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Chemical Information Literacy at a Liberal Arts College

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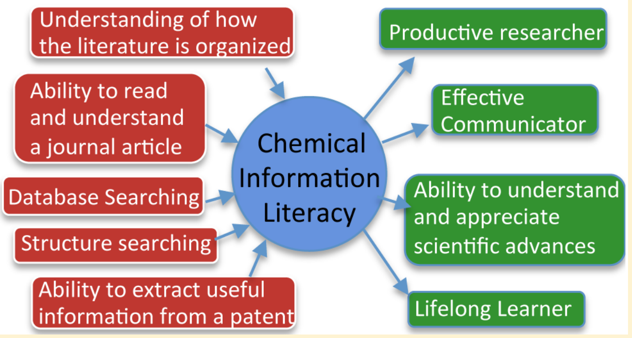
Supporting Information

ABSTRACT: Chemistry majors at Goucher College are now required to take a 1-credit course in their sophomore year entitled Chemical Information Literacy. Students in the course learn the structure and organization of the chemical literature, and how to carry out searches of various databases for topic, author, chemical compound, or structure. They learn related skills such as how to use a citation manager to organize citations, and how to use a structure-drawing program. Students are also exposed to the patent literature, and databases of molecular properties. A highlight of the course is a unit on current events in which students learn how to read a paper for general content even if they do not understand every word of it. The course culminates in students choosing a topic of interest to them, and preparing an annotated bibliography that can be used for writing a review article in a subsequent course. As a result of this course, students learn the skills required to be productive researchers, and develop an appreciation for the breadth of chemistry within the first half of their college careers. Furthermore, use of both the ACS journals subscription and the SciFinder search engine among students increased dramatically as a result of this course.



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A liberal arts education is designed to prepare students to be lifelong learners, and to develop students' critical thinking skills. An essential tenet of lifelong learning is knowing where to get good information, and how to evaluate the reliability of that information. The chemical literature is extensive, and there are a variety of databases designed to aid in searching the literature. In addition, the American Chemical Society Committee on Professional Training has published a list of specific skills related to chemical information literacy that students should develop.[1]

Chemical information literacy[2] includes an understanding of how the literature is organized, the ability to read and understand a journal article, extract useful information from a patent, and search databases for references and molecular properties. Students who are literate in chemical information are more productive researchers, have the ability to understand and appreciate scientific advances, and have learned some of the skills that will help them become lifelong learners. Chemical information literacy will also help students become more effective communicators. First, a student literate in chemical information will be more familiar with the content of published work, and can draw on that knowledge in their own presentations (written, oral, or poster). Second, through reading the number of papers in the literature required for this course, students should develop a better appreciation for what constitutes good scientific writing.

There are numerous strategies and activities that have been published in this *Journal* regarding teaching chemical information.[3−6] For example, modules for searching and reading the primary literature have been created for general,[7−11] organic,[12−15] and analytical[16] chemistry courses, as well as "Introduction to research" courses.[17,18] There are published activities in which students learn how to use SciFinder Scholar.[13,19,20] Complete courses in chemical information literacy have been reported at both the undergraduate[21] and graduate[22] level. The idea of a dedicated course in a liberal arts setting is not a new one. Many of our peer schools have such a course, and a paper describing one appeared in this *Journal* 16 years ago.[21] However, in 1999, STN Easy was the state of the art search engine for the CAS database, and many databases that exist today did not yet exist; therefore, an update is timely. Furthermore, the activities presented in the Supporting Information associated with this paper maximize the use of freely available resources, which is particularly useful for schools with fewer subscriptions.

■ RATIONALE FOR THE COURSE AND HOW IT FITS INTO OUR CURRICULUM

The specific need for further instruction in chemical information literacy at Goucher College stems from the fact that our students need to develop information skills in order to carry out the required projects in their upper level courses as

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well as become productive researchers. We investigated the various models for teaching information literacy skills and decided on a dedicated 1-credit course that would be required for the chemistry major and taken by students during the spring semester of their sophomore year. Students who complete this 200-level course will go on and take another 1-credit 300 level course entitled "Chemical Communication" in which they utilize the skills learned in this course to prepare a review article, poster, and oral presentation on a topic of their choice. The college's Curriculum Committee enthusiastically approved the creation of both courses, citing the importance of the development of student skills.

We decided to offer a stand-alone course in order to allow students to explore topics within chemistry that interest them, rather than only become exposed to the literature of a particular subdiscipline. Furthermore, there was really no room in our content-rich existing courses to incorporate the level of treatment of chemical information that would truly be useful to students. Many of our students begin independent research in the summer after the sophomore year, and we wanted this course to be in place before they begin a research project. Finally, we wanted this course to be a small group experience for our sophomores that will begin the process of creating a community of chemistry majors. All of the chemistry courses that they take up to this point (General and Organic Chemistry) are relatively large classes, with the majority of the enrolled students not being chemistry majors, and we wanted to focus instruction about chemical information on students who will continue taking chemistry courses.

We do not have a dedicated science librarian at Goucher, so we decided that a faculty member within the department would offer the course. In this article, I discuss the structure of the course I developed, as well as some of the specific topics we cover and assignments that students complete.

■ DESCRIPTION OF THE COURSE

The major topics covered in the course can be found in Table 1.

The course begins with a general overview of the scientific literature including a discussion of the types of papers found in journals, the difference between primary and secondary sources, and a survey of print resources available at a small liberal arts college. Students are taught the importance of citations, how one can use citations to find previous work in the area as well as related work, and how to use the citation manager RefWorks.

Table 1. Major Topics in Chemical Information Literacy Course

Topic	Title
1	Introduction. Why this course? Structure of Chemical Information
2	Primary Literature Overview; Types of Journals; Types of Articles
3	Citations: Why and How? Using RefWorks citation manager
4	Secondary/Tertiary Literature. Review Articles, Compiled Data, Handbooks, Encyclopedias, Methods
5	Abstracting and Indexing resources: Chemical Abstracts/SciFinder, PubMed, PubChem, ChemSpider
6	Formulating an Effective Search Strategy: Searching by text, structure, and citations
7	Patents
8	Current Events. What kind of papers do we find in a current journal, and how do we go about reading them?
9	Structure and Sequence databases: Uniprot, Cambridge Structure Database, Protein Data Bank
10	Spectral and Property databases: NIST Chemistry WebBook, SDBS
11	The Publication Process

Much chemical information is now found in databases, so students explore the SciFinder, PubMed, PubChem, and ChemSpider[23] databases, with an eye for which database would be most appropriate for finding specific pieces of information. They are given several exercises in which they have the opportunity to carry out various types of searches such as topic, author, chemical substance, and chemical structure. For many students, this is their first exposure to a structure drawing program. We discuss older indexing methods such as the Beilstein and Gmelin databases, and their shortcomings. Finally, within this unit they learn a little bit about SMILES and InChI in order to appreciate how modern search engines transform a chemical structure into a searchable string.

Students are also exposed to databases in which they can find data directly as opposed to finding references. Students use the Cambridge Structure Database[24] to examine the crystal structures of small molecules, and two other databases (the Japanese Spectral Database for Organic Compounds (SDBS)[25] and the NIST Chemistry WebBook[26]) to search for spectra. Given that almost half of the students in the spring 2015 class were biochemistry majors, I was sure to include protein sequence and structure databases (Uniprot[27] and the RCSB Protein Data Bank[28]). Students learned how to carry out a sequence alignment query and how to use the Jmol viewer[29] to manipulate three-dimensional structures.

Patents[30] are another important source of chemical information. Students become familiar with the patent literature by considering questions such as What kind of information can you find in a patent? Why should we care about information in patents? How are patents structured? How is it the same as journal articles? How is it different from journal articles? Where within a patent would you look for a specific piece of information? We also consider the people and organizations involved in the patent process, both within the United States and worldwide.

The unit on "current events" was a favorite among students in the spring 2015 class. Students are asked to go through the table of contents of the most recent issue of the *Journal of the American Chemical Society*. For each Communication and Article, they are asked to determine what area of chemistry is best represented by the article—either one of the five traditional subdisciplines within chemistry or an emerging interdisciplinary area. Then, they are asked to vote for at least two articles that they would like to study in more detail. From their votes, I chose one Communication and one Article to study in depth. This year, one article was about gold nanorods, and the other was an organic methodology paper. I think it is important to include one paper describing the synthesis of compounds (usually organic) and one paper describing measurements of chemical or biochemical properties. Through this exercise, students realize that they do not need to read every word of a paper in order to be able to extract the most important results.[31] For example, the abstract, the last paragraph of the introduction, and the figures/tables/schemes are where they should focus their effort. They will undoubtedly come across some unfamiliar terminology, and they need to decide if they need to look up the meanings of unfamiliar words or whether they can pass over those words without losing too much of the overall idea of the paper.

Having explored what chemical information is, and how to find it, we also consider the publication process—in other

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words, how discoveries become chemical information. Topics discussed include journal-specific requirements as articulated in the Instructions for Authors, what happens to a paper after it is submitted, and the open access model of publishing.

STUDENT ASSIGNMENTS

The major project for the semester was for students to create an annotated bibliography on a subject of interest to them. They were asked to choose either:

- The work of a particular chemist working in academia
- A specific research topic
- A specific molecule or class of molecules (including drugs)

They were required to have at least 20 total references in their bibliographies with at least 4 references coming from the past 3 years, and 12 of the 20 coming from the primary literature. For each reference, students wrote a short summary of the paper in their own words. Three students chose to study the work of a single chemist (Dale Boger, Sarah Reisman, and David Nichols), two students chose single molecules (Methylphenidate and Nicotine), and the remaining six students chose more general topics (Advances in Drug Delivery, Copper Contamination of Natural Waters, Anticancer Drugs, Methods of Detection for Cancer, Artificial Photosynthesis, and Gold Nanorods). The breadth of topics chosen by students spans the chemical subdisciplines and provides support to the approach of a freestanding course rather than just integrating chemical information exercises into the organic chemistry course.

Students completed six other assignments over the course of the semester. As an introduction to the primary literature, they were asked to choose 8 ACS journals and find out information such as the scope of the journal, what kinds of articles are published, and the impact factor. To gain skills with using a citation manager, they were asked to import a list of articles written by a particular author in 2014 into RefWorks, then output a bibliography in two different journal styles (*Organic Letters* and *Biochemistry*).

After learning how to execute searches using SciFinder, students completed several tasks. They prepared a complete list of papers written by an assigned author in 2014, then they chose a topic of interest from a list of hot topics in chemistry, found a review article, and identified a leading researcher in the field. In addition, they carried out a topic search to find out information about a new drug that was approved in 2014, and they carried out a structure search to locate a preparation of a small organic molecule. The ability for all students to use SciFinder together in class is only possible as a result of the recent decision by CAS to no longer restrict the number of SciFinder seats included in our subscription plan. Students then used PubMed to search for information about a class of cancer drugs.

A textbook entitled *Chemical Information for Chemists: A Primer* by Judith Currano and Dana Roth has recently been published.[32] There is a lot of good material in this textbook, and I used it extensively when preparing course materials, but I decided to make it optional for students, because the sophomore students for whom this course is targeted would struggle to extract the useful information out of the long chapters with lots of facts in them.

HOW CLASSES WERE RUN

The class met for 50 min once a week for 14 weeks. I created a student handout for each major topic. Copies of the handouts are included in the Supporting Information. I would demonstrate the use of each electronic resource covered during the class, and I asked students to bring a laptop to each class meeting so that they could follow along. During some of the classes, the students would work on some of the assignments described above. Some topics (open access vs traditional subscriptions) lent themselves to lively discussions, while others were more straightforward presentations of the material. Discussions sometimes explored worthwhile tangents such as how to choose a graduate school and research advisor. In the future, handouts will be posted in advance so that students can read them before coming to class. This will free up more class time for discussion and for students to be able to do more hands-on work.

EXAM AND GRADING

There was one exam, administered during the final exam period. The exam was 35 points written, and 65 points practical. On the written part, students had to demonstrate mastery of the terminology of the course and know which resource they would use to find what kind of information. For the practical portion, students were given five tasks. They had to do an author search, a subject search on a drug using the patent literature, a structure search to find a synthesis, a protein sequence search, and a spectral search. Students received and submitted the practical portion electronically carrying it out on their laptop. The specific questions asked students to copy specific pieces of information that they found onto the electronic copy of the exam.

The grade was broken down as follows:

Class Participation and classwork: 20%
Homework Assignments: 25%
Major Project (Annotated Bibliography): 25%
Final Exam: 30%

Most students who handed in all of their assignments received most of the points for those assignments, so the final exam was most critical in differentiating A students from B students.

EFFECTS OF THE COURSE ON STUDENTS

This course is now required of all chemistry majors, and it will ordinarily be taken during the sophomore year. While we had only three sophomore chemistry majors this year, there were 11 students in the class this past semester including three senior chemistry majors, one junior chemistry major, one junior biology major, and three sophomore biochemistry/molecular biology majors. Clearly, the idea of this course appealed to a wide range of students at a variety of different points in their college careers.

The course definitely met its objective of introducing students to the chemical literature and methods of searching, and encouraged them to begin reading the literature. The number of papers downloaded from ACS journals increased by 59%, and the number of SciFinder searches increased by nearly 600% from between January and April of 2014, before this class existed, to January and April of 2015.

The longer-term outcome of this course would be for students to be able to perform effective literature searches related to their research projects. Since most of the enrolled students have not yet begun a research project, we are not yet

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able to assess this outcome. However, both of the seniors in the course who were doing independent research demonstrated a greater capacity for finding relevant information in the literature than previous generations of Goucher senior research students.

Student course evaluations confirmed that students found the course to be useful. Eight out of 10 students rated the course "Excellent" or "Good" overall, and 9 out of 10 responded "Always" or "Most of the time" to the question "Did the written work (exams, quizzes, papers, problems, etc.) contribute to your understanding of, and your ability to apply the course materials?" The following statements are representative of the narrative comments on the student evaluations:

> *All of the topics covered will be useful throughout the rest of my college career and helpful for future research.*
>
> *Showed us very relevant and helpful information about databases that can be used for research.*
>
> *The material was presented by example and we learned how to use real world data sources. The focus on the big picture and how to use data sources for writing papers along with in class activities was a great way to learn.*

■ CONCLUSION

This article outlined a freestanding 1-credit course on chemical information literacy taught by a chemistry faculty member and appropriate for a primarily undergraduate institution. Students who successfully completed the course learned about the structure of the literature, how to read papers and patents, and how to search for information in databases. The course was well received by students and fills a clear gap in our curriculum. The skills that students learned will help them become more productive researchers, effective communicators, critical thinkers, and lifelong learners.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00422.

> Course syllabus, handouts for each topic, in-class assignments, and homework assignments (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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