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Perspectives and Criteria for Chemical Information Instruction

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A review of Committee on Professional Training (CPT) guidelines since 1960 shows increasing emphasis on adequate library resources and chemical information instruction. Results of a survey are discussed and show that chemistry departments face major obstacles in implementing information instruction. Suggestions are offered for meeting these difficulties that challenge faculty, administrators, librarians, and CPT to meet the CPT's information and library guidelines.

INTRODUCTION

The American Chemical Society (ACS) established the Committee on Professional Training (CPT) in 1936 to help improve the quality of chemical education. Major activities of CPT include development of guidelines to ensure high-quality undergraduate programs for students planning careers in chemistry and evaluation of programs designed to meet these guidelines. The 50th anniversary of CPT's establishment was celebrated with a symposium, held at the April 1986 ACS National Meeting, that featured speakers who reviewed the past, present, and future of CPT from overall and specific topic perspectives. Chemical information was one of the specific topics represented. A 23-page booklet briefly summarizes all talks presented.[1] This paper is an expansion of the talk presented at the Symposium and updates the information to the present.

Chemical information instruction should be a vital part of every chemistry student's education. Yet, many faculty and librarians see a need to improve the extent and quality of instruction. A 1985 review of past activities aimed at providing information instruction shows considerable interest but sizeable gaps.[2] This paper explores in detail difficulties faced by chemistry departments based on an extensive survey and suggests how faculty, administrators, librarians, and CPT can improve compliance with CPT guidelines.

CPT GUIDELINES

An examination of the Committee on Professional Training guidelines over the past 25 years shows a gradually increasing emphasis on library resources and chemical information. Only a few sentences refer to library facilities in 1960 and 1962.[3] By 1965, the guidelines had become somewhat more specific and stated that "the library should carry *Beilstein* and *Chemical Abstracts*" and major journals.[4] In 1972 and 1977, the guidelines declared that "if library holdings do not include *Beilstein* and *Chemical Abstracts*, particularly, the Committee will seek concrete evidence"[5,6] that "the students learn to use these important references".[6] The alternative of searching computerized files instead of printed *Chemical Abstracts* was first proposed in 1977.

The 1983 guidelines include the most significant advances in support of chemical information.[7] Subscriptions to *Chemical Abstracts* would be expected with at least volume indexes, except in rare instances. In those cases the Committee required evidence that students have ready access to *Chemical Abstracts* in neighboring institutions or industrial libraries. The core curriculum should include a systematic use of the chemical literature. A new section discussed chemical literature and information retrieval and, for the first time, called for formal instruction "imparted either through a separate course or integrated into courses". It contended that adequate teaching of the use of the major sources such as *Chemical Abstracts*, *Beilstein*, *Gmelin*, and *Science Citation Index* would generally require formal lectures. Development of computer searching skills for bibliographic and numeric data bases was considered "highly desirable", including online practice.

The Appendix[8] to the 1983 Committee on Professional Training guidelines appeared several months later and includes a chemical retrieval section that lists the competencies that students should master during their undergraduate years and suggests ways in which the library skills may be taught. It specifies that students should acquire a demonstrable, basic understanding of the following: *Chemical Abstracts*; other major secondary works such as *Science Citation Index*, *Beilstein*, *Index Chemicus*, and *Current Contents*; standard reference works such as *Mellor*, *Gmelin*, and *Landolt-Boernstein*; and primary literature sources. To use the primary and secondary literature effectively, students should be familiar with the organization of the chemistry library and with techniques of manual and online literature searching. Specifically, students should be able to

- locate chemical and physical properties of substances, including spectra;
- locate references for the synthesis or reactions of substances or classes of substances;
- locate references to a desired type of chemical transformation;
- identify the Chemical Abstracts Service Registry Number for substances;
- complete a comprehensive subject search;
- compile a complete bibliography of an author's publications;
- locate review papers on 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 computer databases.

Such proficiencies should be taught through formal instruction, either in a chemical information course or integrated into other chemistry courses. Coordination of this teaching effort is essential and can be achieved by designating a faculty member, a librarian, or a professor–librarian team as coordinator(s). Other suggested ways to aid information instruction included the following: sources that provide curricular materials; a list of recommended books and journals;[9] reminder of Chemical

Abstracts Service Small College Program as a way to continue subscribing to *Chemical Abstracts*; and suggestions for less expensive ways of teaching online searching.

The necessity for formal training was repeated in the 1984 report by the ACS Task Force for the Study of Chemical Education in the United States.[10] In its *Tomorrow* report, 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 data bases. Further, the pace of change in information systems is greater than can be accommodated by self-help efforts." The increased necessity for instruction and practice was reinforced in the Information Management section, which also emphasized the role of computers in information retrieval and the need for technical libraries to change from a "collection point" to an active information center.

EDUCATION COMMITTEE SURVEY

In 1983, an Education Committee was established by the ACS Division of Chemical Information to work with chemistry departments to improve the quality of their information instruction programs. The following year, 1984, the Committee conducted a survey of the chemical information programs of 331 chemistry departments to identify difficulties faced by the departments in implementing information instruction. (Selection criteria for including chemistry departments are included in Appendix A.) This information was then used by the Committee to develop ways of helping departments strengthen their programs. Because of this practical emphasis on aiding chemistry departments, the survey included questions about time, staff, and financial resources not found in previous surveys. Two hundred and eighteen departments responded to the initial two-page survey, with an additional 62 responding to the follow-up survey. (Of these 62, 32 returned the two-page survey, while 30 opted to return an abbreviated form on a postcard.) Survey results reported here are based on 250 two-page responses and 30 postcard responses. (See Appendixes A and B for information about the survey.)

In 1984, 89 (32%) of the 280 departments offered a chemical information course, which enables the instructor to ensure coordinated and comprehensive coverage. A course, on the other hand, may create an artificial situation and may lack direct application to laboratory activities. However, 140 (56%) of 250 departments felt their curriculum was too crowded to accommodate a separate course.

At the same time, 176 or approximately 63% of the 280 departments integrated instruction into several courses. (Some of these schools offer a separate course as well.) These schools felt that information instruction is especially effective if it is an integral part of a course and information work is related to course success. Such course-integrated instruction may be haphazard and discontinuous, so the combination of coordination, comprehensiveness, and relevancy to academic success is important to pursue, but may be difficult to achieve. In addition, 65 (26%) of the 250 departments that answered the two-page survey said they lacked time in courses to include information instruction. Forty-five (18%) of these 250 departments claimed there was not time in courses *and* the curriculum was too crowded.

What can be done to change this perception? First, one could take a new look at courses—there are usually efficient ways to incorporate information components into courses in a meaningful context. Second, consciousness-raising workshops that describe successful programs and demonstrate feasibility of such integration could be offered by the ACS Divisions of Chemical Information and Chemical Education at national, regional, and local ACS meetings. Third, department chairmen who are aware of and concerned about chemical information could assign coordination responsibilities to faculty, a faculty-librarian team, or a librarian.

FACULTY SUPPORT

Faculty support is crucial, especially for integrated instruction. Yet, in the 1984 survey, faculty at 66 (23%) of the 280 schools gave information instruction low priority, and at 108 schools (38%) faculty are too busy to stress information activities. It is true that faculty are busy with multiple responsibilities—teaching, research, and committees (internal and external). In addition, some faculty lack awareness of the value of informed searching and are therefore not likely to support information instruction. These professors can be found in both research and nonresearch institutions. Some faculty feel students can learn from laboratory co-workers whenever they need information in the research laboratory. Also, some faculty prefer that students ask them when literature references are needed, a practice which occurs most frequently in more prestigious institutions. In the real world, however, graduates do not have professors to rely on to answer their information questions.

How can more faculty support for information instruction be achieved? The objective is to alter doubting professors' perceptions so they believe and advocate the idea that informed information searching is part of chemical literacy—that to become a productive chemist includes becoming an efficient and knowledgeable information user. Several specific efforts could help achieve this objective. Librarians must take the initiative to demonstrate the value of informed searching for individual faculty research. In addition, they should convince students of the importance of learning effective information search techniques by providing relevant references from computer searches and by emphasizing practical and efficient use of printed and computerized sources. These students can then influence their professors to develop more positive attitudes and support information instruction. Respected research colleagues can also influence doubting faculty by noting how expert searching and utilization of up-to-date sources aided refinement of research ideas and teaching objectives or evaluation of grant proposals. In addition, workshops could be conducted by the ACS Chemical Information and Chemical Education Divisions to inform and stimulate interest among reluctant faculty.

In 1984, faculty at 24 (10%) of 250 schools indicated that they did not feel qualified to teach chemical information. This is probably an underestimate, because it is not easy to stay current and incorporate changes into courses. There are frequent changes in sources, new titles begin frequently, and rapid changes occur in computer searching capabilities. To aid faculty in staying up-to-date, the ACS Chemical Information and Chemical Education Divisions could hold workshops at national, regional, and local ACS meetings. Publishers might provide information packets for instruction, and a speakers bureau established by these two ACS Divisions could provide informed speakers.

Faculty who support and may actively seek to incorporate information instruction into their courses also experience time constraints. Opportunities to meet with colleagues and librarians to discuss information instruction techniques can provide the extra incentive and implementation ideas needed to influence their instruction. The ACS Division of Chemical Information's Education Committee has begun a program of inviting those faculty and their chemistry librarian to meet with Division members to discuss information instruction.

CURRICULUM RESOURCES

To teach information instruction, it is helpful to have access to reference sources and to computer searching. In 1984, 63 (25%) of 250 schools felt that it was too expensive to subscribe to some major reference sources (e.g., *Beilstein*, *Chemical Abstracts*, *Index Chemicus*, *Gmelin*, *Science Citation Index*) and journals, and 108 schools (43%) said that online searching costs were too expensive. (The survey was conducted before the Chemical Abstracts Service Academic Program began, which has provided many additional schools with less expensive computer access.) With less expensive sources of searching and the availability of training files, more schools could provide computer search training, if not automatic access when needed throughout the year. This assumes, however, that the equipment is also accessible, which is an expense that all departments and libraries cannot afford.

Remedies might include making available inexpensive online training files to all schools, without any strings attached. This requires cooperation from data-base producers and vendors. Publishers can aid the cause by offering alternative access to expensive printed reference sets, such as *Beilstein* and *Gmelin*. Lists of core journals and books, such as the 1982 list of titles cosponsored by the ACS Division of Chemical Education and the ACS Department of Educational Activities, could be provided to schools that may not find it easy to select books and journals. Also, the Committee on Professional Training guidelines can be used by chemistry department chairmen to justify additional resources to college administrators. The cost of providing computer search training, including online practice, should be given the same priority as running a laboratory.

The availability of instructional materials also affects instruction. However, survey respondents noted a lack of instructional materials: 47 (19%), curriculum materials; 68 (27%), practice questions; 44 (17%), tests. That is understandable. Textbooks and audio–visual materials are outdated very quickly; they may be too general, or they may not be particularly relevant. Appropriate problem sets are generally lacking, and their reuse over time is limited. It is extremely time-consuming to develop good curricular materials, especially effective practice questions.

Instead of traditional textbooks, one might consider developing flexible versions of curricular materials that could be easily updated. An example is the computer searching modules developed by the Education Committee of the ACS Division of Chemical Information, which are designed as lecture and hand-out materials when instructors introduce students to computer searching.[11] Alternative ways of providing instruction, such as computer-assisted instruction,[12] should be developed. Curriculum materials developed by instructors and publishers are now available from the clearinghouse jointly sponsored by the ACS Division of Chemical Information and the Special Libraries Association Chemistry Division.[13] A more general information instruction clearinghouse is LOEX,[14] which offers a limited selection of chemistry materials. A 1984 bibliography, compiled under the direction of Gary Wiggins, lists journal papers and instruction materials produced by publishers of reference sources.[15] Copies are available from the ACS/SLA clearinghouse or from this author. Additional publishers' assistance should be enlisted to develop curriculum materials that instructors can utilize to teach use of their publications. The Education Committee of the ACS Division of Chemical Information actively encourages publishers and vendors to produce teaching aids.

CHEMISTRY LIBRARIANS

Librarians play an important role in increasing faculty awareness and support. However, there are too few librarians with chemical subject expertise. In answer to the question about the title of the librarian with primary responsibility for working with the chemistry department, 87 institutions did not answer or listed a nonscience librarian. Thirty-one of these institutions grant Ph.D.'s. In these situations, it is difficult or impossible for chemistry faculty and students to understand the contribution an active information specialist can make toward their research and teaching programs. Some librarians lack credibility with faculty, and many libraries lack adequate numbers of professional staff with subject expertise.

To change this, academic library administrators and chemistry faculty need to develop a greater awareness of the importance of hiring librarians that do have chemical expertise. Certainly, the minimum should be to hire a librarian with a science background who can develop chemical subject expertise. These library administrators need to stress continuing education and to support it financially. They also need to pay appropriate salaries so that the few librarians who do have science backgrounds are not all wooed away to industry.

Librarians need to assume the active role of chemical information specialist and instructor. Librarians can accomplish these objectives by attending workshops on how chemists use information and chemical sources, how to teach efficient use of sources at the technical level appropriate for the audience, and how to conduct effective chemical computer searches. Such workshops could be sponsored by the ACS Divisions of Chemical Education and Chemical Information, as well as by other information organizations, such as the American Society for Information Science, the Association of College and Research Libraries, and the Special Libraries Association. Providing opportunities to interact with good role models will help, also. In addition, guidance and support from supervisors are essential.

CONCLUSION

It is imperative that the American Chemical Society, through the Committee on Professional Training, encourage chemistry departments to seek the resources and develop the expertise required for strong information programs, the objective being to add efficient information usage as a requirement for chemical literacy. The chemical information community encourages the Committee on Professional Training to look at its follow-up of the guidelines, to ask specifically for documentation on how departments meet the guidelines and students acquire information competencies, and to consider discontinuing certification to programs that do not meet the guidelines. Help is available to accomplish this, both for the CPT and for chemistry departments, through the ACS Division of Chemical Information, along with other information societies (such as the American Society for Information Science, the Association of College and Research Libraries, and the Special Libraries Association).

APPENDIX A: 1984 CHEMICAL INFORMATION INSTRUCTION SURVEY

1. Purpose of survey
   The purposes of the survey were to gather information about difficulties encountered by chemistry departments in providing chemical information instruction and to learn how the Chemical Information Division's Education Committee could assist chemistry departments in improving their information instruction programs.
2. Selection criteria for inclusion in the survey:
   a. All Ph.D. granting universities listed in the 1983 *ACS Directory of Graduate Research*.
   b. Institutions which granted 4 or more MS degrees in 1982 and 1981.
   c. Institutions which granted 8 or more certified BS degrees in 1982 and 1981.

d. Four-year private liberal arts colleges which were baccalaureate origins of 90 or more Ph.D. degrees, 1920–1980.
e. Five institutions which granted more than 25 uncertified degrees in 1982.

3. Survey returns
   a. Initial mailing
      331 two-page surveys mailed and 218 returned for a 65% return rate
   b. Follow up mailing
      Follow up letters offered respondents the option of completing the original two-page survey or an abbreviated form on a postcard.
      32 two-page forms returned. Increased return rate of full two-page survey to 250 (75%).
      30 postcards returned. If these responses are given equal weight as the two-page survey, the return rate increased to 280 (80%).
4. Survey with responses
   a. Two-page survey: 250 responses
   b. Postcard survey: 30 responses
   Respondents' comments are available on request from the author.
5. 1984 members of the ACS Division of Chemical Information's Education Committee: Dr. Robert Buntrock (AMOCO); Professor Marjorie Caserio (University of California at Irvine); Carol Drum (University of Florida); Professor Paul Gaus (The College of Wooster); Professor George Gorin (Oklahoma State University); Arleen Somerville (University of Rochester), Chairman; Dr. Gary Wiggins (Indiana University)

APPENDIX B: CHEMICAL INFORMATION INSTRUCTION QUESTIONS

1. How does your Department teach chemical information?
   86 separate course
      53 required? ____frequency
      ______when taught in last 5 years
      68 taught by faculty
      15 taught by librarian
      17 taught by faculty and librarian
   159 within framework of a lecture or lab course. Which course(s):
      32 organic chemistry lecture
      80 organic chemistry laboratory
      50 seminar
      other (specify)
   13 self-paced workbooks
   108 include information about computer searching
      55 include "hands-on" practice
   101 informal dissemination by faculty
   17 not covered in any course
2. What problems/difficulties has your Department faced in providing chemical information instruction?
   Please check the relevant points. Indicate with an * those items for which our Committee could be most helpful to you.
   140 curriculum too crowded for a separate course
   65 no time available within courses
   47 lack curriculum materials
      what topics:
   68 lack appropriate problem sets
   44 lack appropriate test(s) for
      specific topics (which?)
      29 overall evaluation of library skills
   75 faculty too heavily committed to other teaching responsibilities
   20 faculty do not feel qualified to teach
   55 low faculty priority
   24 librarian unavailable for teaching
   8 librarian too busy
   18 librarian does not feel qualified to teach
   5 low librarian priority
   56 lack funds to acquire major sources in library:
      34 *Beilstein* 24 *Science Citation Index*
      7 *Chemical Abstracts* 35 *Gmelin*
      22 *Current Abstracts of Chemistry* and *Index Chemicus*
      ______other
   97 lack funds to teach computer searching for:
      28 demonstrations
      83 student online practice
      25 lecture preparation
      lack faculty or librarian with computer searching skills in chemistry
      other (please specify)
3. Is computer searching of external chemical information databases (e.g., *Chemical Abstacts*) used by your Department?
   53 routinely 41 rarely
   109 sometimes 10 never
   If done, who conducts the searches:
   93 faculty 19 other researchers
   53 students 157 librarians
4. List full names of faculty most interested in chemical information instruction (for possible future contact).
5. List name of chemistry librarian, or librarian with primary responsibility for chemistry, and state title and address.
6. Additional comments are most welcomed. (Please use back of sheet, if needed.)
7. Completed by
   Title
   University name
8. Return to:
   Ms. Arleen N. Somerville
   Carlson Library, Hutchison Hall
   University of Rochester
   Rochester, New York 14627

POSTCARD SURVEY

How does your Department teach chemical information?
3 in a separate course 17 within established courses
14 informal instruction other(?)
Major obstacle to providing formal instruction is lack of
21 time 7 personnel 1 facilities 2 interest or need
Are off-campus computerized databases being used to get chemical information?
5 no 24 yes (by whom?)
Which person on your faculty or in the library is most involved in chemical information retrieval?
Name Position
Name and Title of responder
Institution name

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(12) An example is STN Mentor, a family of computer-based training tutorials designed to explain how to search for information on databases available on STN International. For example, two STN Mentor disks provide introductory training for CAS Online databases and for author searching on all STN databases.
(13) Clearinghouse for Chemical Information Instructional Materials, c/o Carol Carr, Chemistry Library, University of Pennsylvania, Philadelphia, PA 19104.
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An Oxidation Number Assignment Expert for CHEMPROF

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To construct a computer program module for CHEMPROF capable of tutoring students in the assignment of oxidation number to inorganic compounds, we have studied the constraints on oxidation number assignment and developed a model that is both reliable for computer implementation and comprehensible by students. The model strives to precisely define and circumscribe this domain and to give it a complete declarative description. This rule-based approach will allow computer-aided instruction to expand beyond the limitations of predefined drill and prescripted solutions to problems.

INTRODUCTION

The study of chemistry is the study of the ownership of electrons. In every chemical reaction, that ownership changes. This "ownership" is traditionally represented in terms of the oxidation number of the atom. Chemistry students are then taught the principles of electron ownership and transfer in terms of oxidation-reduction reactions.

The assignment of oxidation numbers, however, has always been somewhat arbitrary. In fact, only for elements and ionic compounds does this ownership number closely approximate an integer. In other cases, electrons are assigned to atoms to which they do not completely belong. Although not chemically exact, such assignments permit the novice to grasp why reactions are occurring and allow the expert to manipulate reaction equations without excessive syntactical baggage.

Several years ago we began work that would establish the basis for CHEMPROF,[1,2] an intelligent tutoring system for general chemistry students. To develop such a tutoring system, domain experts that could solve problems through the application of chemical principles were first needed. Such experts also had to produce solution traces that the computer could then use to teach students how to solve particular problems. The assignment of oxidation numbers was selected as a useful and manageable topic to tackle first. Not unexpectedly, though, in attempting to teach a computer to assign oxidation numbers we found the topic to be more complex than it at first appeared, as the rules commonly used to teach assignments[3-5] were in part incomplete or inconsistent.

The primary problem we faced was that of declarative incompleteness of the domain. This problem in the development of expert systems had already been identified in earlier work such as DENDRAL (which interpreted low-resolution mass spectra)[6] and MYCIN (which identified microbiological organisms).[7] Part of the difficulty arises from the definition of terms. Human experts in a particular field use terminology that is clear to them, but which may be difficult to precisely define for the benefit of nonexperts. Were several experts to supply definitions, these most likely would not be fully compatible. To quibble over any differences may seem like hairsplitting to those unfamiliar with formal logic, but if the inconsistencies cannot be resolved, then a computer program cannot be written to work in the affected area of knowledge. It is, in fact, this lack of clear definition that has caused some chemists to regard oxidation numbers as a questionable parameter. This situation is unfortunate because it is hard to define and work with the concepts of oxidation and reduction without having a means of bookkeeping electrons. Consequently, formalizing the definition of an (inorganic) oxidation

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