a unique challenge. The American Chemical Society's commitment to formal instruction in both the 1983 CPT guidelines and the 1984 education task force report should encourage chemistry departments to seek resources and develop the expertise required for strong instruction programs. The alternatives suggested in the CPT guidelines of offering a course or integrating instruction into several courses provide flexibility in planning curricula. If a course is utilized, the instruction should be relevant and rigorous, while instruction integrated into a variety of courses should be comprehensive and coordinated. Increased availability of information in computerized form will require continual updating of training and curricular materials. Successful efforts to provide knowledgeable and enthusiastic instructors, relevant and timely curricular materials, and affordable information sources will require the joint commitment of chemistry faculty, librarians, professisonal societies, publishers, and computer-searching organizations.

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Teaching of Chemical Information Science to Graduates

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An overview of graduate education in information science is presented, with special attention to the teaching of chemical information science in graduate schools of library and information science. These curricula are contrasted with those in computer science; master's programs are compared with doctoral studies, and a promising future is foreseen for research and development.

INTRODUCTION

Ten years before the appearance of this journal and at approximately the time that UNIVAC I was made commercially available, the American Library Association's Committee on Accreditation (COA) coincidentally decided that the master's degree would be the first professional degree in library science. For the past 35 years COA, acting under the authority of the Council on Post-Secondary Education, has maintained that only those individuals well grounded in the arts and sciences would be admitted to these master's degree programs. The purpose has been to defer the teaching of professional matters involving library and information science until after students have majored in traditional disciplines including, but obviously not limited to, chemistry. The principal models that inspired this approach were medicine and law.

From time to time, other professional associations and societies in information processing have expressed an interest in accrediting programs or certifying individuals, but the Council on Post-Secondary Education has ruled that the COA would have sole authority for accrediting professional programs in librarianship and closely related areas. To its credit, the COA has sought input from sister societies such as the American Society for Information Science (ASIS) and the Special Libraries Association (SLA), and members from these and other associations serve both on COA and on site teams that visit and assess graduate programs throughout the U.S. and Canada.

Some chemistry graduates subsequently enter programs in computer science; however, the majority of chemistry librarians and formally trained chemical information specialists graduate from schools of library and information science, the best of which encompass both computer-based systems and traditional methods of information handling. While departments of computer science sometimes have courses or programs in information retrieval, the majority continue to address problems of hardware and/or applied mathematics—usually depending on whether the parent unit is an engineering school or a department of mathematics. Not to be overlooked in all of this is the simple fact that many employers insist on a degree from a school whose program has been accredited by the COA.

A complete account of the historical reasons for the existing situation in education for information science is clearly beyond the scope of this paper. However, those readers interested in pursuing the topic are referred to Shera's classic work entitled *The Foundations of Education for Librarianship*, in which he discusses the interrelationships between and among traditional librarianship, documentation, and information science.[1]

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STRUCTURE OF THE PROGRAMS

Herman Skolnik, the first and long-time editor of this journal, once wrote that chemical information science "...is without a bridge to academic chemistry departments."[2] And it is true that few of the master's level programs described permit a real major in chemical information science, choosing rather to concentrate on scientific literature, science documentation, and general theoretical and practical matters of concern to everyone involved in information retrieval.

