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Integrating Information Literacy into the Chemistry Curriculum

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Integrating Information Literacy into the Chemistry Curriculum

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Foreword

The ACS Symposium Series was first published in 1974 to provide a mechanism for publishing symposia quickly in book form. The purpose of the series is to publish timely, comprehensive books developed from the ACS sponsored symposia based on current scientific research. Occasionally, books are developed from symposia sponsored by other organizations when the topic is of keen interest to the chemistry audience.

Before agreeing to publish a book, the proposed table of contents is reviewed for appropriate and comprehensive coverage and for interest to the audience. Some papers may be excluded to better focus the book; others may be added to provide comprehensiveness. When appropriate, overview or introductory chapters are added. Drafts of chapters are peer-reviewed prior to final acceptance or rejection, and manuscripts are prepared in camera-ready format.

As a rule, only original research papers and original review papers are included in the volumes. Verbatim reproductions of previous published papers are not accepted.

ACS Books Department

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Preface

Information literacy, the ability to find, evaluate, and use information resources, is an important skill for future chemists. Students and scientists need to distinguish between information provided by Wikipedia, ChemSpider, research journals, and the New York Times, depending on the intended use of the information sought. Instructors and librarians may often teach these skills through stand-alone database demonstrations, video tutorials, and lectures. However, it is possible to teach these skills in a more contextual and integrated manner by designing chemistry assignments that incorporate information literacy as a learning outcome. We hope this book will be useful for librarians and chemistry instructors who are designing courses in which students develop information literacy in the context of a chemistry course at two-year colleges, public and private universities, and high schools.

The chapters in this book review the current state of information literacy in chemistry and provide concrete examples of assignments and interventions aimed at teaching information literacy skills in chemistry curricula. A wide range of options are offered for integrating information literacy into college-level chemistry courses, including general chemistry, organic chemistry, science courses for students not majoring in science, and chemistry capstone research courses.

This book is split into three thematic sections. The first three chapters discuss concepts that may be found throughout the chemistry curriculum: data information literacy, chemical safety, and risk assessment; and provide an introduction to information literacy standards, including the recent Association of College and Research Libraries (ACRL) Framework for Information Literacy for Higher Education, as they apply to chemistry. The second set of chapters describe assignments and activities for students pursuing a chemistry major. In these chapters, the instructional focus is on using chemistry-specific information tools, managing chemical information and data, and contextualizing authority in chemical literature. The last set of chapters shift the focus to activities in which students find chemistry-related information from a variety of sources and then present the information in ways that a non-chemist could understand. In these activities, the students often create new chemistry information products for consumption by the general public, such as Wikipedia articles, training documents for a science museum, articles in an online journal, and videos posted to popular video-sharing websites. To complete these tasks, students needed to develop an understanding of the chemistry concepts while building the ability to communicate their understandings to the general public unfamiliar with some of these topics.

The chapters in this book were inspired by an information literacy symposium during the Biennial Conference on Chemical Education (BCCE) held at Grand Valley State University in August 2014. The purpose of this symposium was to start a conversation between chemists and librarians about integrating information literacy and other library-related activities into chemistry classes. This book was designed to help that conversation continue. Most chapters were authored by pairs of librarians and chemistry instructors, so that expertise and perspectives are provided by both. We believe that the design and implementation of integrated information literacy activities benefit from partnerships between librarians and chemistry instructors. We hope these case studies inspire more such collaboration in chemistry education and beyond.

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Chapter 1

Chemical Information Literacy: A Brief History and Current Practices

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This chapter examines the evolving standards for information literacy in higher education, with an emphasis on chemical information literacy. It describes the gradual progression from one of the first published definitions of the term "information literacy" to the Framework for Information Literacy for Higher Education, adopted by ACRL in 2016. The Competencies for Undergraduate Chemical Information Literacy, which describe information skills that every chemistry undergraduate student should acquire, map very well to the Framework, and this chapter offers recent examples from literature describing classroom exercises that support the various skills and competencies.

The History of the Information Literacy "Movement" and Background of the Use of the Term

In order to understand how educators are integrating information literacy into the chemistry curriculum, it is first necessary to understand what individuals who employ the term "information literacy" mean by it (*1*). Armed with this understanding, one can begin to explore what information literacy means in a chemical context.

Origins of the Term "Information Literacy"

The term "information literacy" in the library and information science literature came into common use in the early-to-mid 2000s, and its use increased sharply as the decade progressed. However, the origins of the term can be found approximately 20 years prior. A Scopus search for the exact phrase "information literacy" (performed Feb. 17, 2016) yields 4434 documents (*2*). When one analyzes the references by publication year, the oldest relevant result is a paper from 1983 (*3*). This document, a conference paper by Eileen Trauth of the School of Management at Boston University, presents a novel alternative to the commonly presented "computer literacy" courses of the mid 1980s. She postulates that "the rationale for computer literacy stems primarily from the pervasiveness of information processing technology in our society" (*4*). Her idea is to present a course in "information literacy" rather than in computer literacy: "what should be the focus of attention is the information itself. The computer is viewed as a tool – albeit the major tool – used in the processing of information. Thus, it is studied – but from the viewpoint of its relationship to the information. …the goal is the capability of working with the information in whatever form it arrives and by whatever means it is processed – via computer or otherwise" (*4*).

Four years later, in 1987, the president of the Association of College and Research Libraries (ACRL), a division of the American Library Association, appointed a Presidential Committee on Information Literacy with the following charge:

> *(1) to define information literacy within the higher literacies and its importance to student performance, lifelong learning, and active citizenship; (2) to design one or more models for information literacy development appropriate to formal and informal learning environments throughout people's lifetimes; and (3) to determine implications for the continuing education and development of teachers* (*5*)

On January 10, 1989, the committee produced a report on the subject, which is freely available online (*5*). This report focuses on the need for an "information-literate" citizenry and methods of building a population that is "able to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information" (*5*). It describes, in glowing and patriotic strokes, the benefits to society of citizens capable of finding and using information appropriately. The model of lifelong learning that it endorses for both educational and real-world endeavors employs active, inquiry-based teaching techniques that include the judicious use of information resources. The report closes with six recommendations:

- Organizations must critically evaluate methods of organizing and accessing information, redesigning and reorganizing, where necessary, to allow for self-directed learning;
- ALA should establish a "Coalition for Information Literacy" to highlight the benefits to society of an information literate public;

- More research should be conducted into the benefits derived from appropriate application of information, both in education and in day-to-day life;
- Government officials should ensure that educational objectives for their states support information literacy and a move from passive, regurgitative-style learning to active learning, using information to create knowledge;
- Teachers should be trained in and evaluated based on these new educational criteria; and
- ALA should relate the idea of information literacy to the concepts presented at the White House Conference on Library and Information Services (*5*).

While, to a large extent, the report focuses on information literacy in K-12 education, it does indicate that college-level studies could be similarly structured.

The 2000 ACRL Information Literacy Competency Standards for Higher Education

Eleven years after the report of the Presidential Committee on Information Literacy, ACRL released a set of Information Literacy Competency Standards for Higher Education. These competency standards were in effect from the time of their adoption, January 18, 2000, until they were rescinded on June 25, 2016 (*6*). They retained the definition set forth by the Presidential Committee, focusing on the relationship between information literacy and both technology and lifelong learning; in the course of reflecting on these relationships, they mirror some of the themes first presented by Eileen Trauth:

> *Information literacy, on the other hand, is an intellectual framework for understanding, finding evaluating, and using information – activities which may be accomplished in part by fluency with information technology, in part by sound investigative methods, but most important, through critical discernment and reasoning. Information literacy initiates, sustains, and extends lifelong learning through abilities which may use technologies but are ultimately independent of them (6).*

According to ACRL, someone who is "information literate" can perform the following tasks:

- *Determine the extent of information needed*
- *Access the needed information effectively and efficiently*
- *Evaluate information and its sources critically*
- *Incorporate selected information into one's knowledge base*
- *Use information effectively to accomplish a specific purpose*
- *Understand the economic, legal, and social issues surrounding the use of information, and access information ethically and legally (6).*

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The document is divided into two sections: introductory material that describes the concept of information literacy and the importance of teaching and integrating information literacy concepts in higher education, and five standards, embodying competencies that all students should assimilate in the course of their college and graduate education (*6*). Each of the five standards is accompanied by one or more performance indicators, or behaviors that a student will demonstrate if he or she has become competent in this area. Below each performance indicator is a series of more granular outcomes that can be used to assess how well the student demonstrates performance in that area. The combination of standards, performance indicators, and outcomes provides a very prescriptive set of competencies and assessment criteria, around which university educators can structure training modules, classes, and assignments to teach their students to be information-literate scholars.

2006: The Information Literacy Standards for Science and Engineering/Technology

In June 2006, ACRL published an adapted set of standards for information literacy to apply specifically to science and engineering curricula. The resulting *Information Literacy Standards for Science and Engineering/Technology* resulted from work by the ALA/ACRL/STS Task Force on Information Literacy for Science and Technology. The adapted standards attempt to place information literacy in the context of scientific research, framing information retrieval and use as an iterative process that extends throughout the course of a scientific endeavor. They stress the need of students to review the results of their searches and to revise their search strategy when necessary; in fact, this skill is so important that they place it in the very definition of the term:

> *Information literacy in science, engineering, and technology disciplines is defined as a set of abilities to identify the need for information, procure the information, evaluate the information and subsequently revise the strategy for obtaining the information, to use the information and to use it in an ethical and legal manner, and to engage in lifelong learning (7).*

In this document, the standards are taken directly from the five aspects of the definition of information literacy presented above. Once again, each standard is accompanied by a series of performance indicators and outcomes that aim to demonstrate the student's proficiency in that area. As with the previous set of standards, local implementation is the main challenge and tends to be uneven between institutions and even within a single school, especially given the fact that instructors are struggling to find adequate time to present students with an appropriate level of subject-specific content.

- ***Standard One****: The information literate student determines the nature and extent of the information needed (7).*

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This standard has been reproduced verbatim from the more general ACRL document, although the performance indicators and outcomes are adjusted to reflect the nature of scientific research. Contemporary trends indicate that the implementation of the first standard, the determination of the scope of information need, is frequently left to the student himself or herself, although instructors using "information-intensive" assignments in their courses do frequently include in the assignment description the extent of external information required.

- ***Standard Two***: *The information literate student acquires needed information effectively and efficiently.*
- ***Standard Three***: *The information literate student critically evaluates the procured information and its sources, and as a result, decides whether or not to modify the initial query and/or seek additional sources and whether to develop a new research process (7).*

The second standard is also reproduced verbatim from the 2000 document, and the content of the third standard is very similar to its counterpart, as well. The authors deviate from the third standard in the 2000 document by placing greater emphasis on the iterative nature of information seeking and retrieval, which is epitomized by its final performance indicator and outcomes:

The information literate student:

7. Evaluates the procured information and the entire process. Outcomes include that the student:

a. *Reviews and assesses the procured information and determines possible improvements in the information seeking process.*
b. *Applies the improvements to subsequent projects (7).*

The third standard is shared between the subject instructors or faculty members and librarians and information specialists; both groups present students with a series of "red flags: that may point to publications of dubious quality (authority, currency, bias, source, etc.), while subject specialists alone tend to focus on methods of evaluating the actual science.

- ***Standard Four***: *The information literate student understands the economic, ethical, legal, and social issues surrounding the use of information and its technologies and either as an individual or as a member of a group, uses information effectively, ethically, and legally to accomplish a specific purpose (7).*

Standard Four recognizes the fact that, in science and engineering disciplines, published or presented information represents a record of the experiments and research performed elsewhere. As a result, the focus of information seeking is not on the location of the information itself but on the use of information to accomplish an experimental purpose, highlighting the need of the researcher to give credit to the individuals who pioneered the methods being used. This topic is becoming increasingly popular among educators; research and publication ethics education, particularly the appropriate use and reuse of information, is beginning to filter down into the undergraduate curriculum, with a heavy emphasis on the avoidance of plagiarism. This topic is challenging for the "mash-up generation," for whom ownership of and appropriate reuse of published intellectual property represent fluid concepts.

- ***Standard Five**: The information literate student understands that information literacy is an ongoing process and an important component of lifelong learning and recognizes the need to keep current regarding new developments in his or her field (7).*

This standard focuses on the fact that, to do good science, it is necessary to retain access to information "in perpetuity," so that none of the excellent methods previously developed will be lost to the mists of time, while, at the same time staying up to date with current methods and breaking developments in the field. Research in most areas of science and engineering is expensive, and it is important to have immediate access to information that will indicate procedures that are likely to work (or fail) in order to prevent waste of resources.

Chemical Information Literacy

The CPT Guidelines

The American Chemical Society has an approval process for undergraduate degree programs that is administrated by its Committee on Professional Training (CPT). A school can apply for degree approval, and CPT will review the application, interview the department chair, and visit the department, prior to determining whether or not to grant approval. Schools whose degree programs are ACS-approved may offer their students "ACS certified" bachelor's degrees, which, according to CPT, "signifies that a student has completed an integrated, rigorous program including introductory and foundational course work in chemistry and in-depth course work in chemistry or chemistry-related fields. The certified degree also emphasizes laboratory experience and the development of professional skills needed to be an effective chemist" (*8*). One of these professional skills is the ability to effectively and efficiently use the chemical literature, and, in fact, an entire section of the most recent (Spring 2015) edition of the ACS CPT Guidelines, Section 7, is devoted to the development of "non-traditional" student skills.

The introduction to this section states that "programs must provide experiences that go beyond chemistry content knowledge to develop competence in other critical skills necessary for a professional chemist" (*8*). It goes on to say that "either dedicated courses or integration of learning opportunities throughout the curriculum can be used to assess student skills" (*8*). The six areas of skills included in Section 7 are:

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- *Problem solving skills*
- *Chemical literature and information management skills*
- *Laboratory safety skills*
- *Communication skills*
- *Team skills*
- *Ethics* (*8*)

Within the section related to the chemical literature, CPT requires that students be able to search the literature using a variety of different methods, to evaluate the information that they retrieve, to apply the information found to their work in the chemical discipline, and to manage data, citations, and research notes effectively (*8*). A supplement to the CPT guidelines (*9*) offers an expanded view of the skills and techniques that the students should learn over their course of study, either through means of a dedicated course in chemical information or through integration of information skills throughout the curriculum.

Inclusion of chemical information competencies in the CPT Guidelines is by no means a recent development, and Arlene Somerville briefly summarizes the earlier evolution of the chemical information component of the guidelines in her 1990 paper, which, in turn, expands on a talk that she gave at an ACS National Meeting symposium in honor of the 50th anniversary of CPT (*10*). The guidelines have certainly evolved since the 1960s, during which time CPT seemed more concerned with the contents of the library than the students' instruction in its use. In the late 1970s, CPT indicated that, if institutions lacked the *Beilstein Handbuch der Organischen Chemie* and *Chemical Abstracts*, they could fulfill this requirement by proving that their students had nevertheless learned how to use them (*10*). By the time the guidelines were revised in 1983, the chemical information requirements had been expanded significantly and, for the first time, required students to be taught information retrieval skills in a formal setting of some type (*10*). The 1983 guidelines included an appendix, which listed the tools with which students needed to be familiar, as well as the general information retrieval skills that they should have mastered by the time they completed their degree programs. A side-by-side comparison of the concepts from the chemical information retrieval section 1983 appendix and the current Chemical Information Skills supplement (Table 1) shows few changes to the desirable information retrieval skills. Skills listed in bold face appear in both documents; those that are not bold are unique to one or other of the documents.

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Table 1. Side-by-Side Comparison of Suggested Chemical Information Skills That Appeared in CPT Supporting Materials in 1983 and 2015

1983 CPT Guidelines, Appendix[a] *as represented in Somerville, 1990 (10)*	***CPT 2015 Supplement***[b] *(9)*
... [S]tudents should acquire a demonstrable, basic understand 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* Lanolt-Bornstein*; 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***	*… [S]tudents should be able to* ***• Efficiently locate chemical and physical properties of substances, including spectra*** ***• Efficiently locate references for the detection, characterization, or reactions, including syntheses, of desired compounds or classes of compounds*** *• Be able to obtain information on a substance through a variety of searching strategies, including structure searching and searching by molecular formula and name* *• Identify key references and use citation searching of articles to locate more current articles on the topic of interest* ***• Complete a comprehensive subject search*** ***• Compile a complete bibliography of an author's publications*** ***• Locate recent review articles on a subject*** ***• Know the importance of patents and be able to search for patents on a subject*** *• Use a bibliographic program to organize information and prepare a scientific paper* *Information should also be provided in data management and archiving, record keeping…, and managing citations and related information….* *Students need to develop the ability to determine the quality of the information obtained.*

[a] Adapted with permission from Somerville, A. *J. Chem. Inf. Comput. Sci.* **1990**, *30*, 177. Copyright 1990 American Chemical Society. [b] Adapted with permission from American Chemical Society Committee on Professional Training. Chemical Information Skills. http://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/chemical-information-skills.pdf (accessed April 27, 2016). Copyright 2015 American Chemical Society (All Rights Reserved).

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Information Competencies for Chemistry Undergraduates: The Elements of Information Literacy

Historically, many larger colleges and universities have had little difficulty fulfilling the CPT requirements; they have well-stocked libraries and librarians trained in chemistry or a related science, who are accustomed to teaching students the complexities of chemical information with its multitude of entry points. However, smaller institutions frequently hire only one librarian to support multiple science and engineering disciplines. This individual may not hold a degree in chemistry, making him or her unfamiliar with the research patterns of chemists and thus not cognizant of the advanced chemical information skills required by students preparing for graduate study or individual research. This leaves faculty members with the task of teaching their students the necessary skills to fulfill the CPT requirements, and they are frequently not formally trained in chemical information, have limited experience teaching information retrieval techniques, and are further hampered by lacking class time to devote to this endeavor. The ACS Division of Chemical Information (ACS CINF) and the Special Libraries Association Chemistry Division (SLA DCHE) have long been mindful of this problem, and SLA DCHE has offered workshops in chemistry and chemical information, aimed at non-chemist librarians, while ACS CINF presented regular training sessions in teaching chemical information, which were largely aimed at chemistry faculty members. However, in-person trainings offered at large national meetings reached only a subset of the individuals who desired assistance in integrating chemical information skills into their curricula.

In 2004, DCHE convened an *ad hoc* committee on information literacy, with the goal of producing a set of information competencies for undergraduate chemistry majors and an accompanying resource list that could be used by any experienced or inexperienced chemical information educator. The first edition of the *Information Competencies for Chemistry Undergraduates* was published in 2006; the second edition, compiled jointly by individuals from DCHE and the CINF Education Committee, was released in 2011. This document serves two purposes: it supplies institutions with a list of specific chemical information skills that all undergraduate chemistry students should know before graduation, and it offers a recommended list of resources that libraries supporting chemistry departments should offer. One of the key goals of the document is to

> *Serve as a bridge between the ACS Committee on Professional Training (CPT)* Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs *(2008) and information literacy standards developed by the American Library Association (ALA) Association of College and Research Libraries (ACRL and its Science and Technology Section (STS) including: ALA/ACRL/STS* Information Literacy Standards for Science and Engineering/Technology *(2006) , and ALA/ACRL* Information Literacy Competency Standards for Higher Education *(2000)* (*11*).

The document goes on to lay out specific competencies, divided into four sections which are listed below, along with a description of the competencies contained.

- **“The Big Picture: The Library and Scientific Literature**”
  Students are expected to gain an understanding of the organization and contents of the library and the purpose and skills of a librarian; understand the purpose of the different types of chemical literature, the ways in which various types of literature sources (primary, secondary, and tertiary) are compiled, and methods of evaluating and applying literature to a problem; and learn and demonstrate ethical practices in using and reusing information found (*11*).

- **“The Chemical Literature**”
  Students are expected to learn various techniques of using secondary databases to locate chemical literature, including tertiary background information and primary journal articles, conference papers, and patents. In addition to traditional text-based searching, students should be able to use the unique entry points to the chemical literature, such as substance identifiers and structure-based substance and reaction searching, to locate relevant material (*11*).

- **“Properties, Spectra, Crystallographic, and Safety Information”**
  Students should be able to locate physical and chemical properties of substances, their spectra and crystal structures, and information relevant to the safe handling of substances, as well as basic laboratory safety information (*11*).

- **“Scientific Communication and Ethical Conduct”**
  Students should be aware of the various ways of communicating the results of one’s research to others, know how to manage and cite references correctly, and learn and practice the code of ethics followed by chemists (*11*).

The SLA DCHE/ACS CINF document is unique in that it presents a list of specific chemical information skills that all practicing chemists should know, and, after discussing each skill in detail, it indicates one or more information retrieval tools in which one could use that skill, as well as other documents or resources to which one could go for additional information about the topic or skill described. This provides instructors in chemical information with good ideas of specific skills to teach their students and free and fee-based databases in which they can demonstrate the use of these skills. What it does not give them is a sense of ways in which they can integrate the skills holistically into an undergraduate chemistry curriculum.

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An Overview of Information Literacy in the Chemical Literature

Having established the origins of the term “information literacy” and reviewed the ACRL, ACS, and SLA DCHE/ACS CINF documents germane to the teaching of information literacy in the chemistry classroom, it is next important to review the chemical literature dealing with information literacy. A SciFinder search for the exact phrase “information literacy”, run in the *Chemical Abstracts* and MEDLINE databases in mid-February of 2016, yielded 458 unique hits, with duplicate MEDLINE records removed from the hit set. The term increased in popularity from its first occurrence in 1985; 68 of these mentions (15%) occurred in 2015, and 18 articles or abstracts published in the first few months of 2016 included the term. An analysis of the hits by database indicates that the term is much more common in the health science literature than in the chemistry literature, with 365 of the deduplicated hits (~80%) coming from the MEDLINE database.

When one focuses solely on the *Chemical Abstracts* references including the term “information literacy” (as typed, without conceptualizing or autostemming), one sees that, of the 91 records (two are false hits), 39 are journal articles and 52 are conference papers or presentations. The first instance of the term in a *Chemical Abstracts*-indexed document is in 2001; 26 of the papers were published in the *Journal of Chemical* Education, and, of these, 14 come from the 2016 special issue focused on chemical information (*12*). Clearly, these are not the only papers that discuss the concepts described in the ACRL documents; they are simply those in which the authors use the exact term “information literacy,” and they serve to demonstrate the concepts and practices that chemists and chemical information specialists associate with this term.

A word frequency analysis reveals similar indications of various authors' definitions of “chemical information literacy.” The 91 true hits from SciFinder were imported into EndNote, which was used to generate to a Word document consisting solely of their titles and abstracts. This document was then imported into NVIVO, and a word frequency analysis was performed, capping the set at the top 1000 words of three letters or more. Words that were clearly related (for example, singulars and plurals) were grouped together, and the results were sorted in order of decreasing frequency. The top 30 results appear in Table 2.

It is interesting to note that the names of relatively few information resources appear in the 1000 most-used words. Table 3 displays the 10 total resources mentioned, along with the number of times each name appeared and the number of abstracts in which it appeared.

These papers have an astonishing breadth, discussing full graduate and undergraduate courses in chemical information, concerted efforts to integrate chemical information classes throughout the undergraduate course of study, and individual classes or activities that can be used to teach students information literacy skills relevant to study in the chemical sciences.

Table 2. Top 30 of the 1000 Most Frequently-Used Terms in *Chemical Abstracts*-Indexed Documents on Information Literacy, Based on a Word-Frequency Analysis of SciFinder Results

Word	*Count*
chem, chemical, chemistry, chemists	365
information	332
student(s), students’	278
literacy, literate	169
science(s), scientific, scientist(s)	142
course(s)	118
use(d), using	118
skill(s)	112
research, researchers, researching	101
learn, learned, learning	100
develop, developed, developing, development(s), developmental	84
literature	84
lab(s), laboratory	71
search(es), searching	66
instruction, instructional, instructions, instructor(s)	62
taught, teach, teaching	60
year(s)	60
resource(s)	57
presentation(s), presented, present(s)	54
libraries, library	53
program(s)	53
write, written, writing	52
integrate(s), integrated, integrating, integration	50
undergraduate(s)	48
librarian(s)	45
data	44
provide(s), provided	44
article(s)	42

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Table 2. (Continued). Top 30 of the 1000 Most Frequently-Used Terms in *Chemical Abstracts*-Indexed Documents on Information Literacy, Based on a Word-Frequency Analysis of SciFinder Results

Word	*Count*
assignment(s)	39
faculty	39

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Table 3. Ten Information Resources That Appeared in the 1000 Most Frequently-Used Terms in *Chemical Abstracts*-Indexed Documents on Information Literacy, Based on a Word-Frequency Analysis of SciFinder Results

Word	*Cou-nt*	*Abstracts*
Wikipedia, Wikipedians	35	8
WikiHyperGlossary, WHG	22	3
SciFinder	19	8
ChemSpider	5	4
CSD	4	1
EndNote	4	2
Google	4	3
Scopus	4	2
CAS	3	3
Reaxys	3	3

Tying It All Together: The 2015 ACRL Framework for Information Literacy for Higher Education

In February 2015, ACRL released another document, which it called its *Framework for Information Literacy for Higher Education*. It described this document as a “cluster of interconnected core concepts, with flexible options for implementation” (*13*). The framework consists of six “frames,” which incorporate information literacy concepts that students should master before the end of their college or graduate careers; the mastery and application of the concepts within these frames will necessarily become more developed as an individual gains experience integrating the use and knowledge of information in the practice

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of his or her discipline. The authors of the *Framework*, therefore, revised the definition of "information literacy" to recognize this ongoing development of skills throughout an individual's career:

> *Information literacy is the set of integrated abilities encompassing the reflective discovery of information, the understanding of how information is produced and valued, and the use of information in creating new knowledge and participating ethically in communities of learning (13).*

The introductory material also presents the authors' opinions of the roles of various individuals in the information-rich educational enterprise of the twenty-first century. It states:

> *Students have a greater role and responsibility in creating new knowledge, in understanding the contours and the changing dynamics of the world of information, and in using information, data, and scholarship ethically. Teaching faculty have a greater responsibility in designing curricula and assignments that foster engagement with the core ideas about information and scholarship within their disciplines. Librarians have a greater responsibility in identifying core ideas within their own knowledge domain that can extend learning for students, in creating a new cohesive curriculum for information literacy and in collaborating more extensively with faculty (13).*

In addition to the goal of more accurately representing the complex concept of information literacy, the *Framework* also aims to bring together individuals from across the educational enterprise, including librarians, faculty members, and administrators, with the common goal of increasing students' skills in the areas related to the six frames. The several appendices of the document are each addressed to one of these varied audiences, and each presents ideas and possible implementation techniques for use by that particular group of educators, librarians, or administrators.

Each individual frame is accompanied by a set of "knowledge practices", or suggestions of methods by which students can increase their understanding of and familiarity with the concepts embodied in the frame, and a set of "dispositions". The dispositions present concrete skills, practices, and understanding related to the concepts of the frame that students should develop over their course of study (*13*). Since the *Framework* is not prescriptive, it does not attempt to dictate to educators the order in which the various concepts should be presented to the students; rather, it implies that different aspects of the various frames can be integrated over the duration of the students' courses of study. The authors even go so far as to explicitly state that they are presenting the frames in alphabetical order so as to disabuse readers of the notion that certain skills have greater importance or that some should be presented prior to others.

We will now examine the six frames and determine how each applies to the chemical information competencies described by CPT and SLA DCHE/ACS CINF, presenting the frames in the same order as they appear in the *Framework* document. Each section begins with the name and description of the frame, taken directly from the *Framework* document, maps the appropriate skills and competencies from the SLA DCHE/ACS CINF *Information Competencies* document, and closes with a few recent examples from the chemical information literature that describe the application of relevant competencies within the classroom. These examples are not comprehensive, but are some of the many articles on this topic that exist.

"Authority Is Constructed and Contextual"

> *Information resources reflect their creators' expertise and credibility and are evaluated based on the information need and the context in which the information will be used. Authority is constructed in that various communities may recognize different types of authority. It is contextual in that the information need may help to determine the level of authority required (13).*

This frame deals with information evaluation, and several of the SLA DCHE/ACS CINF competencies in the "Scientific Literature" subsection of Section 1: Big Picture, map nicely to it, namely "d) Understand and apply criteria for evaluating the authority and appropriateness of a document or information source", "e) Demonstrate critical thinking by evaluating information...", and "f) Understand the general nature of the peer review process" (*11*). The multitude of information sources available for students to use and the ease of access with which they are provided may tempt students to employ a familiar and user-friendly source repeatedly, without once questioning its veracity. Integration of the "Authority" frame into chemistry classes involves teaching students to develop and apply criteria for evaluating individual pieces of information and the efficacy of the tools they use to locate them.

Information Evaluation Techniques

Many criteria for evaluating information are consistent across disciplines and have been described by this author in a previous ACS Symposium Series volume (*14*). They include examining the author's credentials and institution, evaluating the reputation and impact of the source in which the information is presented, determining whether or not the information is up-to-date, checking the agreement between the content of the source and other published methods, being aware of obvious and hidden biases and agendas, and ensuring that an appropriate and balanced selection of information is cited in the references of the document (*14*).

Currano and Foster offer a graphical method of determining the overall quality of a source through the means of a line drawing, a common technique used by engineers to aid in ethical decision making. Each criterion is assigned a line having a statement of a positive paradigm at one end and a negative paradigm

Flener Lovitt et al.; Integrating Information Literacy into the Chemistry Curriculum
ACS Symposium Series; American Chemical Society: Washington, DC, 2016.
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at the other end. The position of the source in question is marked on this spectrum by putting an X closer to the appropriate paradigm. After evaluating the source using all appropriate criteria, one can determine the overall reliability of the source by weighting the various criteria, balancing the locations of the various X marks, and assigning the source an overall score (*14*).

Miller and Chengelis Czegan also approach the evaluation of information in their general chemistry course, in which they attempt to increase students' science literacy. They teach their students to locate information and then think critically about its reliability, taking into account the aforementioned criteria for information evaluation, but also beginning to teach them some tips for evaluating the science itself and focusing on peer review as a pre-publication check of the quality of the source. The students must then apply these evaluation techniques to several journal articles and Web sites before approaching a controversial area of science and beginning to draw conclusions for themselves (*15*).

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Peer Review

Traditional chemical information training has always highlighted peer review as a method of judging the reliability of a source, but students are liable to fall into the trap of believing that, just because an article is peer reviewed, it is correct. They do not fully realize that, with the exception of *Organic Syntheses* and *Organic Reactions*, most peer-reviewed journals do not require the reviewers to repeat experiments in their own laboratories when performing their reviews. As a result, although the researchers' methodology has been judged to be sound, the actual results may later be found to be irreproducible. Some recent articles introduce the idea of having students review one another's work in an endeavor to teach them about the peer review process or to improve the quality of the students' final assignment submissions.

Jones and Seybold introduced a peer-review component to their students' term project to improve the quality of the students' submissions and to give them a taste of the process in which authors and reviewers of scholarly journals participate. The students reviewed one another's projects following an established protocol, and the authors of the projects then revised their work according to the critiques of the reviewers. On the whole, their students found this exercise to be very useful (*16*).

Zwicky and Hands applied peer review to the term project in their "Chemical Literature" course. In their course, students were required to prepare a term project explaining their use of information search tools in researching a topic of their choice. Other class assignments allowed the students to practice their peer review skills on a pseudo-research paper and an actual accepted chemistry journal article, prior to receiving three of their peers' term projects to formally review. The students had the opportunity to revise their papers, incorporating the points made by the student reviewers, and they submitted the revisions as their final semester papers (*17*). The peer review exercise not only gave the students "real-life" experience of the scientific publishing process, but it gave student reviewers an opportunity to reflect upon the chemical information concepts that they and the reviewees had learned within the course of the semester and to demonstrate their understanding of these concepts through the content of their reviews.

The Advent of Data Provenance

One aspect of authority of particular importance is that of data integrity; when evaluating data, it is relevant to question whether or not the data are original to the publication in which they appear, and, if they are not, whether or not it is necessary to trace them to their original source. For example, property values in a handbook are lifted from the primary literature, in some cases with a reference to the originating article, but in other cases with limited or no indication of the original source of the values. Many times, the student can use the reported value with no further effort required; however, some values, particularly outlying values, can be better understood by examining the experiments from which they derived, looking at the credentials of the scientists who performed those experiments, and comparing the experimental procedures to other established methods to determine their likelihood of accuracy. While there are currently few examples of classroom exercises designed around specific issues in data integrity and provenance, this is clearly an area in which students can use guidance, particularly as the amount of readily-available, open access research data increases.

"Information Creation as a Process"

> *Information in any format is produced to convey a message and is shared via a selected delivery method. The iterative processes of researching, creating, revising, and disseminating information vary, and the resulting product reflects these differences (13).*

This frame deals with information as it fits into the research process, including the document types and information sources available, their relative strengths and weaknesses, and when to use them to greatest effect. ACRL exhorts students and instructors alike to focus on the structure and purpose of the information and how it is produced and compiled without excessive emphasis on format. Several of the SLA DCHE/ACS CINF competencies apply to this part of the *Framework*:

- Section 1.1: Library
    a) "Understand the organization of the library and know how to use library tools… to obtain desired information and references (*11*)"
    b) "Understand the purpose and characteristics of different information-finding tools… and choose appropriate tools for a particular information need... (*11*)"

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- Section 1.2: Scientific Literature

    a) "Understand the flow of scientific information and how information is communicated among scientists, both formally and informally… (*11*)"
    b) "Understand the nature and purpose of different types of scientific literature…" (*11*).

When teaching chemical information, then, it is important that students understand the differences between various types of information sources, the purpose of each source of information, and under what circumstances one should choose one type of information over another. For example, primary literature in chemistry mainly appears in the journal literature, reports, and patents. A journal article is written by the scientists who performed the work; its purpose is to communicate a clear and accurate method for performing a certain experiment and to explain what the results of the experiment mean and why they are valuable, and its authors want others to use and cite their methods. A patent, on the other hand, is written by a team of scientists and lawyers, and, while it must provide enough information to enable someone with a reasonable level of skill in that area of science to reproduce the results, its main purpose is to indicate those areas of technology to which the assignee is granted exclusive use for a set period of time. Therefore, although the patent provides researchers with proof-of-concept of a scientific advance, it does not provide them with a method that they can apply to their own research unless they seek permission from the rights-holder. Finally, a research article in a journal provides readers with the specifics of a piece of research, while a review article or book places that discrete piece of research in context with other findings.

Students need to learn these sometimes-subtle differences between the different types of literature available to them and be guided through appropriate training and assignments towards the types of literature that best suit each research need that they might have. Furthermore, it can be helpful for instructors to teach students exactly how to read chemical journal articles and patents so that they can extract relevant information in an efficient manner. There are a number of interesting examples of this in the chemical information literature.

Greco reports that he taught students to focus their attention on specific areas of the article in order to get a sense of the scope and importance of the paper (*18*), while Jensen and coworkers used a title and abstract writing assignment to teach students to read and comprehend journal articles in organic chemistry (*19*). Pence used RSS feeds of *Inorganic Chemistry* ASAP articles to teach students best practices in reading research articles. Each week, she taught students how best to read a specific section of a journal article (abstract, figures, discussion, etc.) and then assigned homework that required the students to locate the answers to questions in the corresponding section of an article from that week's feed (*20*). Finally, MacMillan and Shaw tackled the complicated issue of familiarizing students with the patent literature, requiring students to locate patents on a topic assigned to them and giving them the opportunity to use the patent information alongside other sources of information in their written work (*21*).

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"Information Has Value"

> *Information possesses several dimensions of value, including as a commodity, as a means of education, as a means to influence, and as a means of negotiating and understanding the world. Legal and socioeconomic interests influence information production and dissemination (13).*

This frame begins to address the complex and esoteric area of the "economics of information." Many students' access to information, particularly at large research institutions, has become easy and seamless. A student using an Internet-connected device on his or her college campus can type a few words into a search engine and quickly retrieve a vast array of information, ranging from researchers' interests or opinions stated on their personal Web sites to excellent peer-reviewed articles on a topic. Because he or she has not paid any money for the information at the time of the transaction, it is tempting for the student to view the information as being "free." Even more seasoned academics can fall into this trap; Van Noorden states, "The [journal] subscriptions tend to be paid for by campus libraries, and few individual scientists see the costs directly. From their perspective, publication is effectively free (*22*)."Libraries have done a great deal to counteract this assumption, including adding institutional branding to journal and database Web sites, but it is still important to remind students that, in order for the information to be accessible, somebody somewhere must have paid something. That cost could be paid by individuals wishing to read the article or individuals wishing to publish the article. It could come from a grant or from advertising. Knowing the source of the revenue stream that funded the information can also help students to evaluate the information, as financial interests can frequently be a source of bias in information sources.

Students of chemistry are frequently flabbergasted when they learn the prices of some of their favorite journals and databases, but sharing these facts with them and hypothesizing reasons behind the high prices of chemical information is important to their understanding of their science and may inform their future publication practices. Recent articles have postulated that contributing factors in the high prices and dramatic price increases of scientific journals include the practice of journal "bundling" and the fact that a large percentage of journals are published by a very small number of publishing houses (*23*). The latter issue is a particular problem in chemistry, where the percentage of articles published by the five largest chemistry publishers (Reed-Elsevier, Wiley-Blackwell, Taylor & Francis, Springer, and the American Chemical Society) has increased from about 40% of all chemistry articles during the mid 1970s to about 70% by the early 2010s (*24*). The chemical sciences discourage dual publication, the publication of the same material in multiple settings, which is also known as "self-plagiarism" or "text recycling," and each journal becomes a monopoly because it is the only place where a scientist can access a particular fact, interpretation, or experimental technique. Larivière and coworkers state, "each journal has the monopoly on the scientific content of papers it publishes: paper A published in journal Y is not an alternative to paper B published in journal Z" (*24*). This policy is known as the

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Ingelfinger rule, as a result of a high-profile 1969 editorial from *The New England Journal of Medicine*, attributed to Franz J. Ingelfinger and entitled "Definition of 'Sole Contribution'":

> *Papers are submitted to the* Journal *with the understanding that they, or their essential substance, have been neither published nor submitted elsewhere (including news media and controlled circulation publications). This restriction does not apply to (a) abstracts published in connection with meetings, or (b) press reports resulting from formal and public oral presentation (25).*

The more important the discoveries a journal publishes, the more value that journal will have to the research community. The chemical journal literature, then, is a commodity whose price reflects what the market is willing to pay for it. An interesting 2002 statement by the Office of Fair Trading in the UK, describing the findings from a report that they had published in mid 2001, indicated the following.

> *The Report found that price competition is not a dominant feature of the market. Many journals have a particular reputation or specific focus in the subject matter that they cover, and there is often an unwillingness of researchers or institutions to substitute a cheaper journal. The price sensitivity of demand for many journals is thus very low and journals are generally perceived as competing on quality rather than price. Certain journals can even be regarded as markets in their own right, due to the lack of demand substitutability (26).*

One could, then, hypothesize that prices of chemistry journals may also be affected by the presence of a large, robust, and wealthy chemical industry whose research and development scientists also require access to journal literature.

The information contained within individual articles has a value in and of itself that is even less easily quantified. The prominent chemist Frank Westheimer is credited with the statement, "Why spend a day in the library when you can learn the same thing by working in the laboratory for a month?" (*27*), a quotation frequently used and abused by chemistry librarians and chemists attempting to exhort their students to spend time doing background reading before "hitting the lab." However overused it may be, the quotation is very useful in approaching the financial value of chemical information. Assume that a chemist spends a month in the laboratory, running twenty-five failed reactions before finally arriving at a solution to a synthetic puzzle. The cost of that solution would include the cost of the chemist's salary for the month, the cost of chemicals, and the costs associated with running the equipment needed to perform the necessary reactions and characterizations, all of which could be extremely high. Now assume that the chemist has spent a day in the library searching and reading the literature, finds a published synthesis that can be adapted to the substrate at hand, and achieves a reasonable result after running only three reactions over the course of two days. The cost of this solution is much lower, even when one considers the costs associated with the database searches and journal articles read. Therefore, the

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value of a good library and effective information retrieval skills is extremely high in an expensive and potentially dangerous scientific field like chemistry.

Finally, it is important for students to understand that not all useful information is published in the journal literature; the patent literature also presents a wealth of novel findings that may interest chemists. Unlike journal articles, however, the purpose of a patent is to *exclude* others from using the material protected in its claims, giving the rights holder a chance to monetize the invention. Although the patent documents are free to read, they are more indicative of science that one is *not* allowed to use freely, rather than science that one may employ at will; thus, patents make their own contribution to the complexity of the economics of chemistry and chemical information.

In addition to referring to the intrinsic value of the literature, this frame also deals with the ethics of using and reusing information, and the knowledge practices and dispositions within it include many skills relating to an understanding of how to use the work of others in a responsible and ethical fashion. As such, it is related to the following SLA DCHE/ACS CINF competencies:

- Part 1. Big Picture…, Section 1.2 "Scientific Literature"
    - *g) Understand scientific ethics and accountability and have an awareness of intellectual property issues and developments in scholarly communications including those affecting author's rights, the use of copyrighted materials in research and instruction, and open-access initiatives related to the scientific literature (11)*
- Part 4. "Scientific Communication and Ethical Conduct"
    - *4.2 ETHICAL CONDUCT: Chemistry undergraduates should learn the professional standards of chemists as articulated in the ACS "Chemist's Code" and in relevant works on scientific ethics; understand that science is filled with ethical judgments; recognize the ethical component of complex situations; and analyze complex ethical problems and design appropriate solutions (11).*

Research and publication ethics is becoming an increasingly important aspect of information literacy. The National Academy of Science's publication *On Being a Scientist* (*28*) and Francis Macrina's *Scientific Integrity: Text and Cases in Responsible Conduct of Research*, now in its fourth edition (*29*) have many useful case studies that can serve as starting points when holding class discussions around research and publication ethics. While librarians have historically taught students to avoid plagiarism, the fact that it is so easy to use and reuse published information means that students will frequently copy and paste material, particularly non-textual material, directly from its source to their work without thinking about whether or not they need permission to do so. Individuals teaching information literacy need to go beyond teaching students to cite sources

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and to impress upon them the need to request and receive permission to reuse and adapt the work of others, as well as their own published work if they have transferred copyright to a publisher. This topic can be introduced at the same time as the economics of information because it also deals with the concept of dual publication.

There are several examples of the teaching of research ethics in chemical information courses. Hollenbeck and coworkers described a restructuring of an organic chemistry laboratory course in 2006. In addition to revamping the laboratory part of the course, they turned it into a writing-intensive course, incorporating instruction for students in writing chemistry research papers. This included a discussion of responsible conduct of research, in which the students examined two case studies relevant to work in both the teaching and research laboratories (*30*). Fakayode briefly mentions training students in "ethics in research, scientific writing, and plagiarism" to students in an analytical laboratory course run under the GILEs ("guided-inquiry laboratory experiments") model (*31*). Jones and Seybold examined ethical breaches in scientific publication during two sessions of their semester-long undergraduate professional skills course. Like Hollenbeck and coworkers, they examine case studies surrounding unethical publishing practices and then try to write a series of rules that would have helped the perpetrator to avoid the predicament in which he or she landed, finally comparing these rules to published ethical guidelines (*16*). Currano implemented a two-class segment dealing with the ethics of scientific communication in her graduate-level chemical information course, requiring the students to complete the CITI Responsible Conduct of Research modules as homework for the ethics classes (*32*). This served a dual purpose; students receive a base-line education in research ethics, and, as completion of the CITI modules are required for any researcher working under an NSF or NIH grant, they complete their university-mandated ethics trainings prior to entering a research laboratory.

"Research as Inquiry"

> *Research is iterative and depends upon asking increasingly complex or new questions whose answers in turn develop additional questions or lines of inquiry in any field (13).*

The first part of the research process is generating an idea and converting it into a compelling research question. This has, historically, been in the domain of the subject expert, who teaches students the ways in which to think within their discipline, demonstrates the types of questions that can be asked and answered, and, thus opens the door for creative thought on the part of the students. The education literature is replete with examples of assignments that allow students to do more than simply regurgitate information learned. These activities encourage students to produce interesting output and challenge them to think about their subject the way a practitioner would. The recent move towards inquiry-based learning has led many instructors of both laboratory courses and traditional chemistry lecture courses to consider methods of using exploration and experimentation to teach students the necessary material. This trend lends

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itself well to the inclusion of information-intensive assignments, with students not only learning to search the scientific literature, but also to apply the retrieved information to chemical problems. This is most closely aligned to the following SLA DCHE/ACS CINF competency:

- Part 1. Big Picture…, Section 1.2. "Scientific Literature"
    - o *e) Demonstrate critical thinking by evaluating information, drawing conclusions from the literature, and following a logical path of inquiry (11).*

Clearly, information found outside of class textbooks and laboratory manuals is needed to help generate and develop these research questions. General background reading from books or encyclopedia articles can help inspire an area of research interest. Once the student has an idea of what he or she wants to learn and has articulated a statement of research purpose, the next step is to break that statement into its constituent concepts. This is not always as straightforward as the students might think; however, once it is accomplished, the student is left with a list of concepts to explore.

Bruehl and coworkers, writing in 2015 before the approval of the *Framework*, described the ways in which they consciously attempted to implement all of the previous ACRL information literacy competencies into a general chemistry laboratory course. Relevant to this frame, they adopted an inquiry-based model of learning across all aspects of the class, including information literacy. After learning to locate and read scientific literature, the students were asked to use the literature to design a new general chemistry experiment based on previously published experiments. This gave the students the opportunity to search the published literature, determine possible experimental designs, and then continue to use literature resources to perfect their design. The students tested and optimized their designs, and the unit culminated with written documentation for the experiment and an oral presentation to their peers (*33*).

More recently, Schultz and Li described the use of a problem-based learning (PBL) approach in an organic chemistry laboratory course and attempted to determine whether PBL experiments would, in the absence of traditional information retrieval instruction, teach information literacy skills. They determined that the PBL approach was best supplemented with some traditional information literacy training to help the students apply literature to chemical problems in a problem-based environment (*34*).

Loo used a blended traditional and Process Oriented Guided Inquiry Learning (POGIL) approach in a synthetic inorganic chemistry laboratory course. Instead of doing a "one-shot" training session, he created a POGIL worksheet that demonstrated the techniques that he wanted the students to learn and had them work through it in groups in a step-wise process. He required the students to work in groups to complete a number of tasks, all of which were designed to have them arrive at the learning objective. While the process was time-consuming for the instructor, he found it extremely effective in terms of student learning (*35*).

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"Scholarship as Conversation"

> *Communities of scholars, researchers, or professionals engage in sustained discourse with new insights and discoveries occurring over time as a result of varied perspectives and interpretations (13).*

Chemistry has some clearly defined realities, which are not open to much interpretation. A reaction either works or it does not work (although, occasionally, premature or fraudulent publication will indicate success when a reaction actually failed, or authors may inadvertently omit steps, leading readers to obtain results different than those described in the paper). Differences of opinion will, however, arise on the mechanism by which the reaction proceeded or the reasons for the observation of a particular phenomenon. Novice learners frequently lack the scientific expertise to determine the most likely explanation for such phenomena, so, it is important for them to counter this lack of experience with extensive reading. They should seek out a balanced view of a topic, trying to understand all possible angles as much as they can, and being careful to evaluate the sources of the facts that they are reading, as has already been described. With the ease of electronic self-publishing, students are able to make their own appropriate contributions to the field through blog postings, Wikipedia editing, Skype conversations in class with experts, and even posters on their own research presented at national meetings.

Stockman describes an interesting activity that could be used in upper-level chemistry courses, in which students are assigned journal articles as required reading. Over the course of a semester in two separate courses, he scheduled teleconferences or videoconferences with the authors of journal articles that the class had been required to read. The meetings took the form of conversations; students were required to read and discuss the article prior to the start of the sessions with the authors, and the instructor allowed the conversations to be steered by the students' individual questions (*36*). Four years earlier, Hamstra and coauthors describe a similar activity that mingled blogging and Web conferencing; upper-level students attended live Webinars given by individuals in a variety of chemistry-related careers and were required to blog about the experience (*37*).

As has been mentioned in previous sections, many activities involving the integration of information skills into chemistry courses involve some form of written or oral output: a laboratory report, a presentation to peers, a term project. However, Walker and Li describe a slightly different way in which students can contribute to the scholarly conversation. By editing Wikipedia articles about chemistry, students are able to make their work available to the rest of the scientific community and the broader world. Walker and Li identify four benefits to the students of Wikipedia editing over a traditional term paper, the last two of which are:

> (3) Interacting with classmates and peer editors on Wikipedia around the world during the information creation process;
> (4) Presenting an opportunity to make information they created available to the world instantly (*38*).

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Prior to making their articles available to the rest of the world, the students review one another's work, allowing them internal, as well as external, conversations (*38*).

This frame also reflects the need to stay up-to-date in one's field of study, which is challenging for everyone, even seasoned researchers, given the proliferation of information that began in the latter half of the twentieth century (*39*). The use of repeated and targeted searching can be useful, and the search alerts features of many of the chemical information resources can make this much easier. However, targeted searches, while being useful when approaching a particular project, can lead one to a "tunnel vision" problem, in which one becomes so focused on literature related to the problem at hand that one overlooks other interesting articles that, while not being related to the current research, will inform later projects or developments. The presentation of today's e-journals on a computer does not lend itself to browsing, but many of the mobile displays do allow individuals to swipe vertically to browse an individual article and horizontally to move to the next article in the issue (*39*). Even with increased ability to browse, though, the proliferation of journal titles makes it difficult for anyone, particularly a student, to stay up-to-date with the literature by browsing one's favorite journals. Interesting updates can be found in trade magazines like *Chemical & Engineering News*; news items in scholarly journals like *Science* and *Nature*; daily newspaper science sections, particularly the *New York Times* science section; and, surprisingly social media streams like Facebook, LinkedIn, and Twitter. Students at major research institutions can also take advantage of the many departmental seminars and symposia offered by their chemistry departments, as well as meetings of local sections of the American Chemical Society and any ACS national and regional meetings that occur locally. Developing current awareness skills and beginning to network with senior scientists as an undergraduate will go a long way to becoming a successful professional chemist.

"Searching as Strategic Exploration"

> *Searching for information is often nonlinear and iterative, requiring the evaluation of a range of information sources and the mental flexibility to pursue alternate avenues as new understanding develops (13).*

This frame encapsulates everything that usually comes to mind when one hears the words "chemical information education." It begins with the identification of information need, already discussed in a previous frame, and aligns with the entirety of Section 2, "The Chemical Literature", and Section 3, "Properties, Spectra, Crystallographic, and Safety Information", of the SLA DCHE/ACS CINF Competencies (*11*). It is important to note, however, that search skills should represent only one aspect of learning to locate information. This frame also focuses on the need to select appropriate sources and types of information based on the research question itself. This may include information presented in the popular press; through the legal, regulatory, and business literature; and through the Web sites of companies and interest groups (*14*).

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The literature is burgeoning with examples of how students can be taught information selection and retrieval skills in the course of their work, and only a few recent, representative examples are presented here. Tomaszewski describes a search strategy that he calls the "Imploded Boolean Search," in which he teaches students to intersect the reference results from search sets that were the products of three different types of search; the first is the result of a search for a chemical or a reaction, the second uses a numeric value, and the third is a basic keyword search (*40*). This teaches the students to think creatively about information retrieval and offers some possibilities for refining overly large result sets. In a previous article, he presented an interesting case study, in which a librarian was present during two lab sessions in an undergraduate laboratory course. Students were able to ask point-of-need search questions and receive immediate assistance (*41*). Swoger and Helms presented an exercise in which students were introduced to the structure of the chemical literature and then dove into an information retrieval exercise using SciFinder (*42*). Jacobs and coauthors describe development a virtual delivery of chemical information retrieval techniques, which then freed class time for other activities (*43*).

Conclusions

The *Framework for Information Literacy for Higher Education*, adopted by ACRL in January 2016, marks a subtly different approach to information literacy than that found in previous standards. As it states in its first appendix, "The frames are intended to demonstrate the contrast in thinking between *novice learner* and *expert* in a specific area; movement may take place over the course of a student's academic career" (*13*). ACRL recommends the integration of competencies embodied by the frames throughout the students' curricula, rather than as single, one-shot information literacy sessions. This argues for a concerted approach to integrating information literacy in the curriculum.

The SLA DCHE/ACS CINF *Information Competencies for Chemistry Undergraduates* do an excellent job of describing all of the information skills that students need to learn over the course of their undergraduate chemistry degree programs and, therefore, embody the spirit of the new *Framework*. The challenge, therefore, is to figure out ways to integrate the chemical information literacy skills laid out in the SLA DCHE/ACS CINF document in a way that allows students to build on previously-learned material without being redundant. A recently published example by Yeagley and coworkers presents a cohesive program of study that they refer to as a "stepping stone approach" (*44*). They begin with "stepping stone" courses that give students a guided introduction to the literature and proceed to "bridging courses," which require students to begin to use literature in support of pre-defined areas of their work in the teaching laboratory. The program concludes with the "capstone" courses, in which students are emulating the information seeking behaviors of research chemists, developing their own theses and performing literature research that is then reviewed by peers and instructors (*44*).

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The easiest way to implement the *Framework* across the chemistry curriculum would be to have a single individual or group monitoring the different tasks and skills used in various classes. This could be the chemistry or science librarian, or it could be the job of the chemistry department's curriculum committee. Whatever the case, the key to the matter is communication. Instructors should converse regularly about the novel educational experiments that they are implementing in their classes and the level of expectations that they have of students entering their class, and members of the faculty should recognize and take advantage of the expertise of their subject librarians, who can recommend and teach the students techniques that will support their work in the classroom and the lab, while preparing them to become tomorrow's chemists.

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References

1. Segments have been excerpted, with permission, from the following ACRL documents, which are protected by Creative Commons Non-Commercial Share-Alike licenses: Presidential Committee on Information Literacy: Final Report; Information Literacy Competency Standards for Higher Education; Information Literacy Standards for Science and Engineering/Technology; and Framework for Information Literacy for Higher Education. The excerpts are cited and italicized for ease of identification.
2. While similar searches were performed in other indexing and abstracting services, the Scopus search is presented here because Scopus, an extensive, multidisciplinary database, yielded the largest body of relevant results.
3. In actuality, there is one Scopus result from 1975 but upon closer inspection it turns out to be a false hit.
4. Trauth, E. M. In *Information literacy course: A recommended approach*; Bonnette, D., Ed.; National Educational Computing Conference 1983, Baltimore, MD, June 6−8, 1983; Computer Society Press: Baltimore, MD, 1983.
5. Association of College and Research Libraries. *Presidential Committee on Information Literacy: Final Report* [Online]; 1989; http://www.ala.org/acrl/publications/whitepapers/presidential (accessed April 27, 2016).
6. Association of College and Research Libraries. *Information Literacy Competency Standards for Higher Education* [Online]; 2000; http://www.ala.org/acrl/standards/informationliteracycompetency (accessed September 19, 2016).
7. ALA/ACRL/STS Task Force on Information Literacy for Science and Technology. *Information Literacy Standards for Science and Engineering/Technology* [Online]; 2006; http://www.ala.org/acrl/standards/infolitscitech (accessed April 26, 2016).
8. American Chemical Society Committee on Professional Training. *Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs* [Online]; American Chemical Society: Washington, DC, 2015; http://www.acs.org/content/

dam/acsorg/about/governance/committees/training/2015-acs-guidelines-for-bachelors-degree-programs.pdf (accessed April 26, 2016).
9. American Chemical Society Committee on Professional Training. *Chemical Information Skills*; http://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/chemical-information-skills.pdf (accessed April 27).
10. Somerville, A. N. Perspectives and criteria for chemical information instruction. *J. Chem. Inf. Comput. Sci*. **1990**, *30*, 177.
11. Special Libraries Association Chemistry Division; American Chemical Society Division of Chemical Information. *Information Competencies for Chemistry Undergraduates: The Elements of Information Literacy*, 2nd ed. [Online]; 2011; http://chemistry.sla.org/wp-content/uploads/cheminfolit.pdf (accessed April 27, 2016).
12. *The Chemical Information Special Issue of the Journal of Chemical Education* is v.93 n.3, from March 8, 2016.
13. Association of College and Research Libraries. *Framework for information literacy for higher education* [Online]; 2015; http://www.ala.org/acrl/standards/ilframework (accessed April 26, 2016).
14. Currano, J. N.; Foster, K. R. Hunting and Gathering: Locating and Evaluating Information on the Cusp between Science and Legislation. In *Science and the Law: Analytical Data in Support of Regulation in Health, Food, and the Environment*; ACS Symposium Series 1167; American Chemical Society: Washington, DC, 2014; p 13.
15. Miller, D. M.; Czegan, D. A. C. Integrating the Liberal Arts and Chemistry: A Series of General Chemistry Assignments To Develop Science Literacy. *J. Chem. Educ*. **2016**, *93*, 864.
16. Jones, M. L. B.; Seybold, P. G. Combining Chemical Information Literacy, Communication Skills, Career Preparation, Ethics, and Peer Review in a Team-Taught Chemistry Course. *J. Chem. Educ*. **2016**, *93*, 439.
17. Zwicky, D. A.; Hands, M. D. The Effect of Peer Review on Information Literacy Outcomes in a Chemical Literature Course. *J. Chem. Educ*. **2016**, *93*, 477.
18. Greco, G. E. Chemical Information Literacy at a Liberal Arts College. *J. Chem. Educ*. **2016**, *93*, 429.
19. Jensen, D., Jr.; Narske, R.; Ghinazzi, C. Beyond Chemical Literature: Developing Skills for Chemical Research Literacy. *J. Chem. Educ*. **2010**, *87*, 700.
20. (a) Pence, L. E.; Pence, H. E. *RSS and social tagging: On the desktop and in the classroom*; presented at 233rd ACS National Meeting Chicago, IL, United States, March 25-29, 2007; CHED 020. (b) Petkewich, R. New Education Tools. *Chem. Eng. News* **2007**, *85*, 44.
21. MacMillan, M.; Shaw, L. Teaching Chemistry Students How To Use Patent Databases and Glean Patent Information. *J. Chem. Educ*. **2008**, *85*, 997.
22. Van Noorden, R. The true cost of science publishing. *Nature* **2013**, *495*, 426.
23. (a). Origgi, G.; Ramello, G. B. Current Dynamics of Scholarly Publishing. *Eval. Rev*. **2015**, *39*, 3. (b). Volkmann, U.; Schimank, U.; Rost, M. Two

Worlds of Academic Publishing: Chemistry and German Sociology in Comparison. *Minerva* **2014**, *52*, 187.
24. Larivière, V.; Haustein, S.; Mongeon, P. The Oligopoly of Academic Publishers in the Digital Era. *PLoS One* **2015**, *10*, e0127502.
25. Definition of Sole Contribution. *N. Engl. J. Med.* **1969**, *281*, 676.
26. Office of Fair Trading. *The market for scientific, technical, and medical journals: A statement by the OFT*; OFT396; UK, September, 2002; http://www.econ.ucsb.edu/~tedb/Journals/oft396.pdf (accessed July 11, 2016).
27. Corey, E. J.; Frank, H. Westheimer, major figure in 20th century chemistry, dies at 95. *Harvard Gazette* **2007**April19.
28. National Academy of Sciences National Academy of Engineering and Institute of Medicine of the National Academies. *On Being a Scientist: A Guide to Responsible Conduct in Research*, 3rd ed.; National Academies Press: Washington, DC, 2009.
29. Macrina, F. L. *Scientific Integrity: Text and Cases in Responsible Conduct of Research*, 4th ed.; ASM Press: Washington, DC, 2014.
30. Hollenbeck, J. J.; Wixson, E. N.; Geske, G. D.; Dodge, M. W.; Tseng, T. A.; Clauss, A. D.; Blackwell, H. E. A New Model for Transitioning Students from the Undergraduate Teaching Laboratory to the Research Laboratory. The Evolution of an Intermediate Organic Synthesis Laboratory Course. *J. Chem. Educ.* **2006**, *83*, 1835.
31. Fakayode, S. O. Guided-inquiry laboratory experiments in the analytical chemistry laboratory curriculum. *Anal. Bioanal. Chem.* **2014**, *406*, 1267.
32. Currano, J. N. Introducing Graduate Students to the Chemical Information Landscape: The Ongoing Evolution of a Graduate-Level Chemical Information Course. *J. Chem. Educ.* **2016**, *93*, 488.
33. Bruehl, M.; Pan, D.; Ferrer-Vinent, I. J. Demystifying the Chemistry Literature: Building Information Literacy in First-Year Chemistry Students through Student-Centered Learning and Experiment Design. *J. Chem. Educ.* **2015**, *92*, 52.
34. Shultz, G. V.; Li, Y. Student Development of Information Literacy Skills during Problem-Based Organic Chemistry Laboratory Experiments. *J. Chem. Educ.* **2016**, *93*, 413.
35. Loo, J. L. Guided and Team-Based Learning for Chemical Information Literacy. *J. Acad. Libr.* **2013**, *39*, 252.
36. Stockman, B. J. Student-Led Engagement of Journal Article Authors in the Classroom Using Web-Based Videoconferencing. *J. Chem. Educ.* **2015**, *92*, 120.
37. Hamstra, D.; Kemsley, J. N.; Murray, D. H.; Randall, D. W. Integrating Webinar and Blogging Technologies into Chemistry Seminar. *J. Chem. Educ.* **2011**, *88*, 1085.
38. Walker, M. A.; Li, Y. Improving Information Literacy Skills through Learning To Use and Edit Wikipedia: A Chemistry Perspective. *J. Chem. Educ.* **2016**, *93*, 509.
39. Currano, J. N. Maintaining a Sustainable Scholarly Record. In *Teaching and Learning about Sustainability*; ACS Symposium Series 1205; American Chemical Society: Washington, DC, 2015; p 163.

40. Tomaszewski, R. The Concept of the Imploded Boolean Search: A Case Study with Undergraduate Chemistry Students. *J. Chem. Educ.* **2016**, *93*, 527.
41. Tomaszewski, R. A Science Librarian in the Laboratory: A Case Study. *J. Chem. Educ.* **2011**, *88*, 755.
42. Swoger, B. J. M.; Helms, E. An Organic Chemistry Exercise in Information Literacy Using SciFinder. *J. Chem. Educ.* **2015**, *92*, 668.
43. Jacobs, D. L.; Dalal, H. A.; Dawson, P. H. Integrating Chemical Information Instruction into the Chemistry Curriculum on Borrowed Time: The Multiyear Development and Evolution of a Virtual Instructional Tutorial. *J. Chem. Educ.* **2016**, *93*, 452.
44. Yeagley, A. A.; Porter, S. E. G.; Rhoten, M. C.; Topham, B. J. The Stepping Stone Approach to Teaching Chemical Information Skills. *J. Chem. Educ.* **2016**, *93*, 423.

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Chapter 2

Building Data and Information Literacy in the Undergraduate Chemistry Curriculum

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The Literature and Seminar sequence at James Madison University has been used to develop the chemistry information literacy skills of chemistry majors for over four decades. These courses have been continually updated to emphasize information literacy skills for the twenty-first century. This chapter describes the methods that have been developed to improve chemical, data and general information literacy at a large, public, primarily undergraduate institution. The focus of the first semester course, described in this chapter, is on skill building rather than teaching specific resources. It is a model of integration and collaboration between chemistry faculty and chemistry librarians. Changes in information resources, disciplinary standards, and assessment are used to inform and refine course instruction. While implementation of a course is always unique because of the size, curricular structure, culture, and students associated with an institution, we think that the approach described herein will be applicable to other programs.

Introduction

Chemistry is a discipline that requires knowledge of a diverse range of skills and content. Much of the focus of undergraduate preparation is on the development of content knowledge and laboratory skills. However, chemistry graduates need to master many more skills. A critical competence is the mastery of chemical literature and information management skills, which are outlined in the 2015 American Chemical Society Committee on Professional Training (ACS CPT) Guidelines for undergraduate chemistry programs (Student Skills).

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Essential student skills include the ability to retrieve information efficiently and effectively by searching the chemical literature, evaluate technical articles critically, and manage many types of chemical information. Students must be instructed in effective methods for performing and assessing the quality of searches using keywords, authors, abstracts, citations, patents, and structures/substructures…. Students' ability to read, analyze, interpret, and cite the chemical literature as applied to answering chemical questions should be assessed throughout the curriculum. Instruction should also be provided in data management and archiving, record keeping (electronic and otherwise), and managing citations and related information (1).

Chemical information is highly structured and organized, and encompasses diverse materials ranging from property information, protocols, and analyses to articles in the primary, patent, and review literature. Increasingly, the definition of scholarly information is expanding beyond the traditional scientific literature to include nontraditional products, such as data. The guidelines developed by the ACS CPT and the Information Competencies for Chemistry Undergraduates (*2*), developed by the Special Libraries Association Chemistry Division (SLA DCHE) and the ACS Division of Chemical Information (ACS CINF), help to ensure that bachelor's level students have the basic skills needed to find and use the chemical literature effectively. The Information Competencies for Chemistry Undergraduates that are a major focus of the course described in this chapter are summarized below; other competencies can be found online (*2*).

Competency 1.1 - Library Use. Students should…

- understand the organization of the library and know how to use library tools and library services to obtain desired information and references;
- understand the purpose and characteristics of different information-finding tools, e.g. catalogs, indexing and abstracting databases, subject guides, and web search engines, and choose appropriate tools for a particular information need; and
- request help from librarians, faculty, and teaching assistants when needed and consult online training materials when available.

Competency 1.2 - Scientific Literature. Students should…

- understand the flow of scientific information, and how information is communicated among scientists, both formally and informally;
- understand the nature and purpose of different types of scientific literature, including journals, magazines, patents, proceedings, dissertations, monographs, handbooks, encyclopedias and dictionaries, grey literature, and technical reports;
- be able to read and interpret citations for the different types of scientific literature;
- understand and apply criteria for evaluating the authority and appropriateness of a document or information source;

- demonstrate critical thinking by evaluating information, drawing conclusions from the literature, and following a logical path of inquiry;
- understand the general nature of the peer review process; and
- understand scientific ethics and accountability and have an awareness of intellectual property issues and developments in scholarly communications including those affecting author's rights, the use of copyrighted materials in research and instruction, and open-access initiatives related to the scientific literature.

Competency 2.1 - Background Information. Students should…

- know how to find chemistry-specific sources of background information such as encyclopedias, treatises, compiled works, and review articles.

Competency 2.2 - Articles and Other Chemical Literature. Students should…

- be able to identify and obtain various types of scientific literature.

Competency 2.4 - Chemical Substances, Reactions and Syntheses. Students should…

- have an understanding of the unique features of chemical literature, and be able to use these unique features to find needed information.

Competency 4.1 - Scientific Communication. Students should…

- be aware of the different methods for presenting research;
- understand the reasons for citing the literature in one's own writing;
- demonstrate the ability to cite using appropriate formatting and standard abbreviations; and
- be familiar with software that allows for storing, managing, and formatting bibliographic references or citations.

Competency 4.2 - Ethical Conduct. Students should…

- learn the professional standards of chemists as articulated in the ACS "Chemist's Code" and in relevant works on scientific ethics;
- understand that science is filled with ethical judgments;
- recognize the ethical component of complex situations; and
- analyze complex ethical problems and design appropriate solutions.

Information literacy has been incorporated into professional standards across many scientific disciplines, and specific guidelines have been adopted in chemistry and engineering (*3*). Multiple approaches have been used to build information literacy skills in the chemistry curriculum. Increasingly, activities related to chemical information literacy have moved from the resource or tool-based arena towards skill building and application. As recently as 2010, a retrospective of

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chemical information literacy was focused entirely on resources and collections rather than classroom activities (*4*). While there are examples in the literature of student engagement and chemical information literacy prior to 2010 (*5–9*), most of published work occurs after this time (*10–48*).

Some instructional strategies have focused primarily on tool use and proficiency, such as the effective use of SciFinder, Scopus or patent databases (*12*, *16*, *22*, *30*, *41*, *49*). These articles are helpful resources to learn more about exercise design and the impact of scientific literature instruction with respect to student performance. Other articles show how information literacy can be introduced in the laboratory setting (*9*, *14*, *21*, *25*, *28*). Recognizing the quantity of chemical literature available and the difficulty of building the skills required to find and use it effectively, some programs have approached chemical information literacy in a sequenced or scaffolded fashion (*10*, *13*, *15*, *17*, *20*, *26–28*) or treat information literacy in a stand-alone course (*11*, *18*, *27*, *29*, *34*, *35*). Given that the natural "home" for this content straddles two domains, chemistry and library science, it is not unusual to see some level of collaboration between the chemistry faculty and chemistry librarians when developing courses or activities (*10*, *12*, *14*, *15*, *18–20*, *29*, *30*, *32*, *38*). While many of these research literature courses can be taught by the chemistry faculty alone, the rapidly changing nature of information sources and data information literacy make the co-teaching model with a chemistry librarian especially attractive.

While faculty have effective strategies for keeping up to date in their field, they are not always aware of the changes in the information landscape, particularly those that are outside of their research and teaching domains. Librarians often become aware of these changes and trends in information science, particularly those that are outside of a faculty member's core discipline, and can educate faculty about emerging trends and changing standards. Recent changes, for example, may require faculty to develop data management plans before submitting grant proposals and to register for unique persistent identifiers provided by communities such as ORCID – Open Researcher and Contributor ID (*50*) before submitting research articles.

Data information literacy (DIL) is an emerging area within librarianship and scientific disciplines. Data information literacy is a relatively new term in librarianship and has not achieved the same penetration in the profession, let alone outside it, as information literacy. Carlson et al. define DIL as merging "the concepts of researcher-as-producer and researcher-as-consumer" (*51*). While this may seem important only in the research sphere, it is critical that undergraduates have at least some exposure to these ideas because many will have careers in fields where fluency in working with data will be an important skill and asset. In addition to developing chemical information literacy skills students must develop data information literacy skills. Twelve competencies associated with DIL were created by the Data Information Literacy Project, an Institute of Museum and Library Services (IMLS) grant-funded initiative. They investigated the DIL needs of researchers and developed a curriculum to address those needs (*51*). The competencies include *cultures of practice, data management and organization, data curation and reuse, ethics and attribution*, *data conversion and interoperability, metadata, data preservation, data processing and analysis,*

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data quality and documentation, data visualization and representation, databases and data formats, and *discovery and acquisition of data* (*51*).

Understanding how to manage the data that one produces, while also recognizing how to find and use data effectively and ethically, is an activity that is seldom formally taught (*51*). Some research communities, like the crystallography community, have a long history of sharing data, and working towards standard formats and filetypes, and training community members to make data easily sharable (*52–55*). Until recently, this has been the exception rather than the rule. With the increase in collaborative or large-scale projects that require some level of data sharing and mandates from federal funding agencies for data management plans, data management has become a critical skill in chemistry. Data producers need training in data information literacy.

While ACS CPT specifies only data management in its guidelines, a basic awareness of DIL concepts provides a foundation for the students to build upon as they continue their studies or begin their careers. This is clearly a growing area in chemistry. Within ACS, there has been an increased focus on data as evidenced by the ACS Division of Chemical Information technical sessions at the Spring 2016 National Meeting. Session titles include "Chemistry, Data, & the Semantic Web: An Important Triple to Advance Science," "Driving Change: Impact of Funders on the Research Data & Publications," and "Global Initiatives in Research Data Management & Discovery" and include cosponsors from the Division of Medicinal Chemistry and the Division of Computers in Chemistry, among others (*56*).

Chemistry and librarian faculty who have established teaching relationships have an opportunity to weave elements of data information literacy into the curriculum. Recognizing the professional and scholarly value of information, including data as a resource, we have modified our course to include more elements of data information literacy, particularly data management, reuse, and the research lifecycle. Introducing undergraduate students to the concept of data as a scholarly product can be a challenge since not all of them have been involved in a research experience and have not encountered data "in the wild." In this chapter, we will describe how we weave chemical information literacy and data information literacy into the course that we teach, how we have modified instructional styles to address the skills that our students already have, and the challenges of introducing these ideas to undergraduate students.

Challenges Uncovered through Course Assessment - Observations on Our Information Seekers

Information Literacy Instruction at James Madison University

James Madison University (JMU) is a large, master's comprehensive public university in Virginia. As of 2015, 91% of the student population of over 20,000 was undergraduate (*57*). The Chemistry and Biochemistry department at JMU is an undergraduate degree-granting department, which graduates between 30-45 majors each year. For over four decades, the department has required chemistry majors to complete a pair of independent courses that focus on the chemical literature, Literature and Seminar (Lit&Sem) I and II. Each course lasts for one 14-week semester and students are advised to take these courses in consecutive semesters after completing two foundation level chemistry courses (*1*); students usually take this course during the junior year. Lit&Sem I currently meets for 90 minutes each week and requires that students attend seminar outside of class. Students must take the course for a letter grade. Lit@Sem I is co-taught by a chemistry faculty member and a science librarian; the chemistry faculty member assigned to the course does most of the course grading. Lit&Sem II is taught only by a chemistry faculty member, although students are encouraged to consult with the science librarian. Lit&Sem I focuses on methods of locating, reading, interpreting and organizing specific information from the chemical literature, and Lit&Sem II prepares students to present a literature-based seminar and paper on a topic in the chemical sciences. These courses also address professional ethics, developing a professional online presence, and career readiness. A course outline for Lit&Sem I is provided in Table 1 and a detailed syllabus can be found in the JMU institutional repository, JMU Scholarly Commons (*58*).

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Table 1. Course Outline for Literature and Seminar I

Week	*Class Topic*
1	Introduction to Literature & Seminar
2	Effective reading strategies
3	Identifying key findings
4	Summarizing and article and writing
5	Ethics
6	Finding information: General resources
7	Finding information: Scholarly databases (Scopus)
8	Data management
9	Finding information: Scholarly databases (SciFinder)
10	Finding information: Scholarly databases (PubMed and Patents)
11	Searching in action: Learning about new topics
12	Searching in action: Identifying and choosing resources
13	Searching in action: Identifying and choosing resources
14	Chemistry ILT (Information Literacy Test) and SALG (Student Assessment of Learning Gains)
15	Final exam

The ACS CPT guidelines have always driven instructional content in the Lit&Sem courses. These standards helped to provide guidance in determining outcomes both in Lit&Sem and in other courses in the curriculum. In the most recent guidelines (*1*), the ACS CPT identified problem solving skills, chemical literature and information management skills, laboratory safety skills, communication skills, team skills, and ethics as critical skills that students need beyond chemistry content knowledge. Lit&Sem I explicitly addresses chemical literature and information management skills, communication skills, team skills, and ethics.

Instruction Informed by Assessment

James Madison University and the Department of Chemistry and Biochemistry have a robust culture of assessment that helps identify performance trends and determine areas of need. We assess skills associated with information literacy every year using two in-house inventories: the Academic Skills Inventory (ASI) and the Chemistry Information Literacy Test (ILT). We also monitor performance on student assignments and exams and responses on the Student Assessment of Learning Gains (SALG) (*59*) in the Lit&Sem sequence to guide curricular changes. The ASI consists of 90 statements where students self-report whether they have a particular skill by choosing whether a statement that describes that skill applies to them. It asks students about skills that are specifically addressed in Lit&Sem including scientific communication (4 questions), interpersonal/team skills (1 question), ethics (4 questions), and information literacy skills (14 questions). The ASI is administered to all students at the start of their first year, second year, and a few months prior to graduation during a university-wide assessment day. Students show great gains in information literacy skills between their second year and their senior year.

The ILT is a major-specific information literacy test, developed with the chemistry librarian, to assess chemical information literacy knowledge at a more granular level. The ILT aligns with both the Association of College & Research Libraries Information Literacy Competency Standards for Higher Education (*60*) and the Information Competencies for Chemistry Undergraduates and includes questions about citations, appropriate sources of information, plagiarism, and information types. Each year, the results of the ILT undergo statistical analysis to identify areas of growth and need, although this can be a challenge with the relatively small sample size year after year (*18*). The ILT also includes a section on student-reported comfort levels with various search tools and information types. This section of the test is administered to first semester sophomores and then as a pre- and post-test in the Literature & Seminar sequence. From this data, we can localize where in the curriculum students are developing comfort with different search tools and we can determine learning trends as they relate to information literacy. The ILT and student results have been described previously (*18*).

The SALG (*59*) focuses on the degree to which a course has enabled student learning. Students assess and report on their own learning and on the degree to which specific aspects of the course have contributed to that learning. This instrument was customized to match Lit&Sem I and allows the instructors to ask about class-specific learning objectives and content delivery. The version of the SALG used in Lit&Sem I is freely available on the SALG site to registered users.

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To access the instrument, create a course, reuse a public SALG, and search for the instructor, course and semester (Reisner, CHEM 481, Fall 2015).

Changes in Course Delivery and Instruction Methods

For many of the past 15 years, Lit&Sem I was presented in lecture format. The instructors would *tell* students about the information competencies as defined by SLA DCHE/ACS CINF then have them complete activities that reinforced these competencies (*18*). By assessing student performance on the chemistry ILT and search assignments, we found that students developed the mechanics of searching via the tools (usually databases) but did not develop comprehensive and efficient information search strategies. Students did not think about how ideas relate to one another and what the purpose of a particular publication may be. Students also were not developing the skills to manage the information that they acquired, be it in the form of references, data, or annotations.

Course instructors observed that students could choose a tool to use, but did not necessarily choose the best tool. They were focused on task completion and defined success as obtaining a result, not necessarily a high quality result. They had a tendency to fall back to general information seeking skills, using Google or Wikipedia, with little attention to the reliability or quality of the resource. Even though they had seen research database resources in prior classes, they defaulted to strategies that they had been using since before college. They also tended not to question whether their search produced a reliable result or the best result. For many students, the search itself was superficial and success was defined as finding *something*. In this age of easy information access, students need to build the skills to search, filter and refine effectively. To do this, they need to develop critical reading and evaluation skills.

To address the apparent lack of both skill retention (from their earlier courses) and skill development, we shifted our approach to focus on developing critical reading, searching, evaluation, and data management skills. First, students must become critical and deep readers. They must be able to identify the components of a journal article and the key points from the paper so they can understand how research fits into the broader context. This is a key step to the development of effective and efficient search strategies. By developing critical reading skills the students can develop a framework from which to search. Once students recognize the depth of content in an article, with consideration to supplemental information and associated data, they are more inclined to switch to a specialized research database, away from general search tools like Google. With the large amounts of information to which they have access and are asked to process, students are receptive to adopt tools that help them manage the data, but it is still not a workflow that is ingrained in their default processes. These observations helped the instructors recognize that a different emphasis was needed in this course. To break poor research habits of students, the instructors changed the structure of the Lit&Sem class to emphasize the skill development rather than search tools use.

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(Re)Designing a Course To Improve Information Literacy in Chemistry

Changes in the structure of information resources and easier access to information resources had already had a major impact on how chemical information has been taught at JMU. Using several years of assessment data and personal experience, the Lit&Sem instructors decided that the course needed a radical revision. Lecture-based instruction was too didactic and hybrid or online deliveries did not perform well and were not embraced by the students (*18*). We came to the decision that more in-class time would allow for group activities and guided practice. Overcoming the disconnect between tool use and research and communication skill-building was not feasible in a 60 minute class. Upon consultation with the department head, the instructors secured 90 minutes of curricular time per week and moved the class into a flexible learning environment. This classroom was equipped with movable tables and chairs, multiple projection points, and dry-erase walls. Once the space and time were set, the instructors took a backwards design approach to the course redesign.

The first step in a backwards design approach is to determine the learning outcomes for the class (*61*). By consulting the SLA DCHE/ACS CINF competencies, the instructors developed a list of broad goals and associated specific outcomes (Table 2). Some of these concepts are covered in other chemistry courses. For example, ethics is covered in Biochemistry (CHEM 361) and preliminary literature searching is covered in the second semester of the sophomore lab, Integrated Inorganic/Organic Laboratory II (CHEM 288L). Rather than frame the instruction from prior coursework as redundant, the instructors recognized the value of repetition and of scaffolding the content, so that students could build upon previous knowledge and reinforce appropriate knowledge structures. The instructors were able to plan each week of class time to align with specific objectives and then determine the evidence and activities that the students would need to demonstrate and complete to help achieve those goals (*58*). Early on, we decided that one strategy to help meet those goals would be repetition. Students would use resources multiple times, to help create both comfort and habit. With repeated experience, we felt that students would be more likely to turn to these resources in the future. We also made a stronger effort to compare and contrast the tools throughout the semester, so that students could differentiate between and identify when to use each resource. The structure of the course, a summary of the assignment and how these assignments map onto specific learning objects can be found in JMU's Institutional Repository (*58*).

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Table 2. Course Goals for a Student Completing Literature and Seminar I

Course Learning GoalsA student should be able to…	***Specific Learning Objectives***
… discuss the structure of the chemical literature	• find an article from a citation in the chemical literature • recognize the purpose of a DOI • explain how information is communicated among scientists • explain the process, strengths, and limitations of peer review
… identify appropriate information sources	• identify the difference between peer-reviewed and non peer-reviewed articles • select high quality information sources
… use resources to find chemical information	• know the major chemistry databases & texts for finding chemical information • identify the best resources for starting a search • perform a comprehensive search on an author, molecule or topic • refine searches to target information • examine the relevance and importance of resources • find additional resources by following citations (in and to an article)
… manage chemical information	• recognize ethical practices for managing information • identify best practices for data management • develop strategies to keep current in chemistry
… understand technical articles	• list and define unknown vocabulary and ideas in a scientific article • restate the purpose and key findings of a scientific article • interpret data (what it says and what it does) • analyze a scientific article for the most important outcomes of the research study • create a short summary in clear and concise language • evaluate the quality of the research study
… communicate effectively using written language	• identify the relevance and application of the research • use formal written English • construct effective paragraphs • distill the most important ideas from a research article • distinguish between plagiarism, patchwork plagiarism and effective summarizing • construct an effective summary from research ideas and background • integrate content to tell an effective story • revise writing to improve structure, clarity, and story • evaluate the quality of written work (yours and your peers)

The course was built around new instructional space on campus which allowed us incorporate more group activities and peer instruction. The classrooms facilitate this teaching style because they feature flexible furniture, wall-to-wall writeable surfaces, multiple projection points and movable teaching stations. The classroom was laid out so there was no "front of the room" which shifted the focus from the instructors to the students. Instead, groups of four students faced each other. This focus on group activities and peer instruction meant that group dynamics became a part of both the physical and organizational (grading) structure of the class.

Because group work became an important element in the course, the instructors turned to the "CATME Smarter Teamwork" system (CATME) to implement best practices in building and implementing teams (*62*). CATME allows the students to input their schedules, preferred leadership style, language comfort levels, and any other information that would be helpful to know for group work and then groups the students together based on those inputs and any instructor criteria (group size, gender balance, etc…) (*63*). Using this software to group the students had two benefits: 1) the students felt that the groupings were intentional and there was less potential for schedule conflict and 2) the students were able to provide peer feedback to their groupmates regarding work contribution. We hoped that this would help the students feel more empowered by their membership and more motivated to be an equal contributor. CATME also provided students with accountability for and feedback on their performance as group members (*64*, *65*). Students assessed and received feedback from their peers near the midpoint and end of the semester.

To capitalize on the student-centered environment, we designed in-class activities and assignments that were in line with each week's objectives (*58*). Lecture was kept to a minimum. While some activities could be completed at home, much of the coursework was completed in class. We started each day with administrivia then moved to a warm-up activity exercise where students used the writable walls to note their opinions or knowledge about the topic of instruction. This helped students to activate their prior knowledge, identify content strengths and weaknesses, and allowed for some real-time tailoring of lecture instruction. After a detailed treatment of the subject, the groups then worked through 1-2 exercises, with time for discussion and debriefing after each exercise. At times, the students drove the discussion, building off one another's contributions, as well as offering dissent and opposing approaches.

Before students can use databases effectively, they need to develop critical reading, writing and analysis skills. Instruction and assignments in weeks 2-4 focused on these goals. Students read papers outside of class and prepared vocabulary lists and summarized paragraphs to help them master content. Through these activities, students engaged in informal writing. We analyzed the content of the articles through in class discussion and helped them to transition to formal writing by having them collaboratively write article summaries. Since revision is such an important part of the writing process, we had students revise group summaries individually and gave them additional opportunities to revise their own writing. Students gained additional practice with writing fluently by writing papers on eight science seminars that students were required to attend.

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By addressing reading, writing, and analysis skills early in the semester, the instructors believed that students would be less likely to use surface-level mechanical manipulation of databases to find literature. With this structure, students do not begin searching the literature until nearly halfway through the semester. The first time students formally used a research database to complete a task was week 7 (Table 1). By that time, students had practice identifying key ideas and determining how information in a paper relates to other papers. They were prepared to perform keyword searches and to understand why something was referenced or why a paper might be cited by others. The rest of the semester was devoted to developing expertise with specific databases (weeks 7, 9, and 10), improving searching techniques (weeks 7 and 9-13), and differentiating when to use different databases (weeks 12 and 13).

The next challenge in course design was to weave elements of data information literacy into the curriculum. Our goal was to introduce students to data management, reuse, and the research lifecycle. The focus on critical analysis early, and understanding of how science is communicated through the literature, helped set the stage for an in-depth session on data management. Data management is often associated with good laboratory practice and is most frequently taught in the curriculum through keeping notebooks in the teaching and research laboratories. However, students must also understand why it is important in the literature given the increase in data as a scholarly product, often as supplemental information. Lit&Sem provides a unique opportunity to introduce multiple concepts within the aforementioned data information literacy frame of *cultures of practice*. By delivering this content within the discipline, students can assimilate this information into other frameworks that have been built, such as ethics and information discovery. Throughout the course, students received information on the ethics, organization, discovery, and synthesis of information (usually in the form of journal articles, chemical structures, and other literature). Introducing the role of data in this ecosystem built upon that previous experience.

The instructors tried to find concrete representations of the abstract concept of research data, given that not all students participate in undergraduate research. The first effort, in 2012, used examples of personal photo collections or desktop file folders, which were too simplistic. Students rushed through the exercise and were not able to translate the naming protocols to the research environment (related to the *data management and organization* competency) when asked about it later (*51*). In subsequent years, the instructors utilized a hands-on group exercise where the students performed a card sort based on experimental data. Students renamed and organized a series of given files to improve their ability to find and identify appropriate files in the future (*27*). Part of the class period was also spent discussing media storage, archiving data, and file backup methods. It appeared that most undergraduates in the Lit&Sem classes had not thought about these ideas, but a passive lecture was not an ideal way to deliver abstract content. While the students could connect to the subject matter, the exercise was narrowly focused on file naming and file organization hierarchy. Upon assessment, some students noted "data management" as a skill that was learned, while others felt that it was busy work.

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Learning from these prior experiences, the instructors opened the data management session of the redesigned Lit&Sem with the excellent YouTube animation from the NYU Health Sciences Libraries, "Data Sharing and Management Snafu in 3 Short Acts" (*66*). This short video illustrates the difficulties of data sharing and management when one makes no plans to do so at the beginning of the research project. The humor and brevity of the video helped engage the students in a discussion of all of the roadblocks that the researcher encountered when trying to gain access to a dataset. In an attempt to build upon the deep reading and analysis work that occupied the first half of the semester, the instructors decided to adapt a graduate exercise from the Oregon Health and Science University called "The Gummi Bear Challenge" (*67*). This was meant to be a hands-on, low content knowledge activity that would illustrate the many approaches to documenting and communicating data. Unfortunately, aspects of the exercise - that the data themselves were meaningless and that the methods of description was the real point - were too abstract for the students to feel comfortable during the session. Even though the inconsequential subject matter was supposed to reduce cognitive load, it actually created cognitive stress for the students since they were more accustomed to working with tangible, lab-produced data. This is an exercise where the autonomous and self-directed culture of graduate school is an asset and is not easily transferable to the undergraduate classroom.

Analysis of Student Gains

We have looked at student performance and gains using the JMU Chemistry Information Literacy Test (ILT), the Student Assessment of Learning Gains (SALG), and student course work. We looked at quantitative data from the ILT and SALG and qualitative data from the SALG and student assignments. Data were collected with protocols approved by the James Madison University Institutional Review Board. We found that students made gains in their reading, writing, analysis, and search skills as they progressed from their sophomore year to the end of this course sequence. In spite of our predictions that students would make greater gains in the new course format, no statistically significant differences were observed in the quantitative data that were collected over the last four years. Therefore, all data will be reported in aggregate from the past four years.

As part of the ILT, students were asked to self-assess their knowledge and comfort level with specific reference sources, databases, and information management tools using the following scale: 1 = never used this resource; 2 = used, but not comfortable; 3 = comfortable; 4 = expert. Prior to fall 2015, the ILT was administered as a pre-test in Lit&Sem I (fall) and a post-test in Lit&Sem II (spring). Not all students completed the semester in sequence so data were stripped to remove students who were not enrolled in the sequence during a single academic year and non-consenting students. In the most recent iteration of the class, the pre- and post-tests were administered during the same semester.

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Students who dropped the course or did not consent to participate were dropped from the study.

Across all years, a pattern of improvement is seen in student comfort levels, with students reporting greater comfort at the post-test than the pre-test (N = 100: N = 26, Spring 2014; N = 35, Spring 2015; N = 39, Fall 2015). Data are arranged from the largest gains to the smallest gains (Table 3). It is not surprising, given the focus of the Lit&Sem coursework, that the greatest gains were observed from Refworks, Scopus, PubMed, SciFinder, and structure databases (*68*). Online and printed handbooks, structure drawing programs, and MSDS are covered in earlier coursework, particularly the second year labs.

Table 3. Self-reported Comfort Level with Resources (Means and Standard Deviations) of Chemistry Majors at the Post-test and Pre- to Post-test Changes

	Post-test	*Gains from Pre-test to Post -test*
Refworks	3.11 ± 0.21	1.76 ± 0.20
Scopus	3.23 ± 0.15	1.47 ± 0.19
PubMed	2.65 ± 0.07	1.05 ± 0.11
Structure Databases	2.87 ± 0.04	0.91 ± 0.17
SciFinder	3.13 ± 0.05	0.81 ± 0.17
Google Scholar	2.71 ± 0.32	0.58 ± 0.13
Online Handbooks	2.62 ± 0.11	0.40 ± 0.26
Structure Drawing Programs	2.96 ± 0.20	0.31 ± 0.03
Printed Handbooks	2.52 ± 0.12	0.24 ± 0.24
MSDS	2.87 ± 0.09	0.14 ± 0.19

In the SALG, students self-report on the gains they make in understanding, skills, and attitude, and how elements of the class help their learning. Students select responses from a Likert Scale: 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, 5 = great gain. Across the four year average, students report making good or better gains in their understanding and skills. Areas where students reported a gain of 3.5 or better are presented in Tables 4 and 5. Questions that were asked for the first time in 2015 do not have mean data and are noted with "N/A."

Despite the lack of statistically significant gains reflected in Tables 4 and 5, the authors observed a highly engaged and participatory classroom dynamic in the revised course. Students participated in thoughtful discussions on search strategies and were able to better analyze text as part of their group work. However, when asked to assess their own gains, these students generally underperformed when compared to previous years' data/methods. Some of this was a result in the change of instructional focus; there was less of a focus on the second semester research paper which led to a decrease in the exploration of modern research in chemistry and less writing. It is possible that these students were more aware of their limitations and thus, did not value the gains that they did make as very great. It is also possible that when asked about applied skills in the abstract, students were not able to quantify the gains that they made. However, one would expect to see these limitations across cohorts. Although beyond the scope of this project, a potential area for research could be in determining if the gains that one could speculate were made because of the redesigned delivery (group work, hands-on activities, data management) were impactful enough to offset the areas where little growth was recorded.

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Table 4. Student Responses to the SALG Prompt, "As a Result of Your Work in This Class, What GAINS DID YOU MAKE in Your UNDERSTANDING of Each of the Following?"

	Mean Score (2012-2015)	*Mean 2015*
Finding chemical information from online databases	4.4	4.2
Conducting a thorough literature search	4.3	4.0
Reading papers from the peer reviewed literature	4.1	4.0
Finding information that can be found in handbooks and other resources	4.0	3.9
Understanding the broader field of chemistry	4.0	3.8
How studying this subject area helps people address real world issues	3.8	3.8
Evaluating / assessing chemical information	3.9	3.7
Scientific misconduct	3.8	3.7
Data management	3.5	3.7
Using citations	3.9	3.6
How ideas from this class relate to ideas encountered in other classes within chemistry	3.9	3.6
Writing about science	3.7	3.4
Impact factors	3.6	3.2

The SALG also allowed for qualitative feedback from the students by allowing them to respond to a prompt about the class. We evaluated responses from several questions over the four years and coded them according to skills that were mentioned. Our classifications were searching the literature, reading the literature, the structure of the scientific literature, a broader view of chemistry, analysis skills (pull concepts from the literature or apply information learned to searching), organizing information, scientific communication, ethics, and grit (perseverance and effort). A comparison across years is detailed in Tables 6-8; only ideas seen in 10% or more of the responses are included.

Table 5. Student Responses to the SALG Prompt, "HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?"

	Mean Score (2012-2015)	***Mean 2015***
Opportunities to use computers in class to explore databases, etc.	4.2	4.2
Doing hands-on classroom activities	3.8	4.0
Attending class sessions	3.7	3.8
Participating in group work during class	3.7	3.8
Listening to discussions during class	3.8	3.7
In class discussion of research papers	4.0	3.7
In class discussion of student writing (collaborative writing on MOFs [metal organic frameworks])	N/A	3.5
Collaborative group searching activities	N/A	3.5

The data were coded according to what the student mentioned in the comment. When we coded the responses we did not interpret what we thought students meant or what their intention may have been. The student must have used clear language in their response in order to receive the corresponding code. For example, "I know how to go about reading scientific literature, and finding this literature from different sources" was coded as "reading the literature" and "searching the literature." A general response along the lines of "I have learned a lot more, seeing as I knew next to nothing to begin with" was not coded and not included in the dataset. Some student responses generated no codes while others generated as many as four codes. Numbers in the table reflect the number of times that a codable response was provided, not the number of students who gave a codable comment. When the two authors disagreed on coding, they discussed their classification and came to agreement.

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Table 6. Student Responses to the SALG Prompt, "Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class."

	2012 (N = 27)	*2013 (N = 31)*	*2014 (N = 35)*	*2015 (N = 39)*	*Average*
searching the literature	52%	71%	40%	39%	50%
reading the literature	22%	32%	31%	21%	27%
structure of the scientific literature	19%	6%	14%	21%	15%
broader view of chemistry	22%	16%	17%	5%	14%
analysis skills	7%	6%	11%	18%	11%
organizing information	19%	10%	9%	5%	10%

Table 7. Student Responses to the SALG Question, "Please comment on what SKILLS you have gained as a result of this class."

	2012 (N = 27)	*2013 (N = 31)*	*2014 (N = 36)*	*2015 (N = 38)*	*Average*
searching the literature	59%	61%	72%	72%	67%
reading the literature	52%	42%	39%	14%	36%
analysis skills	30%	10%	19%	19%	19%
scientific communication	11%	16%	17%	3%	12%
organizing information	19%	6%	17%	0%	10%

Table 8. Student Responses to the SALG Question, "What will you CARRY WITH YOU into other classes or other aspects of your life?"

	2012 (N = 27)	*2013 (N = 31)*	*2014 (N = 35)*	*2015 (N = 38)*	*Average*
searching the literature	36%	48%	51%	60%	50%
analysis skills	48%	19%	40%	37%	36%
reading the literature	28%	23%	17%	17%	21%
organizing information	8%	19%	17%	17%	16%

When we look at responses to the questions about what students will carry with them (Table 8), we saw modest gains in searching the literature and little change in analysis skills, reading the literature, and organizing information. Of course, we have no data on prior knowledge about what students bring to the course. Students have different prior experiences and a well-prepared student (e.g. a student involved in undergraduate research) may be more likely to report smaller gains. However, the student comments highlight some interesting areas of growth in data management skills. Even though the majority of the students reported that the Gummi Bear exercise was the least helpful course activity, these same students provided the following comments:

> *The gummibear assignment felt like it was too different from all the other assignments. It does have its merits, but it seems like the only thing it teaches is how to make your research more easily available to other researchers.*
> *My computer files are becoming better organized by using data management techniques taught in this class.*
> *I have implemented a data management plan in my research.*
> *I also found the data management techniques helpful, because it makes a lot of sense to keep names of files, versions, etc. in such a way that others can easily track and understand what you have done.*

This cohort provided more data management specific feedback than previous cohorts and it indicates that students are adopting data management ideas. To us, this illustrates that data management is a valuable skill at the undergraduate level but that better delivery methods need to be developed.

The responses in Table 9 allow us to see an increase in positive responses to in-class assignments, group work, class discussion, and repetition of content. In 2014 and 2015, we asked students to "Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas." Coding methodology was the same as to what was reported above, but student free responses were evaluated on the elements of the course: the in-class assignments, group work, in-class discussions, repetition of activities, and homework (outside of class). The data in Table 9 are consistent with the transition to more in-class activities and group work in the classroom.

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Table 9. Student Responses to, "Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas."

	2014 (N = 39)	*2015 (N = 37)*	*Average*
in class assignments	9%	60%	34%
group work	0%	43%	21%
homework outside of class	31%	3%	18%
in class discussions	9%	26%	17%
repetition of activities	6%	26%	15%

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The elements that students highlighted in their free responses in 2015 were much more centered on in-class activities (in-class assignments, group work, and in-class discussions) compared to comments from 2014 (homework outside of class).

> *There was sort of a main idea every class, which was then carried over into the homework. This focus on one important topic each day, and the fact that the class built on previous knowledge, helped cement these key ideas.*
> *Key ideas were retained in this class by constantly needing to reuse them for the future assignments. This class does a good job building off of itself.*
> *I liked how each class typically had a lecture portion that was followed by time for working out problems and ideas with our groups. This allowed the ideas to really sink in.*
> *It was very applied and relevant. We used it as soon as we learned it and that helped me to retain it. It was also hands on and that made things work out very well.*
> *I liked the idea of splitting up groups in this class. It allowed room for discussion among group mates that led to more learning through asking more questions.*
> *I liked both the classroom and group setup, as well as the instructional style. The hands-on approach helped me to remember the information better and keep me focused during class.*

We also found some of the comments specific to *how* the class was taught to be especially interesting. One comment in particular illustrates the tension between the pedagogical conditioning that students have experienced up to this point and the team-based and active learning approaches that we tried to incorporate into Lit&Sem.

> *I was not the biggest fan of the teaching style of this class. I think that the powerpoints need to be more structured in terms of explicitly stating what we have learned as we go (eg. a bulleted list of what we should be learning). The exercises helped a lot in learning and, in my opinion, were more beneficial to learning than the actual lectures. However, I do not think this should be the case. Lectures should provide the foundation of learning and the exercises should supplement this and help to create a bank of experience from which students can remember objectives and other facts. In this class, the exercises had more of a 'sink or swim' approach where very little lecture proceeded and then we were thrown into the exercise and had to figure out most of it for ourselves.*

This student felt more comfortable with a highly structured, PowerPoint-driven lecture with exercises serving to supplement didactic delivery. Despite the fact that this student recognized the value of the activities, s/he did not think that this approach was an appropriate teaching strategy. This is consistent with prior observations of student resistance to active learning (*69–71*).

Both the quotes and quantitative data illustrate the importance of group work in the class. We were encouraged that nearly half of the students mentioned group work; previous groups of students did not comment on group activities. An unstated goal for this course was to provide students with team experiences, and they responded (unprompted) that group work contributed positively to their experience. All but three of the student respondents thought that the group work was a positive aspect of this course. Students frequently commented that working in groups was valuable because of the discussion. A few students even remarked that group work helped them improve their collaboration and team-work skills. Negative responses were from students who prefer to do things by themselves, do not like that the grade is dependent on group members, or had a group with poor dynamics. Students were frustrated when they perceived unequal contributions from group members. Of course, we know that as students transition to professional careers, they will work in many group environments and will need to develop the skills to navigate these situations.

Discussion

On the whole, the redesigned Lit&Sem sequence resulted in positive gains across our learning objectives, although some were not as great as we would have hoped. Although the increased curricular time is a benefit, it is still a challenge to meet our objectives in the time allowed. In the past, we closely aligned the two Lit&Sem courses, expecting students in the first course, in the fall, to have selected the topic that they would write about in the spring semester before the fall semester concluded. With the redesign, we decoupled the content and gave more emphasis to reading and searching in the fall semester and shifted the emphasis on communication and writing to the spring. Students recognize that part of the picture is missing, and commented on the SALG that they want more writing and reading practice. This is a structural element that we need to consider in the Department of Chemistry and Biochemistry and recognize that this will inform curriculum delivery.

The unstructured lecture approach, with active engagement intermixed throughout, allowed for organic discussion and connections throughout the semester. A key element that we did not realize that we were introducing was the emphasis we placed on *why* we teach and discuss the material. Through class participation, we made connections to careers, graduate study, and undergraduate research. The clearest evidence for this occurred after the final exam when a student came up afterwards to tell us that she had not known about a particular area of research before learning about it through the reading assignment (*72*) on our final exam and that she was excited to go discuss this with her family since she thought it would be relevant to her family's farm. The translation of research from an article to a student's personal life may not have been an explicit goal for the course, but it was an extremely gratifying moment.

Some of the cognitive roadblocks we have observed require more attention than a one-credit, one-semester course can give. While students recognize the value of specialized research databases, they have yet to fully incorporate them into their workflows, nor can they articulate the quality or selectivity of the resource. It is difficult to retrain a lifelong habit of using Google, which has been good enough for the majority of their information needs, in a single semester. The ability to evaluate authority and determine trust are critical skills that are difficult to develop in a culture where there are "two sides" to the scientific treatment of topics like evolution and climate change. In spite of these challenges, the repetitive assignments we incorporated into our most recent iteration of the course have resulted in students using research databases more frequently to complete the final search assignment of Lit&Sem I. More research on student search strategies, and the instructional methods that produce change to more expert practices are needed.

Both the library and chemistry faculty members have benefitted from the close collaboration that has resulted from this course. Each brings a disciplinary focus - chemistry and data information - to this course. Only as a team are we able to identify the skills that our students need in an evolving information landscape, without overwhelming our students with the information that only experts need to know. We are able to put chemical information literacy standards into the broader landscape of data information literacy, provide a broader perspective on understanding and applying criteria for evaluating the authority and appropriateness of a document or information source, and demonstrating critical thinking by evaluating information and following a logical path of inquiry (*2*), while developing an ability to manage ever increasing amounts of information. Our assessment program helps us to inform instruction (content and methods) and appropriately target interventions to achieve these goals.

Information has many forms. Traditionally, information literacy for chemists has referred to chemical properties and literature. Increasingly, data management and reuse are critical skills for all researchers, including students. As data take on a more prominent role as a primary source of information, and good data management becomes more important to the reuse of data, the ways in which researchers and librarians engage with the data information literacy competencies

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will evolve with the research environment. We have taken the first step towards addressing the ever-broadening landscape of information literacy in our course and we look forward to seeing how the community responds to these changes and how it affects teaching information literacy across the undergraduate chemistry curriculum.

References

1. American Chemical Society Committee on Professional Training ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs;http://www.acs.org/content/dam/acsorg/about/governance/committees/training/2015-acs-guidelines-for-bachelors-degree-programs.pdf (accessed May 19, 2016).
2. Division of Chemical Information Information Competencies for Chemistry Undergraduates; https://en.wikibooks.org/wiki/Information_Competencies_for_Chemistry_Undergraduates (accessed May 19, 2016).
3. Baldwin, V. Library organization information literacy units. *Sci. Technol. Libr.* **2007**, *27*, 93–106.
4. Garritano, J. R. Trends in chemical information literacy and collection development, 2000-2009. *Sci. Technol. Libr.* **2010**, *29*, 235–257.
5. Lee, W. M.; Wiggins, G. Alternative methods for teaching chemical information to undergraduates. *Sci. Technol. Libr.* **1998**, *16*, 31–43.
6. Ricker, A. S. Chemistry information for the undergraduate in a one-credit course. *Sci. Technol. Libr* **1998**, *16*, 45–67.
7. Emmett, A.; Emde, J. Assessing information literacy skills using the ACRL standards as a guide. *Ref. Serv. Rev.* **2007**, *35*, 210–229.
8. Garritano, J. R. Ice cream seminars for graduate students: Imparting chemical information literacy. *Public Serv. Q.* **2007**, *3*, 53–70.
9. Walczak, M. M.; Jackson, P. T. Incorporating information literacy skills into analytical chemistry: An evolutionary step. *J. Chem. Educ.* **2007**, *84*, 1385–1390.
10. Jensen, D., Jr.; Narske, R.; Ghinazzi, C. Beyond chemical literature: Developing skills for chemical research literacy. *J. Chem. Educ.* **2010**, *87*, 700–702.
11. Ashraf, S. S.; Marzouk, S. A. M.; Shehadi, I. A.; Murphy, B. M. An integrated professional and transferable skills course for undergraduate chemistry students. *J. Chem. Educ.* **2011**, *88*, 44–48.
12. Gawalt, E. S.; Adams, B. A chemical information literacy program for first-year students. *J. Chem. Educ.* **2011**, *88*, 402–407.
13. Peters, M. C. Beyond Google: Integrating chemical information into the undergraduate chemistry and biochemistry curriculum. *Sci. Technol. Libr.* **2011**, *30*, 80–88.
14. Tomaszewski, R. A science librarian in the laboratory: A case study. *J. Chem. Educ.* **2011**, *88*, 755–760.

15. Tucci, V. K. Faculty/librarian collaboration: Catalyst for student learning and librarian growth. *Sci. Technol. Libr.* **2011**, *30*, 292–305.
16. Ferrer-Vinent, I. J. Using in-class structured exercises to teach SciFinder to chemistry students. *Sci. Technol. Libr.* **2013**, *32*, 260–273.
17. Klein, G. C.; Carney, J. M. Comprehensive approach to the development of communication and critical thinking: Bookend courses for third- and fourth-year chemistry majors. *J. Chem. Educ.* **2014**, *91*, 1649–1654.
18. Mandernach, M. A.; Shorish, Y.; Reisner, B. A. The evolution of library instruction delivery in the chemistry curriculum informed by mixed assessment methods. *Issues Sci. Technol. Libr.* **2014**, *77*.
19. Reisner, B. A.; Vaughan, K. T. L.; Shorish, Y. L. Making data management accessible in the undergraduate chemistry curriculum. *J. Chem. Educ.* **2014**, *91*, 1943–1946.
20. Tucci, V. K.; O'Connor, A. R.; Bradley, L. M. A three-year chemistry seminar program focusing on career development skills. *J. Chem. Educ.* **2014**, *91*, 2071–2077.
21. Bruehl, M.; Pan, D.; Ferrer-Vinent, I. J. Demystifying the chemistry literature: Building information literacy in first-year chemistry students through student-centered learning and experiment design. *J. Chem. Educ.* **2015**, *92*, 52–57.
22. Swoger, B. J. M.; Helms, E. An organic chemistry exercise in information literacy using scifinder. *J. Chem. Educ.* **2015**, *92*, 668–671.
23. Baysinger, G. Introducing the Journal of Chemical Education's "Special Issue: Chemical Information". *J. Chem. Educ.* **2016**, *93*, 401–405.
24. Zane, M.; Tucci, V. K. Exploring the information literacy needs and values of high school chemistry teachers. *J. Chem. Educ.* **2016**, *93*, 406–412.
25. Shultz, G. V.; Li, Y. Student development of information literacy skills during problem-based organic chemistry laboratory experiments. *J. Chem. Educ.* **2016**, *93*, 413–422.
26. Yeagley, A. A.; Porter, S. E. G.; Rhoten, M. C.; Topham, B. J. The stepping stone approach to teaching chemical information skills. *J. Chem. Educ.* **2016**, *93*, 423–428.
27. Greco, G. E. Chemical information literacy at a liberal arts college. *J. Chem. Educ.* **2016**, *93*, 429–433.
28. Danowitz, A. M.; Brown, R. C.; Jones, C. D.; Diegelman-Parente, A.; Taylor, C. E. A combination course and lab-based approach to teaching research skills to undergraduates. *J. Chem. Educ.* **2016**, *93*, 434–438.
29. Baker Jones, M. L.; Seybold, P. G. Combining chemical information literacy, communication skills, career preparation, ethics, and peer review in a team-taught chemistry course. *J. Chem. Educ.* **2016**, *93*, 439–443.
30. Jacobs, D. L.; Dalal, H. A.; Dawson, P. H. Integrating chemical information instruction into the chemistry curriculum on borrowed time: A multiyear case study of a capstone research report for organic chemistry. *J. Chem. Educ.* **2016**, *93*, 444–451.
31. Cowden, C. D.; Santiago, M. F. Interdisciplinary explorations: Promoting critical thinking via problem-based learning in an advanced biochemistry class. *J. Chem. Educ.* **2016**, *93*, 464–469.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch002

32. Baykoucheva, S.; Houck, J. D.; White, N. Integration of EndNote Online in information literacy instruction designed for small and large chemistry courses. *J. Chem. Educ.* **2016**, *93*, 470–476.
33. Zwicky, D. A.; Hands, M. D. The effect of peer review on information literacy outcomes in a chemical literature course. *J. Chem. Educ.* **2016**, *93*, 477–481.
34. Scalfani, V. F.; Frantom, P. A.; Woski, S. A. Replacing the traditional graduate chemistry literature seminar with a chemical research literacy course. *J. Chem. Educ.* **2016**, *93*, 482–487.
35. Currano, J. N. Introducing graduate students to the chemical information landscape: The ongoing evolution of a graduate-level chemical Information course. *J. Chem. Educ.* **2016**, *93*, 488–495.
36. Kamijo, H.; Morii, S.; Yamaguchi, W.; Toyooka, N.; Tada-Umezaki, M.; Hirobayashi, S. Creating an adaptive technology using a cheminformatics system to read aloud chemical compound names for people with visual disabilities. *J. Chem. Educ.* **2016**, *93*, 496–503.
37. Pence, H. E.; Williams, A. J. Big data and chemical education. *J. Chem. Educ.* **2016**, *93*, 504–508.
38. Walker, M. A.; Li, Y. Improving information literacy skills through learning to use and edit Wikipedia: A chemistry perspective. *J. Chem. Educ.* **2016**, *93*, 509–515.
39. Stuart, R. B.; McEwen, L. R. The safety "use case": Co-developing chemical information management and laboratory safety skills. *J. Chem. Educ.* **2016**, *93*, 516–526.
40. Tomaszewski, R. The concept of the imploded boolean search: A case study with undergraduate chemistry students. *J. Chem. Educ.* **2016**, *93*, 527–533.
41. Härtinger, S.; Clarke, N. Using patent classification to discover chemical information in a free patent database. *J. Chem. Educ.* **2016**, *93*, 534–541.
42. Glasser, L. Crystallographic information resources. *J. Chem. Educ.* **2016**, *93*, 542–549.
43. Rzepa, H. S. Discovering more chemical concepts from 3D chemical Information searches of crystal structure databases. *J. Chem. Educ.* **2016**, *93*, 550–554.
44. Méndez, E.; Cerdá, M. F. Discovering Reliable Sources of Biochemical Thermodynamic Data to Aid Students Understanding. *J. Chem. Educ.* **2016**, *93*, 555–559.
45. Buntrock, R. E. Using citation indexes, citation searching, and bibliometrics to improve chemistry scholarship, research, and administration. *J. Chem. Educ.* **2016**, *93*, 560–566.
46. Love, B. E.; Bennett, L. J. Determining synthetic routes to consumer product ingredients through the use of electronic resources. *J. Chem. Educ.* **2016**, *93*, 567–568.
47. Zardecki, C.; Dutta, S.; Goodsell, D. S.; Voigt, M.; Burley, S. K. RCSB Protein Data Bank: A resource for chemical, biochemical, and structural explorations of large and small biomolecules. *J. Chem. Educ.* **2016**, *93*, 569–575.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch002

48. Gozzi, C.; Arnoux, M. -.; Breuzard, J.; Marchal, C.; Nikitine, C.; Renaudat, A.; Toulgoat, F. Progressively fostering students' chemical information skills in a three-year chemical engineering program in France. *J. Chem. Educ.* **2016**, *93*, 576–579.
49. Ferrer-Vinent, I. J.; Bruehl, M.; Pan, D.; Jones, G. L. Introducing scientific literature to honors general chemistry students: Teaching information literacy and the nature of research to first-year chemistry students. *J. Chem. Educ.* **2015**, *92*, 617–624.
50. *ORCID | Connecting Research to Researchers*; http://orcid.org (accessed May 19, 2016).
51. Carlson, J.; Johnston, L. *Data Information literacy: Librarians, data, and the education of a new generation of researchers*; Purdue University Press: West Lafayette, IN, 2015.
52. Bernstein, F. C.; Koetzle, T. F.; Williams, G. J. B.; Meyer, E. F., Jr.; Brice, M. D.; Rodgers, J. R.; Kennard, O.; Shimanouchi, T.; Tasumi, M. The protein data bank: A computer-based archival file for macromolecular structures. *J. Mol. Biol.* **1977**, *112*, 535–542.
53. Brown, I. D. CIF (crystallographic information file): A standard for crystallographic data interchange. *J. Res. Natl. Inst. Stand. Technol.* **1996**, *101*, 341–346.
54. Hall, S. R.; Allen, F. H.; Brown, I. D. The crystallographic information file (CIF): a new standard archive file for crystallography. *Acta Crystallogr., Sect. A: Found. Crystallogr.* **1991**, *47*, 655–685.
55. Berman, H. M.; Westbrook, J.; Feng, Z.; Gilliland, G. T. N.; Weissig, H.; Shindyalov, I. N.; Bourne, P. E. The Protein Data Bank. *Nucleic Acids Res.* **2000**, *28*, 235–242.
56. American Chemical Society. Division of Chemical Information: Abstract submission; http://www.acs.org/content/acs/en/meetings/abstract-submissions/acsnm251/division-of-chemical-information.html (accessed May 19, 2016).
57. James Madison University. *Facts and Figures*; http://www.jmu.edu/about/fact-and-figures.shtml (accessed May 19, 2016).
58. Reisner, B. A.; Shorish, Y. *Supplemental Materials for Building Data and Information Literacy in the Undergraduate Chemistry Curriculum*; http://commons.lib.jmu.edu/chembio/1/ (accessed June 1, 2016).
59. Mathieu, R.; Carroll, S.; Weston, T.; Seymour, E.; Lottridge, S.; Dolan, C. *SALG - Student Assessment of their Learning Gains*; http://www.salgsite.org/ (accessed May 31, 2016).
60. Association of College and Research Libraries. *Information Literacy Competency Standards for Higher Education*; http://www.ala.org/acrl/sites/ala.org.acrl/files/content/standards/standards.pdf (accessed May 19, 2016).
61. Wiggins, G. P.; McTighe, J. *Understanding by Design*, 2nd ed.; Association for Supervision and Curriculum Development: Alexandria, VA, 2005.
62. *CATME | Smarter Teamwork*; http://info.catme.org/ (accessed May 19, 2016).

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch002

63. Layton, R. A.; Loughry, M. L.; Ohland, M. W.; Ricco, G. D. Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Adv. Eng. Educ.* **2010**, *2*, 1–28.
64. Ohland, M. W.; Loughry, M. L.; Woehr, D. J.; Bullard, L. G.; Felder, R. M.; Finelli, C. J.; Layton, R. A.; Pomeranz, H. R.; Schmucker, D. G. The Comprehensive Assessment of Team Member Effectiveness: Development of a behaviorally anchored rating scale for self- and peer evaluation. *Acad. Manage. Learn. Educ.* **2012**, *11*, 609–630.
65. Loughry, M. L.; Ohland, M. W.; DeWayne Moore, D. Development of a theory-based assessment of team member effectiveness. *Educ. Psychol. Meas.* **2007**, *67*, 505–524.
66. Hanson, K.; Surkis, A.; Yacobucci, K. *Data sharing and management snafu in 3 short acts*, https://www.youtube.com/watch?v=66oNv_DJuPc (accessed May 19, 2016).
67. Vasilevsky, N.; Wirz, J.; Champieux, R.; Hannon, T.; Laraway, B. *Lions, tigers, and gummi bears: Springing towards effective engagement with research data management*; http://digitalcommons.ohsu.edu/etd/3571/ (accessed May 19, 2016).
68. Shorish, Y. *CHEM 481 & 482 - Literature and Seminar I/II: Structures*, http://guides.lib.jmu.edu/c.php?g=321790&p=2153321 (accessed May 19, 2016).
69. Felder, R. M. Hang in there! Dealing with student resistance to learner-centered teaching. *Chem. Eng. Educ.* **2011**, *45*, 131–132.
70. Seidel, S. B.; Tanner, K. D. "What if students revolt?" Considering student resistance: Origins, options, and opportunities for investigation. *CBE Life Sci. Educ.* **2013**, *12*, 586–595.
71. Shekhar, P.; Demonbrun, M.; Borrego, M.; Finelli, C.; Prince, M.; Henderson, C.; Waters, C. Development of an observation protocol to study undergraduate engineering student resistance to active learning. *Intl. J. Eng. Educ.* **2015**, *31*, 597–609.
72. Bralatei, E.; Lacan, S.; Krupp, E. M.; Feldmann, J. Detection of inorganic arsenic in rice using a field test kit: A screening method. *Anal. Chem.* **2015**, *87*, 11271–11276.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch002

Chapter 3

Teaching Chemical Safety and Information Skills Using Risk Assessment

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There is an expectation from graduate schools, professional schools, industry, and K-12 administrators that students acquiring an undergraduate chemistry degree with laboratory research will gain the necessary knowledge and develop the required skills to successfully complete their specific laboratory projects and future jobs safely. This includes knowledgeable handling and management of biological, chemical, and physical laboratory hazards. To do this, students must be able to locate and evaluate chemical, regulatory, and toxicological information from various reliable sources. Traditionally, chemical safety and information literacy have been seen as skills to develop one project at a time rather than discrete chemistry sub-disciplines. However, many chemical educators, safety professionals, and librarians agree that these are more than project-specific skills. Chemical safety and information literacy are learning objectives in their own right. To support effective teaching of these objectives, best learning practices can be applied to the formal structure of "in lab" training and supported with safety and information literacy competencies. Educators should begin to consider developing innovative ways of incorporating the learning objectives and evaluation tools required to help students develop an aptitude for applying knowledge and skills in independent laboratory based work. Education organized around the aspects of knowledge and skill acquisition (accommodation, assimilation, and assessment)

can help create a well-developed undergraduate curriculum promoting ethical, safe, and informed behaviors while increasing chemical safety knowledge that can be transferred from the teaching laboratory to the research laboratory.

Introduction

In the wake of several well publicized and tragic accidents which have occurred in university chemistry laboratories over the past few years, there has been much discussion among stakeholders (e.g., chemistry faculty, institutional administrators, professional organizations, and safety professionals) about how the "safety culture" in academic labs might be improved (*1*). Like most paradigm shifts, it should be expected that evolving our chemical safety culture from "reactive" to "proactive" (i.e., shifting the culture) in academic laboratories will take time. From the intensity of the current discussions, it might seem that the incorporation of chemical health and safety into the chemistry curriculum is a new idea. It is not.

> …clearly the time has come when a basic competency in laboratory health and safety is required of all science and engineering graduates. The sooner this phase of education is included in earnest in chemistry courses and curricula, the sooner we will have fulfilled an ethical obligation (*2*).

The above statement was published in a *J. Chem. Ed.* article in 1977, and yet most chemistry majors still graduate without a specific course in chemical safety on their transcript. This is not to imply that progress has not been made in the teaching of chemical safety, but moving forward from this point requires an evaluation of how future scientists and science teachers are educated in chemical safety within their discipline, especially with respect to hazard and risk management.

Ubiquitous to every wet laboratory is the need for information concerning chemical properties and research methodologies. Chemical information is highly valuable and sought after in chemical industry, medicine, materials, energy, and many other applied sciences. Numerous highly sophisticated and specialized collections of chemical literature and data have evolved to support these demands. However, important information for assessing and managing safety in labs is scattered across numerous sources and proactive searching for potential chemical incompatibility or process hazards poses a significant burden when planning experiments. Proficiency in searching diverse chemical literature has long been recognized as a core activity in the discipline, but as with chemical safety, there has not been widespread active incorporation of information literacy into the curriculum (*3*).

Part of undergraduate education is preparing students for the workforce (*4*), but academia has tended to lag behind industry in promoting safe work environments, thus creating graduates without the needed safety and information skills (*5*). As Livingston noted in 1964, "Scientific research in the campus laboratories is one of the most exciting activities in the world of ideas, and one of

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the least orderly in the world of organizations (*6*).” One recent analysis of OSHA injury and illness data showed that the incidence rates in academic institutions were significantly higher (2.2 per 100 workers) when compared specifically to those of Dow Chemical (0.33 injuries per 100 workers) (*7*). Educational programs that can produce chemistry graduates who have built a knowledge base in chemical safety and information literacy will be much more competitive in the job market.

Teaching and Learning Chemical Safety and Information Management

In 2015, the American Chemical Society Committee on Profession Training (ACS CPT) issued a revision of the *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs*. In the revised edition, chemical safety and information management (along with several other core professional practices) are addressed under “Development of Student Skills (*8*).” Skills represent the ability to apply knowledge, and thus knowledge of a topic is a prerequisite for skill development. Acquisition of knowledge should be embedded in the curriculum – preferably as a subject course that can treat the basic frameworks. Risk assessment is considered a full sub-discipline in the chemical safety industry. Building on the CPT guidelines, the education community needs to develop a framework for incorporating risk assessment into the undergraduate chemistry curriculum.

Chemical safety is more than memorizing safety rules that are offered at the beginning of the semester as a disjointed list of “dos and don'ts” and then hopefully applied to laboratory work. Similarly, information literacy is more than depending on a search box that seemingly magically locates the most pertinent authoritative publications from among millions on the Internet based on a few key terms. Safe, informed, laboratory-based chemical research requires the ability to assess the applicability of previously learned ‘rules’ in different situations and apply them to the work at hand. Conscious application of knowledge is common to practicing laboratory safety and information management and is not an intuitive skill. Effective teaching of these skills involves expanding the knowledge base from rules to assessment techniques and shifting classroom focus from input to outcomes more typical of research and discovery science.

Effective chemical safety and information literacy education for undergraduates can create new cognitive categories in a learning process known as accommodation. Accommodation occurs when a new experience causes a student to alter or maybe even completely rearrange their current thinking (*9*). Assimilation adds new information to existing cognitive categories. Once an individual has established cognitive categories, new information can be added to those categories in the future with less learning effort (*9*). In a simple analogy, accommodation is building a mental box and assimilation is putting things in the box. It is easier to gather and hold onto useful ideas if first there is a box built to put them into. By not directly addressing chemical safety and information literacy as part of the undergraduate curriculum, we are not allowing our future chemists

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to form genuine cognitive accommodation categories around these sub-disciplines impacting their daily lives and future careers as laboratory researchers.

The current trend in undergraduate chemical education is to get students into the research lab as early as possible. At the undergraduate level, students do not yet have much exposure to the scientific research context. Undergraduate programs are focused on familiarizing students with the fundamental principles and models that differentiate the scholarly disciplines. Familiarity with research techniques is developed in lab sections, but the skills for putting these into practice to address novel research problems as expected in a research setting are not intuitive. This challenge for students is further reflected in the need to incorporate information and safety concepts into the research process. The question of how to translate concepts to procedures can be addressed in successive levels of learning outcomes, starting with formulation of rules followed by rationale and finally processes and risk assessment tools.

The underlying frameworks in laboratory safety and information literacy and their application to chemical research could constitute a dedicated course on professional, life-long skill building. However, barriers such as limits on major hours and lack of faculty with the expertise to teach these specialized topics are sometimes cited as reasons why it is difficult to add a course on chemical safety and/or information literacy as a curriculum item on par with the other sub-disciplines of chemistry. This chapter offers an approach for incorporating laboratory safety knowledge and information literacy concepts into existing classes.

Evolving Basic Lab Safety – From Rules to Understanding

In introductory chemistry labs, risk has traditionally been controlled by having students adhere to well-established safety rules addressing several basic categories of hazard (Figure 1) (*10*) and utilizing chemicals and procedures which have hazards that are well classified.

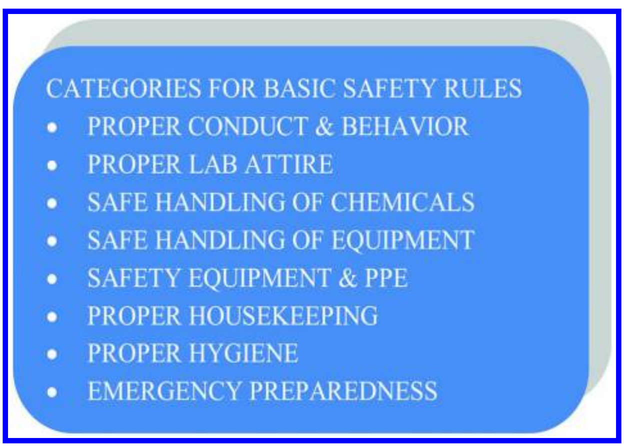

Figure 1. Grouping of Basic Safety Knowledge.

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Undergraduate students in their first chemistry courses do not have the necessary competencies to assess hazards, determine risk, and/or locate reliable information to control risk. It would be negligent for an instructor to allow students to enter their first chemistry laboratory with only the warning: "Be careful, evaluate the hazards and determine the risk prior to work, and use your common sense." Without prior experience, it is difficult to recognize hazards or know how to assess risk. How can information be evaluated if there is no knowledge base?

Rules are useful reminders as outcomes of previous thought, but should not be presented as a disjointed list of those thoughts. Giving a student a list and imploring them to behave accordingly will not promote learning. As shown in Figure 2, basic rules or guidelines can be used to help develop chemical safety competencies. In the chemical safety learning process, accommodation starts with the safety rules which create specific cognitive categories (boxes). Explanation of the rules, lessons learned, historical context, and risk assessment (parsing new ideas into those categories) evolves the rule through assimilation and develops chemical safety competencies. If students are given little additional information beyond the rules to assimilate into their categories, learning may stop at accommodation.

Figure 2. Use Rules to Create Chemical Safety Competencies.

Table 1 shows some examples of rule rationale that can be presented as one introduces a lab class to the rules. As a pre-laboratory assignment, each student could be assigned two or three common rules and asked to research the rationale for the rule. Their results would be discussed prior to the lab – including reliability of the sources of information used in the searches. Exercises like this would make the rule concept more concrete and assist with the assimilation process. Table 2 illustrates the translation of these ideas for a few rules.

After a few laboratory courses, students have developed some basic knowledge about hazards, but have relied on following rules to minimize risk. As experiments and processes become more advanced in upper level undergraduate courses and research, the hazards will become greater, more complicated, and more complex. The rules must evolve from a list of "dos and don'ts" to learning about assessing risk based on the hazards, as illustrated in Figure 3 by the process of selecting personal protective equipment (PPE).

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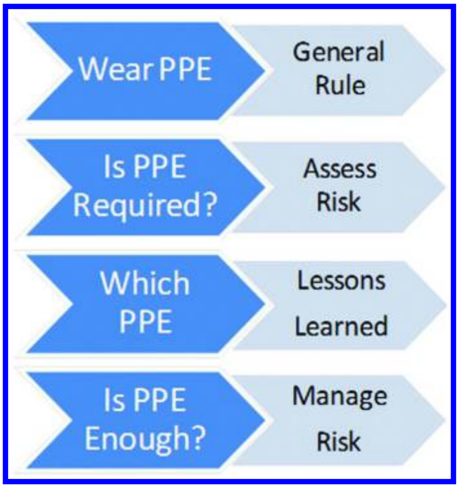

Figure 3. Evolution of a Rule.

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Incorporating Chemical Safety and Information Literacy into Chemistry Curriculum

The reactivity of chemicals is the focus of most chemical study and creating a completely 'safe' fictitious laboratory experience would necessitate elimination of the most active participants in wet laboratory processes – including many organic solvents and oxidizing substances. Educating chemists that have never handled chemicals may be safe, but would produce a very hazardous workforce! In addition to chemicals, there are many other hazards that are likely to be encountered in a laboratory. Any active process involving manipulation of equipment, handling stock bottles and storage containers, and operating at temperatures and pressures other than ambient, presents potential dangers to operators. There are many challenges that face the incorporation of safety concepts into undergraduate chemistry activities, but chemists must be taught how to locate information, determine hazards, and reduce risk to an acceptable level that has been predetermined based on worker experience and/or institutional guidelines. Putting safety concepts to work in a research laboratory setting hinges on the ability of the students to evaluate and assimilate data and information related to the work at hand.

Teaching undergraduate students how to create a risk assessment tool takes learning to the next level by incorporating new conceptual knowledge into the undergraduate curriculum and facilitating assimilation of ideas about safety and authoritative information beyond the basic rules. Performing a risk assessment on a chemical or task requires students to use information to recognize, understand, and prioritize hazards and then consider ways to eliminate or reduce risk to a level that enables work to proceed safely. In this way, risk assessment combines more advanced concepts of chemical safety (toxicology, controls, physical hazards of chemicals, PPE selection, etc.) with chemical information skills. The CPT report on Chemical Information Skills states that, "…the incorporation of exercises that require students to develop familiarity with the chemical literature should be an integral part of the chemistry program (*12*)." Students must go to the literature to gather information that enables the determination of hazards and the evaluation of risk. Creating a risk assessment tool is a perfect exercise to fulfill the CPT informational skill requirement while also teaching risk assessment methodology and critical thinking.

Table 1. A Few Safety Rules Explained

Common Rule	*Rationale for Rule*
Always wear chemical splash goggles when there is a possibility of chemical splash.	Your eyes are irreplaceable. You cannot always predict a potential splash hazard. The risk from splash increases with multiple workers and procedures occurring in the lab.
Confine long hair and loose clothing.	Hair and loose clothing can easily become entangled in moving parts or catch fire when using Bunsen burners.
Never work alone in the laboratory.	Incidents are usually unexpected. When they do happen, time is critical. Someone knowledgeable about the work should be working nearby to assist with an emergency.
Never consume any food or beverage when you are in a chemical laboratory. Do not chew gum or tobacco, and do not smoke or apply cosmetics in the laboratory.	Food and products can become contaminated. Any of these activities can inadvertently transfer chemicals to your mouth or skin.
Always wash your hands and arms with soap and water before leaving the laboratory, even if you wore gloves.	In the lab, contact with chemicals is always a possibility and contact may be inadvertent and go initially unnoticed.
Never pipet by mouth. Always use a pipet aid or suction bulb.	Pipetting by mouth directly exposes the worker to ingestion of chemicals. This technique was discontinued long ago in the US, but it is possible that students may come from countries where this might still be practiced.
Never remove chemicals from the laboratory without proper authorization.	There is no justification for personal use of chemicals. Removing chemicals from a laboratory is unethical and may be illegal.
Report violations of your laboratorys safety rules to your instructoryou could save their lives and your own.	Safety is everyones responsibility. Safety concerns are learning opportunities for everyone when presented without blame.

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Table 2. Rules to Risk

Rule Based (Instructional Labs)	*Risk Based (Research Labs)*
Follow all safety instructions carefully.	Do not change procedures without careful thought as to how this may affect the hazards of the chemicals or processes being used. Following instructions is very important, but action without thought can be dangerous also. Discuss controlling change.
Never perform unauthorized experiments.	Be sure to realize your limitations and ask for clarification when you don't understand something. Follow any laboratory specific Standard Operating Procedures (SOP) without deviation.
Become thoroughly acquainted with the location and use of safety equipment and facilities such as exits, safety showers, and eyewash fountains.	Become an active participant in the maintenance of the safety and engineering equipment (e.g. hoods) in the laboratory. Assign tasks to various lab workers on a rotating basis. Ensure that showers, eyewashes, and exits are never blocked.
Before undertaking any laboratory work, become familiar with the hazards of the chemicals involved.	Perform a hazard analysis or risk assessment using standard methods such as those presented in "Identifying and Evaluating Hazards in Research Laboratories (*11*)" to uncover hazard and reduce risk.

Learning outcomes benefit students by focusing their attention onto what is important (*13*). Learning outcomes also benefit research mentors by ensuring that students have the competencies to work with process specific hazards. The safety professional and librarian contribute by establishing the criteria that will measure the success of the training. A well-written learning objective should contain three components (*9*): desired outcome, or what should be expected of the trainee after training; conditions under which the expected outcome will take place; and standards or criteria that will define an acceptable outcome. Three examples of assignments which can evaluate the quality of an assignment and have specific, assessable learning objectives are presented in Figure 4. For each of these exercises, students are directed to very specific information source.

Basic hazard potential of chemicals is communicated via the classification assigned by the Globally Harmonized System (GHS) symbols and codes that can be found on Safety Data Sheets (SDSs, formerly known as MSDSs) and on chemical supplier bottles and packages (*14*). The National Institutes of Health (NIH) and other agencies provide many databases for finding more extensive chemical property, safety and toxicological information, most of which are indexed by the ChemID Advanced search tool (*15*). The National Academy of Sciences (NAS) recommends use of a Laboratory Chemical Safety Summary (LCSS) to guide chemical information gathering appropriate to the research lab setting (*16*). The National Library of Medicine (NLM) PubChem database compiles data into LCSSs from SDSs and other authoritative safety data sources (*17*). A longer list of information databases can be found at the NLM Enviro-Links for Lab Safety guide (*18*) and in Appendix C.

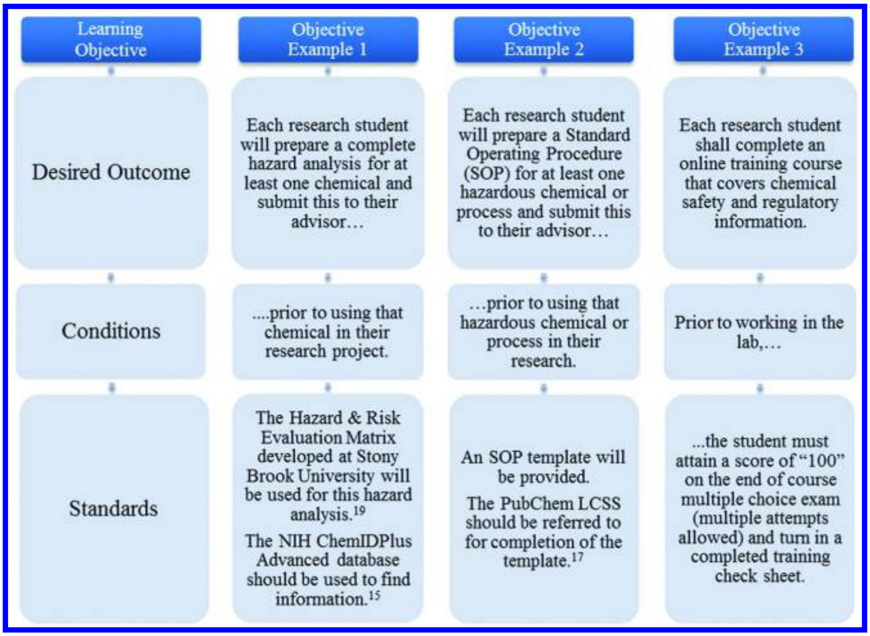

Figure 4. Learning Objective Examples with Components.

The Hazard & Risk Evaluation Matrix from Stony Brook University is a particularly good tool to use for teaching informational skills relevant to risk assessment (*19*). Information is required that cannot be found on many SDSs. Additionally, for many substances, various physical values will often not be published in databases and students have to try and find primary sources. What students often discover is that many chemicals are not well studied and that toxicological and regulatory values are lacking. Students learn from this that "no data available" and "safe" are not synonymous. In fact, if the indicated information required for filling in the matrix cannot be located or is not known (flash point for example), students must assign a high level of risk for use since the hazard is an unknown.

As in the case of assessing safety concerns, entry-level undergraduate students have few competencies developed for managing the primary research literature beyond simple keyword search. Generally, students need to understand where to find authoritative information, how to distinguish scholarly from

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non-scholarly sources, include references in papers without plagiarizing, and properly construct bibliographies. These competencies have been outlined by the Association of College and Research Libraries (ACRL) as part of the research cycle (*20*). Stuart and McEwen previously demonstrated the alignment of this cycle with the risk assessment process (iRAMP) (*21*). An example risk assessment information search process is shown in Table 3. A sample workflow for researching the flammability of glacial acetic acid is illustrated in Figure 5, including documenting sources. The additional data on vapor density collected via PubChem LCSS could prove useful in preventing a potential fire by informing the user about flammable vapors accumulating in low areas.

Evaluating the authority and quality of data is of particular importance in conducting risk assessment. Applying data inappropriately could result in a lab mishap where a worker is exposed or injured. For example, if a substance becomes hazardous upon decomposition, the temperature at which this would happen is critical for working safely with that chemical. Relying on an inaccurately reported decomposition temperature could put workers at risk. The updated 2015 ACRL Information Literacy Framework emphasizes that the authority of information is contextual and thus all sources of information have some bias and scope limitation depending on their purpose (*22*). Many chemical safety databases from NLM aggregate information from a variety of agency sources with a diversity of intended audiences and needs. The information in any one source may not be targeted for all types of use and the user may not realize when information is missing or irrelevant for their context. The profile of information included in SDSs commonly available in many labs is primarily targeted towards transportation of large quantities of chemical materials and may not be fully informative about use of a chemical in a lab setting, such as the example given for the flammability of acetic acid. To use information from any of these sources, researchers need to develop relevant criteria for the conditions of their research project, such as the Evaluation Matrix offered by Stony Brook (*19*).

During this process, students must ascertain if the data they find is at the right scale, for the right forms of chemicals and types of equipment, and reported under similar conditions as specified in their own lab procedures. They may need to convert units, or follow the original citation to determine if the data is appropriate for their project. The importance of checking multiple sources to determine the accuracy of data becomes evident. For example, ChemIDPlus Advanced and PubChem LCSS both include data from multiple sources for comparison (*15*, *17*). Suggested performance indicators and learning outcomes have formed the basis of many rubrics for incorporating these evaluation practices into class exercises (*23*). Further guidance for educators on skill development in using chemistry literature are provided in the CPT Supplemental Guidelines for Chemistry Literature (*12*), and the Information Competencies for Chemistry Undergraduates from the Special Libraries Association (*24*).

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Table 3. Information Search Process for Risk Assessment

Step	*Task (20)*	*Risk Assessment Examples*
Scope	determine the nature and extent of information needed	• Hazard classes (GHS, NFPA) • Physical & chemical properties (flash point, boiling point, vapor pressure, vapor density, pH) • Reactivity and incompatibility • Toxicity indicators (e.g., Median Lethal Dose – LD_{50}) • Exposure limits
Collect	access needed information effectively and efficiently	• SDSs, usually available from major chemical suppliers (e.g., Sigma) • Toxicity and property information from agency safety resources • Reactivity information specialized, often only available in HSDB
Evaluate	evaluate information and sources critically and incorporate selected information into knowledge base and value system	• Do the sources have all the information you are looking for? • Are the sources traceable to authoritative sources or original chemical manufacturer? • Are the data points for the right of form and concentration of the chemical (pure vs. dilute mixture)? • Do the data points have units, are they at the correct scale? If you have data from more than one source, do they agree or disagree? • Do you recognize your knowledge “gaps”
Apply	use information effectively to accomplish a specific purpose	• Have you considered properties at higher temperature or pressure (in case of over-heating or pressure build-up)? • Have you considered related properties such as vapor density or fine powder that could further impact handling?
Document	access and use information ethically, legally and in the context of cultural norms	• Did you include all reference data points used in your risk assessment? • Have you cited all references of data used in your assessment?

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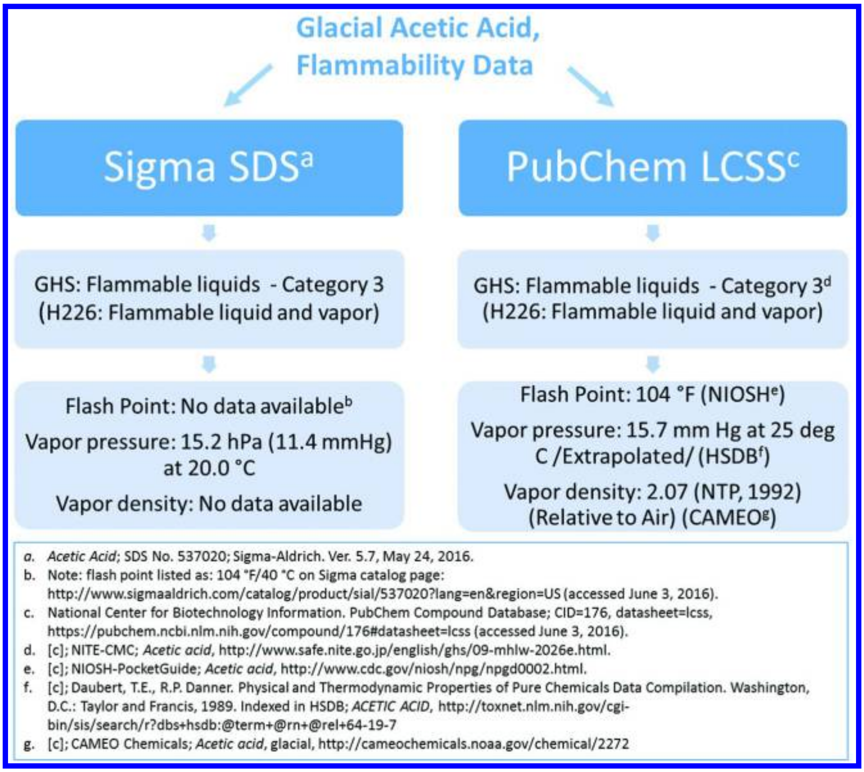

Figure 5. Flammability Data Search Process for Glacial Acetic Acid.

Integrating a Job Hazard Analysis Tool into an Existing Course

In 2015, the ACS Committee on Chemical Safety released their final report document, "Identifying and Evaluating Hazards in Research Laboratories (*11*)." Chapters 8-12 in this document give general guidance on five specific tools (Control Banding, Job Hazard Analysis, What-if Analysis, Checklists, and Standard Operating Procedure Development). Students can be taught to create and use any of the tools, but the Job Hazard Analysis (JHA) lends itself particularly well to both teaching and learning risk assessment and information literacy in the classroom setting. The JHA may go by various names all having similar formats and use, but the commonly recognized version today is the one that OSHA has publicized (*7*, *25*).

In fall 2012, an assignment using the JHA was integrated into the senior capstone course (CHE 4000) at Appalachian State University. This course has one to three sections each semester, depending on the number of students registered. For the period of assessment reported on in Appendix B, the enrollment was between 20 and 40 junior and senior chemistry majors each semester. All students in the ACS-certified degree track are placed into a "research active" section. The other students are grouped together in sections for those not actively engaged in research. The reason for this is that the assignments for the research proposals will be structured differently for students actively engaged in research.

The JHA was incorporated into research proposal activity because it was realized that teaching risk assessment could increase chemical safety, information literacy, and provide data to demonstrate the program effectiveness with regard to teaching chemical safety. From the course syllabus:

> The student will review of the background literature on the chosen topic. Working closely with the course instructor and faculty advisor, the student will develop a research proposal that will be presented to the faculty of the Department of Chemistry in written form and as a poster presentation following guidelines published by the American Chemical Society. You will also write a curriculum vitae (CV), a cover letter, a personal statement, a job hazard analysis and a research proposal that could be submitted to the Office of Student Research (OSR). Specific skills of preparing and defending a research proposal will be common to all students who complete the course (*26*).

The JHA is a particularly good tool to use for this assignment because it forces students to think about the task from a birds-eye view. To facilitate constructive critiquing when grading and for departmental assessment, each student completes the same assignment: Prepare one liter of a 1000 ppm stock solution of copper(II) ions from copper solid (CAS 7440-50-8) and concentrated nitric acid (CAS 7697-37-2) for Atomic Absorption Standards. A completed JHA for this process is shown in Appendix A.

To kick off the assignment, the Chemical Hygiene Officer (CHO), a chemistry department faculty member, attends the capstone course as a guest lecturer. At this time, the students are introduced to the psychology of risk response, various types of hazards, risk assessment, the hierarchy of controls, and the structure of a JHA tool. Students are given a specific template to use, instructions for filling out the template, and a list of credible websites where relevant information can be located. Should the school have a librarian familiar with the required information sources, that person could be invited to the initial lecture to discuss reliable sources. Students are typically given 2 to 3 weeks to complete their initial draft.

Dividing the process into an appropriate number of meaningful steps and assigning an appropriate risk level to those steps often proves particularly difficult for students. For example, the student might give the first step of the procedure as, "Pour 20 mL of concentrated nitric acid into the beaker." This completely bypasses a step which has a significant layer of hazard – removing the acid bottle from storage and transporting it to the hood or counter.

For this exercise, risk must be reported both quantitatively and qualitatively. Various tools are available in the industry to determine a "risk" value based on three parameters – severity of consequence, likelihood, and frequency of exposure. For this assignment, students use a tool that assigns numerical values for the three factors on scales ranging from unlikely or minor to continuous or catastrophic. A semi-quantitative value may be calculated by multiplying the assigned values to estimate risk (*27*). In most cases, risk determination is a new concept for the

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students and can be exaggerated or underestimated easily based on their nascent judgment and limited knowledge of hazards. Grading on student assigned risk values is based on relativity for this exercise. Students must assign the greatest numerical values to the high risk steps and they are not penalized if the numerical values on all steps are inflated, so long as the riskiest step is assigned the highest numerical value.

Students in the capstone course who are actively performing research must also develop a JHA later in the semester for a chemical or task being used in their research project. In this way, these students must apply what they have learned in the initial JHA assignment to an actual laboratory project. This research JHA is a graded component of their final senior research proposal. Students are encouraged to discuss their research JHA with their advisor and obtain an approval signature. Again, this is not a new idea. In 1964, Livingston argued that risk assessment (or what he refers to as "safety considerations") should be added to research proposals. As defined by Livingston, "Safety considerations are those mental processes that determine if hazards to health or property values are likely to be involved in a proposed course of action, and evaluate the steps (*6*)."

Assessing Learning To Demonstrate Acquired Knowledge and Skills

Once the draft is submitted, it is critiqued with comments for improvement by the CHO. Students are given the opportunity to improve their assignment based on the feedback before resubmitting it for grading. If desired, students may schedule appointments with the CHO to review their critiqued draft before preparing their final tool. How reflection aids the accommodation to assimilation process for learning risk assessment is discussed in Appendix B. The purpose of this assignment is not to produce a perfect assessment tool, but to teach students how to think about laboratory hazards, risk, controls (or barriers), and use research information to support their ideas.

The student JHAs are graded on a range of criteria such as considering the hazards associated with the chemical and equipment, the method of risk assessment, and the selection of risk management controls (summarized in Table 4). The full grading rubric used to assess competence is shown in Appendix D. This assignment has been used for the safety component of our departmental program assessment since the fall semester of 2014.

For departmental assessment purposes, the JHA assignment in all sections of the capstone course addresses our program goal, "To acquire a thorough knowledge of laboratory methods and techniques." The student learning outcome (SLO) for this goal that is being assessed is, "Students will evaluate and manage experimental hazards and assess risk." The SLO will be met if, "Seventy percent (70%) of the students score a sum of at least 30 points (60% or "competent") out of a possible 50 points on their completed assignment." This SLO has been assessed for a total of five semesters from fall semester of 2014 through the spring semester of 2016. Evaluation of the assessment is reported in Appendix B.

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Table 4. JHA Grading Criteria

Major Components	*Ideal Documentation*
Header & Footer Information	Job location, date, person preparing the tool, PI signature
Equipment & Chemicals Required	Engineering controls, equipment, chemicals, PPE, ER
Hazards Checklist	Chemical, physical and health hazards
Steps Accurately Describe the Task	Adequate number provided, major steps identified
Personal Protective Equipment	Type and use well defined and documented
Significant Hazards Identified	Chemical hazards, process hazards, equipment hazards
Risk Determination	Method stated quantitatively and qualitatively and appropriately assessed for each step
Controls Sufficient to Lower Risk	Exposure controls, engineering controls, administrative, ER controls, reactivity, environmental/waste, documentation

Overall, the response to this assignment from the students has been very positive. Students will often ask at the end of the semester, "Why don't we learn this earlier in the major?" One student who went on to perform a summer internship wrote back saying,

> We had a company-wide Safety Trivia Day where we got into groups of 4 or 5. It was mainly the interns vs. the employees. They were simple questions about PPE, what to do if you encounter a spill, what to do in cases of emergency, and a few questions based on all of the things we went over in the safety class for research. Two of the questions specifically were "What does GHS stand for?" and "What does JHA stand for?" I highly doubt that many pharmaceutical companies have a Trivia Day, but I'm sure many of them require their employees to know these kinds of things. So, thanks again for teaching me these things in the research safety class (*28*)!

After consideration of these types of comments, the department has moved the JHA assignment to CHE 3000, a junior level introduction to chemical research course. Students in the ACS-certified degree track will continue to complete a JHA based on their research in the capstone course (CHE 4000).

Conclusion

There is a widely held belief that students who graduate with an undergraduate degree in chemistry will have acquired a broad knowledge of a number of supporting skills, including chemical safety, information literacy and ethics, and that this knowledge will have been gained from a cumulative exposure to general rules and various experimental procedures. However, observations from thirty years of teaching undergraduate chemistry majors indicate that it is currently unlikely students have been exposed to complex chemical safety subjects such as risk analysis, hazard determination, toxicant exposure control (aside from putting on gloves and goggles), understanding regulatory agencies and regulations, and how to find peer-reviewed information on toxicants. A dearth of recorded documentation of safety planning in academic research labs suggests it is regarded as secondary to designing chemical procedures at the research level.

Future chemists must learn to work safely with chemicals. Changing culture does not happen spontaneously – or even quickly. The concepts of "safety culture" or "information literacy" are not new and chemical educators must be part of their advancement in the curriculum from middle school on. Educators must be willing to incorporate and embrace the proactive paradigm for teaching both chemical safety and information literacy in as many different ways as possible. If we are expecting a paradigm shift in academic ethical culture to occur, new competencies must be taught as part of the curriculum. Learning these critical thinking and application skills and knowledge should be treated no differently than any other subject.

Students need to learn to effectively recognize hazards, assess and minimize the risks presented by those hazards, and prepare for emergencies (*29*). They should be exposed to chemical safety early and often to facilitate accommodation, which will, in turn, make the assimilation of new knowledge easier later. Students who develop competencies in chemical safety as undergraduates early in their research career creates researchers with a strong "safety culture" who can assimilate more complex chemical safety concepts easier as they progress in their career. Transfer of knowledge into the lab can be more successful if research advisors and mentors understand chemical safety learning objectives and encourage student learning. The theory of risk assessment should be taught to every future chemist. Universities should not only be teaching chemical safety, they should be producing chemistry graduates with concentrations in chemical safety or occupational health & safety who have the knowledge and skill to make informed decisions when assessing the hazards of a laboratory.

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Appendix A – Example JHA for Copper Digestion

Table A1. JHA (Completed Example)

	Job Hazard Analysis – Copper Digestion Job Location: 452 GWH Science Laboratory Group: N/A Date: 03.07.16			
	Activity or Job	Prepare one liter of a 1000 ppm stock solution of copper(II) ions from copper solid (CAS 7440-50-8) and concentrated nitric acid (CAS 7697-37-2) for AAS standards.		
	Completed By	Samuella Sigmann		
	Equipment and Chemicals Required	Metal free volumetric and graduated glassware, metal free Nalgene storage bottle, wash bottle, analytical balance, stirring hotplate w/magnet, copper metal (5N), metal free nitric acid, ultrapure DI water, wire cutter PPE Required: chemical splash goggles, chemical resistant gloves*, lab coat or apron, PPE Optional: face shield Emergency Equipment: Chemical fume hood, eyewash/shower unit, spill tray, stocked spill kit (non-organic absorbent for acid), first aid kit		
Step	*Work Steps and Tasks Describe the tasks / steps involved in the work – in order*	*Hazards Identified for each Task / Step*	*Risk Level (exposure x probability x consequence) Risk Nomogram used*	*Control / Safe Work Procedures for each Task / Step Controls to be implemented*
1	Obtain solid copper (Cu) wire from storage	Dermal contact	Very low <1	Worker will don chemical splash goggles and nitrile gloves Consider a lab coat or disposable apron. Ensure emergency equipment is tested and functioning

Continued on next page.

Table A1. (Continued). JHA (Completed Example)

2	Weigh solid copper (Cu) wire on analytical balance	Dermal contact Cut	Very low <1	Worker will don chemical splash goggles and nitrile gloves Consider a lab coat or disposable apron. Use body awareness when cutting copper wire
3	Transfer Cu wire to a 250 mL beaker	Same as Step 1	Same as Step 1	Same as Step 2
4	Place beaker containing Cu on stirring hotplate in hood, add magnet	Same as Step 1	Same as Step 1	Same as Step 2, PLUS clear hood of all unnecessary equipment and chemicals, especially organic solvents
5	Remove stock bottle of concentrated nitric acid from storage	Chemical splash – Corrosive; eye & skin damage; inhalation (toxic gas); Chemical spill; Oxidizing liquid	Moderate >20, but < 50	Nitric acid is very reactive. Do not underestimate this hazard. Include and review SDS as a control in this JHA. Wear all PPE as above, HOWEVER nitrile does not protect well for concentrated acid – double glove, add polyethylene or butyl rubber. Note location of and visually inspect spill kit w/ neutralizing material Review ER procedures If large spill occurs i.e. 2.5 L bottle, evacuate and notify

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Table A1. (Continued). JHA (Completed Example)

6	Transfer ~50 mL of con nitric to 250 beaker	Chemical splash – Corrosive; eye & skin damage; inhalation (toxic gas); Chemical spill; Oxidizing liquid	Moderate >20, but < 50	Same as step 5 plus work on spill tray
7	Add 30 mL of concentrated nitric acid (16 M HNO_3) Stir as needed	Chemical splash – corrosive; eye damage; inhalation (NO_2, toxic gas) Chemical spill Oxidizing liquid	Low <10	Wear all PPE as above, HOWEVER nitrile does not protect well for concentrated acid – double glove, add polyethylene or butyl rubber WORK IN FUME HOOD – lower sash; set up at least 6" inside Stir slowly with magnet on stir plate to displace nitrogen dioxide (NO_2) a toxic brown gas. Cover with watch glass if needed. Beaker graduations offer sufficient accuracy, so minimize cleaning by not measuring with other equipment.
8	Check for reaction completion – Ensure that Cu wire has completely dissolved	Chemical splash – corrosive; eye damage; Chemical spill	Moderate >10 but <50	Ensure that gas production has stopped before removing from fume hood Add face shield if close inspection of reaction beaker is required – do not hold over body

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Table A1. (Continued). JHA (Completed Example)

9	Add 300 mL of DI water to 1 L volumetric flask	Cuts	Low <1	Use situational awareness when handling glass to avoid dropping or bumping on counter
10	Quantitatively transfer the beaker contents to a 1 L volumetric flask and dilute to volume with DI water	Chemical splash – corrosive; eye damage; Chemical spill	Low <10	Same as Step 6
11	Transfer prepared stock solution to Nalgene storage bottle	Chemical splash – corrosive; eye damage; Chemical spill	Low <1	Same as Step 6 PLUS Check integrity of storage bottle. In addition to appropriate label elements (chemical name, date prepared, concentration) the storage bottle should have the words, "Contains Nitric Acid – do not mix with organic materials"
12	Wash glassware and rinse with 1 + 1 (8M) nitric acid, followed by ultrapure DI water	Chemical splash – corrosive; eye damage; Chemical spill	Low <10	Rinses can transfer from piece to piece and return to stock rinse solution to minimize neutralization – Ensure no organic materials or solvents in wash sink or in waste containers. All nitric acid waste containers should plastic and be labeled as such – CONTAINS NITRIC ACID; DO NOT ADD ORGANIC MATERIALS

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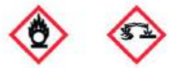
Table A1. (Continued). JHA (Completed Example)

13	Return all equipment to storage			Unplug electrical equipment Close hood sash Wash hands
Hazards Checklist: Chemical corrosive to skin, inhalation of NO_2 (and other gases evolved during this process) can cause may be fat, physical hazard of oxidizing liquid, heat of reaction, possible ER action if conc. nitric acid spills.				
Can someone be exposed to chemicals? Yes	If so, what is the nature of the chemical hazard? Nitric acid is a strong oxidizing acid. The concentrated form will cause blistering and discoloration of skin. Inhalation can cause respiratory edema. SDS Reviewed? Yes  GHS nitric acid, concentrated			
Can someone slip, trip or fall? Possible, but not likely	Can someone injure someone else? Not likely unless others are working in the lab without proper PPE			
Can someone be caught in anything? Not likely	Can someone strike against or make contact with any physical hazards? Not likely other than contact with oxidizing liquid. Possible electrocution hazard with stirring hot plate			
Laboratory Supervisor or PI Comments – This job can be eliminated by purchasing the stock solution if funds allow.				
Laboratory Supervisor or PI Signature: S B Sigmann				Date: 5/30/16
Employees Signature: S B Sigmann				Date: 5/30/16

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Appendix B – Assessment Results

The grading rubric shown in Table D1 was developed to evaluate ten areas of knowledge on the copper digestion JHA as well as standardize grading. During the assessment period for this assignment period, 103 assignments were evaluated. A summary of the data is shown in Figure B1.

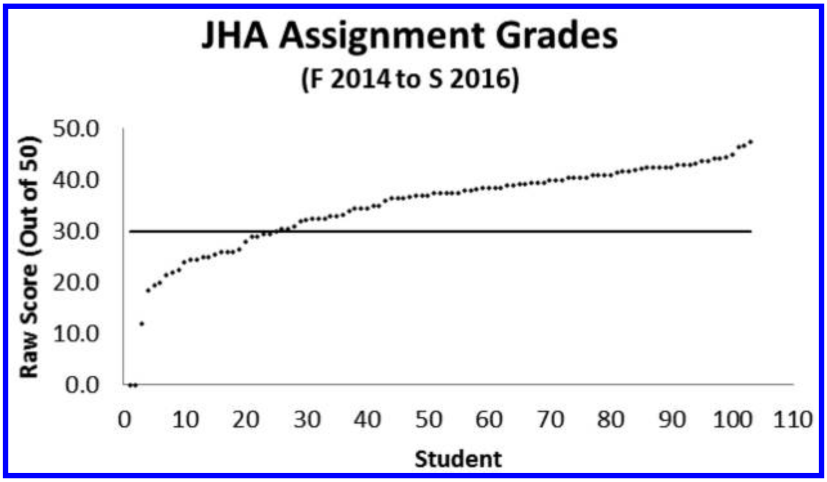

Figure B1. Assessment Data.

Although Figure B1 shows that the criterion (raw score = 30) was met over the full assessment period (77% of the students attained a grade of 60 or better), it should be noted that there were individual semesters when the criterion was not met.

In fall of 2014, the importance of reflective work for this assignment was shown by the data. That semester, the capstone course consisted of students actively engaged in research as well as those on non-research tracks. Students submitted their JHAs for critique and then improved the tools based on that feedback. Only 14 of the 17 students resubmitted their corrected drafts for grading and therefore 3 drafts were scored without corrections. Those grades were included in the grades for the semester assessment. Including the draft grades in the data for that semester resulted in an assignment average of 62% which does not meet the 70% criterion. By not considering the 3 drafts in the data set, the criterion is met at 77% scoring 30 or better.

The importance of reflective learning was also noted in spring 2015 when the students in the non-research section were unable to have the reflective learning experience due to poor timing of the lecture for that section. The lecture was presented too late in the semester and we simply ran out of time to submit a JHA, allow time for comments, and score the JHAs for that section. To compensate for this, students in that section were given a document offering general flaws often seen in JHAs and suggestions for improvement. Even with this "general critique", the assessment criterion for that section (spring 2015) was not met. Only 50%

Flener Lovitt et al.; Integrating Information Literacy into the Chemistry Curriculum
ACS Symposium Series; American Chemical Society: Washington, DC, 2016.

of the students scored 30 or better. Compare this to the section with the research students (spring 2015) where time for reflective work was given and the criterion was met at 82.3%. It is possible, however, that actively performing laboratory research contributed to the higher assignment scores for that section.

Appendix C – Information Sources

Reliable information is vital to completing a useful risk assessment. The links listed in Table C1 will connect chemical workers to more reliable (and in most cases peer reviewed) online resources so that they may access the necessary information to understand the hazards associated with the chemicals used in their laboratory. This will enable workers to create more robust risk assessment tools. These databases and sources are offered by various agencies for free use on the Internet. Please note that some sources are intended for HAZMAT or industrial situations and the information may not be specific to use in a lab and/or quite technical. The Acronym Finder (http://www.acronymfinder.com/) and the Wayback Machine (http://archive.org/web/web.php) of archive webpages may be useful in interpreting data and retrieving broken links.

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Table C1. Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
CAMEO Chemicals http://www.cameochemicals.noaa.gov/search/simple (Available as a web application, mobile website, or as a downloadable application.)	National Oceanic and Atmospheric Administration (NOAA)	The Computer-Aided Management of Emergency Operations (CAMEO) chemicals software allows the user to mix chemicals in a virtual scenario to check for reactivity between chemicals and chemical groups. This is helpful for checking chemical compatibility for storage or waste containers. NB: primarily intended for HAZMAT
Chemical Safety Searches https://en.wikibooks.org/wiki/Chemical_Information_Sources/Chemical_Safety_Searches	American Chemical Society (ACS) Division of Chemical Information (CINF)	The American Chemical Society (ACS) Division of Chemical Information (CINF) provides a review of chemical safety information sources with tips for searching, includes both open and subscription based sources.

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Table C1. (Continued). Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
Chemical Sampling Information https://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html	US Department of Labor (DOL), Occupational Safety & Health Administration (OSHA)	OSHA provides data for those conducting industrial hygiene investigations. Data is concise with known health effects (HE).
ChemIDPlus Advanced http://chem.sis.nlm.nih.gov/chemidplus/	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	The National Library of Medicine (NLM) Specialized Information Services (SIS) provides ChemIDPlus Advanced to pull in chemical information from a variety of agency databases where the search substance is listed. Very powerful. Included in TOXNET.
CHRIS http://www.uscg.mil/hq/nsfweb/foscr/ASTFOSCRSeminar/References/CHRISManualIntro.pdf	US Coast Guard (USCG)	The Chemical Hazards Response Information System (CHRIS) provides useful information on chemical compatibility and emergency response for chemical incidents, especially in transport. NB: primarily intended for HAZMAT
CRW http://response.restoration.noaa.gov/oil-and-chemical-spills/chemical-spills/response-tools/chemical-reactivity-worksheet.html	National Oceanic and Atmospheric Administration (NOAA)	The Chemical Reactivity Worksheet (CRW) is part of the Computer-Aided Management of Emergency Operations (CAMEO) software suite as a downloadable application. It can be used to generate a worksheet to include with a risk assessment. NB: primarily intended for HAZMAT

Continued on next page.

Table C1. (Continued). Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
CSB Reports http://www.csb.gov/	US Chemical Safety and Hazard Investigation Board (CSB)	The US Chemical Safety and Hazard Investigation Board (CSB) is authorized by the Clean Air Act Amendments of 1990 (CAA) as an independent agency that investigates high profile chemically related accidents. Investigations primarily focus on industrial incidents, but provide important root cause information and lessons learned.
e-CFR http://www.ecfr.gov/cgi-bin/text-idx?tpl=%2Findex.tpl	US Government Printing Office (GPO)	At the Electronic Code of Federal Regulations site, regulatory information can be located. Especially useful are those in Titles 29 (Labor) and 40 (Protection of Environment).
eChemPortal http://www.echemportal.org/	Organisation for Economic Co-operation and Development (OECD)	eChemPortal is the OECD Global Portal to Information on Chemical Substances. Federated searches can be conducted across several data sources for chemical substances, properties and GHS classification schema. Indexed by ChemIDplus Advanced.
EDF Scorecards http://scorecard.goodguide.com/index.tcl (add the indicated information in parenthesis to the above address to access the components)	National Environmental Defense Fund (EDF)	The EDF Scorecard program is recognized by the EPA as a reliable database. Chemical Profiles for 11,200+ chemicals (/chemical-profiles) Health Effects data compiled based on the specific target organ or type of disease (/health-effects) Regulations based chemical lists (/chemical-groups)

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Table C1. (Continued). Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
Enviro-Health Links for Laboratory Safety http://sis.nlm.nih.gov/enviro/labsafety.html	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	The Specialized Information Services (SIS) Enviro-Health Links for Laboratory Safety from the National Library of Medicine (NLM) lists information sources relevant for laboratory scale work, including nonchemical hazards.
ERG http://phmsa.dot.gov/hazmat/library/erg	US Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA)	The DOT Emergency Response Guide categorizes hundreds of substances into groups based on emergency response protocols and provides appropriate response information in Guides 111 through 172. NB: primarily intended for HAZMAT (available in mobile applications)
GHS http://www.unece.org/fileadmin/DAM/trans/danger/publi/ghs/ghs_rev04/English/ST-SG-AC10-30-Rev4e.pdf	United Nations Economic Commission for Europe (UNECE)	Globally Harmonized System of Classification and Labelling of Chemicals (GHS) Fourth revised edition.
GHS Purple Book https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf	US Department of Labor (DOL), Occupational Safety & Health Administration (OSHA)	OSHA provides a condensed guide to GHS at this link. (US categories)
HSDB http://www.nlm.nih.gov/pubs/factsheets/hsdbfs.html	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	The Hazardous Substance Data Bank (HSDB) from the National Library of Medicine (NLM) is an expert reviewed database for locating chemical toxicology, regulatory information, and physical properties, etc. for c. 5,000 chemicals. Included in TOXNET.
HAZCOM CFR 1910.1200 http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099	US Department of Labor (DOL), Occupational Safety & Health Administration (OSHA)	Code of Federal Regulations 1910.1200 Hazard Communication (HAZCOM) Standard includes GHS definitions.

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Table C1. (Continued). Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
INCHEM http://www.inchem.org/	World Health Organization (WHO), International Programme on Chemical Safety (IPCS)	INCHEM links to especially useful sites for risk assessment purposes. The site can be searched by registry number (CAS) or compound name. Concise International Chemical Assessment Documents (CICADs) (/pages/cicads.html) Health and Safety Guides (HSGs) (/pages/hsg.html) International Agency for Research on Cancer (IARC) - Summaries and Evaluations (/pages/iarc.html) International Chemical Safety Cards (ICSCs) (/pages/icsc.html)
Internet Resources for (M)SDSs "MS-Demystifier" http://www.ilpi.com/msds/ #Internet	Interactive Learning Paradigms, Inc.	The Safety Emporium laboratory safety supply company provides an overview of dozens of chemical information sites where (M)SDSs from manufacturers, various government agencies, and nonprofit sources can be accessed . A glossary of common MSDS terms is also available at. Includes a glossary and the
IRIS http://www.epa.gov/iris/	Environmental Protection Agency (EPA)	The International Risk Information System (IRIS) system evaluates the health risk posed by numerous substances that occur in the environment on the human population. Indexed by ChemIDplus Advanced.
Laboratory Biosafety Manual http://www.who.int/csr/resources/publications/biosafety/ WHO_CDS_CSR_LYO_2004_11/ en/	World Health Organization (WHO)	The 3rd edition of the WHO biosafety manual is very complete and contains risk assessment information

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Table C1. (Continued). Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
Lab Safety Information Guide http://library.stanford.edu/guides/lab-safety	Stanford University Library	The Stanford Library provides an extensive guide of lab safety related information sources, ranging from substance information to protocols and reaction conditions; some sources may not open for external users.
Lab Standard CFR 1910.1450 https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106	US Department of Labor (DOL), Occupational Safety & Health Administration (OSHA)	Code of Federal Regulations 1910.1450 is commonly referred to as the "Lab Standard". Most academic research laboratories will fall under this regulation in OSHA states.
NIOSH http://www.cdc.gov/niosh/pubs/type.html	Centers for Disease Control and Prevention (CDC)	National Institute for Occupational Safety and Health (NIOSH) link to chemical databases.
NIOSH Pocket Guide http://www.cdc.gov/niosh/npg/default.html		The searchable NIOSH Pocket Guide to Chemical Hazards. Indexed by ChemIDplus Advanced.
NSCEP http://www.epa.gov/nscep/index.html	Environmental Protection Agency (EPA)	The National Service Center for Environmental Publications (NSCEP) site allows one to search for EPA publications (print and digital) by number or title.
PubChem LCSS https://pubchem.ncbi.nlm.nih.gov/lcss/	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	The PubChem Laboratory Chemical Safety Summary (LCSS) data view is provided by the National Library of Medicine (NLM) National Center for Biotechnology Information (NCBI). The PubChem database aggregates chemical safety data from several sources, including several in this chart such as GHS, HSDB, ICSCs, etc. PubChem is searchable by compound name, structure and other common identifiers.

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Table C1. (Continued). Chemical Safety Information Sources List

Site/Link	*Agency or Source*	*Scope & Utility*
RoCs http://www.niehs.nih.gov/research/atniehs/dntp/assoc/roc/	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	Report on Carcinogens (RoCs). National Institute of Environmental Health Sciences (NIEHS) National Toxicology Program (NTP) report (congressionally mandated) on substances that put humans at risk for cancer.
Sigma-Aldrich Technical Bulletins http://www.sigmaaldrich.com/chemistry/chemical-synthesis/learning-center/technical-bulletins.html	Sigma-Aldrich Co.	Sigma-Aldrich offers technical bulletins as guidance on various topics of interest for laboratory workers, including handling air sensitive materials, conversion charts (needles, pressure, etc.), cleaning glassware, working in air free atmospheres, and safe handling of glassware.
TOXNET http://toxnet.nlm.nih.gov/index.html	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	The Toxicology Data Network (TOXNET) from the National Library of Medicine (NLM) allows one to search all the major toxicology databases from one site, including HSDB and ChemIDPlus Advanced.
WISER http://webwiser.nlm.nih.gov/ **WebWISER** Download: http://wiser.nlm.nih.gov/	US Department of Health & Human Services (HHS), National Institutes of Health (NIH)	The National Library of Medicine (NLM) provides the Wireless Information System for Emergency Responders (WISER) "to assist emergency responders in hazardous material incidents. WISER provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, human health information, and containment and suppression advice." Indexed by ChemIDplus Advanced.

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Appendix D - Grading Rubric for Job Hazard Analysis (JHA) for Copper Digestion

Assignment: Prepare one liter of a 1000 ppm stock solution of copper(II) ions from copper solid (CAS 7440-50-8) and concentrated nitric acid (CAS 7697-37-2) for AAS standards.

Students construct a JHA in the instructor provided template (see completed example in Appendix A). All references to additional hazard information, SOPs, risk matrices or other supporting information to control hazards should also be included in the template as links or as attachments. The student prepared JHAs are graded on ten (10) knowledge/information categories shown in Table D1.

Table D1. Grade Sheet for Copper Digestion

Grading Sheet for Copper Digestion JHA *30 is Competent*		
		Points
1	Header & Footer Information	
2	Equipment & Chemicals Required	
3	Adequate Number of Steps Provided to Accurately Describe the Task	
4	Major Steps Identified	
5	PPE Type & Use Well Defined	
6	Hazards Checklist	
7	Significant Hazards Identified in the Given Steps	
8	Method of Risk Determination Stated	
9	Risk Description is Appropriately Assessed for Step (not too high or too low)	
10	Controls Sufficient to Lower Risk	
Total		

Points are assigned as follows:

EXCELLENT (5 pts max)
COMPETENT (3 pts max)
NEEDS IMPROVEMENT [Needs Imp.] (1 pts max)

Example criteria to assign points in each category are shown below.

Required General Information

1. Header & Footer Information

EXCELLENT The JHA lists the job location, date, and person preparing the tool. Signed if hard copy.

COMPETENT One of the required items is missing.

NEEDS IMP. More than one of the required items is missing.

2. Equipment & Chemicals Required

EXCELLENT *Engineering Controls:* chemical fume hood, eyewash/shower unit; spill tray

Equipment: metal free volumetric and graduated glassware, metal free Nalgene storage bottle, wash bottle, analytical balance, stirring hotplate w/magnet,

Chemicals: copper metal (5N), metal free nitric acid, ultrapure DI water,

PPE: chemical splash goggles, chemical resistant gloves, lab coat or apron. (Optional: face shield)

ER: spill equipment

COMPETENT *Engineering Controls:* Chemical fume hood, eyewash/shower unit

Equipment: volumetric and graduated glassware, storage bottle, wash bottle, balance, stirring hotplate w/magnet, copper metal (form not specified), nitric acid, DI water

PPE: chemical splash goggles, chemical resistant gloves, lab coat or apron

NEEDS IMP. *Engineering Controls:* Chemical fume hood

Equipment: volumetric glassware, stirring hotplate, nitric acid, water

PPE: goggles and gloves

Steps

3. Adequate Number of Steps Provided to Accurately Describe the Task

EXCELLENT 8 – 12 unique, meaningful steps

COMPETENT 5 – 7 unique steps

NEEDS IMP. <5 steps

4. Major Steps Identified

EXCELLENT Obtain copper

Weigh solid copper (Cu) wire on analytical balance

Return copper

Transfer Cu wire to a 250 mL beaker

Place beaker containing Cu on stirring hotplate in hood, add magnet

Remove stock bottle of concentrated nitric acid from storage

Transfer ~50 mL of con nitric to 250 mL beaker

Return stock bottle of concentrated nitric acid to storage

Add 30 mL of concentrated nitric acid (16 M HNO_3) – beaker graduations offer sufficient accuracy. Stir slowly to displace nitrogen dioxide (NO_2) a toxic brown gas. Cover with watch glass

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Once gas production has stopped, check for reaction completion – Ensure that Cu wire has completely dissolved.

Add 300 mL of DI water to 1 L volumetric flask

Quantitatively transfer the beaker contents to a 1 L volumetric flask and dilute to volume with DI water

Transfer prepared stock solution to a labeled Nalgene storage bottle

Wash glassware and rinse with 1 + 1 (8M) nitric acid, followed by ultrapure DI water. Wash hands

COMPETENT Weigh solid copper

Transfer Cu wire to a beaker

Place beaker containing Cu on stirring hotplate in hood

Obtain acid

Add of concentrated nitric acid (16 M HNO_3) Stir slowly to dissolve

Once gas production has stopped, check for reaction completion

Transfer the beaker contents to a 1 L volumetric flask and dilute to volume with DI water

Clean up

NEEDS IMP. Weigh solid copper and transfer to beaker

Place beaker in hood

Add of concentrated nitric acid (16 M HNO_3) Stir slowly to dissolve

Dilute to volume with DI water

Personal Protective Equipment (PPE)

5. PPE Type & Use Well Defined

EXCELLENT Chemical splash goggles, gloves of best material documented), lab coat or apron

COMPETENT Goggles, gloves (material not documented), and lab coat

NEEDS IMP. Eye protection and gloves

Hazards

6. Hazards Checklist

EXCELLENT Chemical corrosive to skin, inhalation (toxic gas);

Physical hazard of oxidizing liquid, heat of reaction;

Possible emergency response action required if conc. nitric acid spills

COMPETENT Mention of at least one health hazard (corrosive to skin or lungs)

At least one physical hazard (heat of reaction, oxidizing acid).

NEEDS IMP. Mention of only health hazards.

7. Significant Hazards Identified in the Given Steps

EXCELLENT Dermal contact with metal

Chemical splash – corrosion to eyes, skin, and lungs

Toxic gas

Chemical spill possible

Oxidation hazard (incompatible with organic materials)

Supporting material supplied with JHA (SDS, SOP, etc.)

Electrical
Cuts
COMPETENT Chemical splash/corrosive material
Toxic gas
Chemical spill possible
Supporting material mentioned (e.g. See SDS for nitric acid)
Cuts
NEEDS IMP. Chemical splash/corrosive material
Cuts
No supporting material

Risk

8. Method of Risk Determination Stated
EXCELLENT Method given and risk stated quantitatively *&* qualitatively
COMPETENT Method given and risk stated qualitatively *or* quantitatively
NEEDS IMP. No method given – stated qualitatively
9. Risk Description is Appropriately Assessed for Step (not too high or too low)
EXCELLENT Risk assignments are proportional to actual risk
All steps of high risk are noted as high risk
Low risk steps are recognized
COMPETENT Most high risk steps are identified
Most low risk steps are recognized
NEEDS IMP. High risk steps are not recognized
Low risk steps are disproportionally assigned high risk values

Risk Control

10. Controls Sufficient to Lower Risk

EXCELLENT *Exposure Controls (*PPE): Worker will don chemical splash goggles, nitrile gloves add polyethylene gloves and a lab coat or apron. Add face shield if close inspection of reaction beaker is required – do not hold over body

Engineering Controls: WORK IN FUME HOOD – lower sash; set up at least 6” inside, use spill tray

Administrative Include and review SDS as a control in this JHA. Signed JHA. Information documented.

ER Controls: Spill kit w/ non organic neutralizing material, review ER procedures and spill kit use

Reactivity: Nitric acid is very reactive. Do not underestimate this hazard. Ensure no organic materials or solvents in wash sink or hood.

Environmental/Waste: In addition to appropriate label elements (chemical name, date prepared, concentration) the storage bottle should have the words, “Contains Nitric Acid – do not mix with organic waste”, Rinses can transfer from piece to piece and return to stock rinse solution to minimize neutralization

COMPETENT *Exposure Controls (PPE):* Worker wears goggles, gloves, and lab coat or apron.

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Engineering Controls: WORK IN FUME HOOD
ER Controls: Spill kit w/ neutralizing material.
Reactivity: Ensure no organic materials or solvents in wash sink.
Environmental/Waste: Collect waste and label.
NEEDS IMP. *Exposure Controls (PPE):* Worker wears goggles, gloves, and lab coat or apron.
Engineering Controls: WORK IN FUME HOOD
ER Controls: Spill kit w/ neutralizing material

References

1. Trager, R. UCLA chemist to stand trial for safety violations linked to Sheri Sangji death. *Chemistry World*; May 1, 2013. http://www.rsc.org/chemistryworld/2013/05/ucla-chemist-trial-safety-violations-linked-sheri-sangji-death (accessed Nov. 20, 2015).
2. Lippincolt, W. T. Safety and Health in Academic Laboratories. *J. Chem. Educ*. **1977**, 54, 719. http://pubs.acs.org/doi/abs/10.1021/ed054p719 (accessed June 8, 2016).
3. Currano, J. N. Teaching Chemical Information for the Future: The More Things Change, the More They Stay the Same. In *The Future of the History of Chemical Information;* McEwen, L. R., Buntrock, B. E., Eds.; ACS Symposium Series 1164; American Chemical Society: Washington, DC, 2014; Chapter 11, pp 169–196.
4. Gallion, L. A.; Samide, M. J.; Wilson, A. M. Demonstrating the importance of cleanliness and safety in an undergraduate teaching laboratory. *J. Chem. Health Saf*. **2015**, 22, 28−31. http://www.sciencedirect.com/science/article/pii/S1871553215000031 (accessed June 8, 2016).
5. Kemsley, J. Dow Chemical Teams Up With Universities On Laboratory Safety. *Chem. Eng. News*. 2012, 90, 21−23. http://cen.acs.org/articles/90/i44/Dow-Chemical-Teams-Universities-Laboratory.html (accessed Nov. 20 2015).
6. Livingston, H. K. Safety Considerations in Research Proposals. *J. Chem. Educ*. **1964**, *41*, A785–A789.
7. *Job Hazard Analysis; OSHA 3071; revised 2002*. United States Department of Labor, Occupational Safety and Health Administration. https://www.osha.gov/Publications/osha3071.html (accessed Nov. 20, 2015).
8. American Chemical Society, Committee on Professional Training. Undergraduate Professional Education in Chemistry: *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs*; American Chemical Society: Washington, DC, 2015. http://www.acs.org/content/dam/acsorg/about/governance/committees/training/2015-acs-guidelines-for-bachelors-degree-programs.pdf (accessed Nov. 20, 2015).
9. Blanchard, P. N.; Thacker, J. W. *Effective Training Systems, Strategies, and Practices*, Custom Edition; Pearson Custom Publishing, Pearson: New York, 2010; Chapters 1−5.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch003

10. Sigmann, S. B. *Using traditional safety rules to teach more advanced concepts in chemical hygiene.* CHAS 17, presented at the 249th American Chemical Society National Meeting & Exposition, Denver, CO, March 24th, 2015.
11. American Chemical Society, Committee on Chemical Safety, Hazard Identification and Evaluation Task Force. *Identifying and Evaluating Hazards in Research Laboratories.* Washington, DC, 2015. http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/identifying-and-evaluating-hazards-in-research-laboratories.pdf (accessed Nov. 20, 2015).
12. American Chemical Society, Committee on Professional Training. *ACS Guidelines Supplement: Chemical Information Skills*; American Chemical Society: Washington, DC, 2015. http://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/chemical-information-skills.pdf (accessed Nov. 20, 2015).
13. Alaimo, P. J.; Langenhan, J. M.; Tanner, M.; Ferrenberg, S. M. Safety teams: An approach to engage students in laboratory safety. *J. Chem. Educ.* **2010**, 87, 856−861. http://pubs.acs.org/doi/abs/10.1021/ed100207d (accessed June 8, 2016).
14. *Globally Harmonized System of Classification and Labelling of Chemicals.* United Nations, Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals (UNCETDG/GHS). New York and Geneva, 2003. http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html (accessed Nov. 20, 2015).
15. National Institutes of Health, National Library of Medicine, Specialized Information Services. *ChemIDPlus Advanced, Homepage*. http://chem.sis.nlm.nih.gov/chemidplus/ (accessed Nov. 20, 2015).
16. *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*, Updated Version; National Research Council. The National Academies Press: Washington, DC, 2011. http://www.nap.edu/catalog/12654/prudent-practices-in-the-laboratory-handling-and-management-of-chemical (accessed Nov. 20, 2015).
17. Kim, S.; McEwen, L.; Stuart, R.; Thiessen, P.; Gindulyte, A.; Zhang, J.; Bolton, E.; Bryant, S. PubChem Laboratory Chemical Safety Summary. American Chemical Society, Division of Chemical Education, Committee on Computers in Chemical Education, *ConfChem Newsletter Fall 2015*, November 5, 2015, http://confchem.ccce.divched.org/2015FallCCCENLP3 (accessed Nov. 20, 2015).
18. National Institutes of Health, National Library of Medicine, Specialized Information Services. *Enviro-Health Links for Laboratory Safety, Homepage*. http://sis.nlm.nih.gov/enviro/labsafety.html (accessed Nov. 20, 2015).
19. Stony Brook University, Environmental Health and Safety. *Hazard & Risk Evaluation Matrix, EHSDO368 (rev. 02/13).* http://www.asa.stonybrook.edu/asa/asaforms/EHSD0368/$FILE/EHSD0368.pdf (accessed Nov. 20, 2015).

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch003

20. American Library Association, Association of College and Research Libraries. *Information Literacy Competency Standards for Higher Education*; American Library Association: Chicago, IL, 2000. http://www.ala.org/acrl/sites/ala.org.acrl/files/content/standards/standards.pdf (accessed Nov. 20, 2015).
21. Stuart, R. B.; McEwen, L. R. The Safety "Use Case": Co-Developing Chemical Information Management and Laboratory Safety Skills. *J. Chem. Educ*. **2015**, 93, 516−526. http://pubs.acs.org/doi/abs/10.1021/acs.jchemed.5b00511 (accessed June 8, 2016).
22. American Library Association, Association of College and Research Libraries. *Framework for Information Literacy for Higher Education;* American Library Association: Chicago, IL, 2015. http://www.ala.org/acrl/standards/ilframework (accessed Nov. 20, 2015).
23. Institute of Museum and Library Services. *Rubric Assessment of Information Literacy Skills.* http://railsontrack.info (accessed Nov. 20, 2015).
24. Special Libraries Association, Chemistry Division and American Chemical Society, Division of Chemical Information. *Information Competencies for Chemistry Undergraduates: The Elements of Information Literacy*, 2nd ed. 2011. http://chemistry.sla.org/wp-content/uploads/cheminfolit.pdf (accessed Nov. 20, 2015).
25. Glenn, D. D. Job Safety Analysis: It's Role Today. *Prof. Saf.* **2011**, *56*, 48–57.
26. Ramey, M. A. R. *CHE 4000 Chemistry Seminar, Syllabus Section 101.* Smith Department of Chemistry, Appalachian State University: Boone, NC, 2016.
27. *Hazardous Substances Risk Assessment Form, Other Risk Assessment Resources.* Safetyrisk.net. http://www.safetyrisk.net/risk-assessment-form-templates/ (accessed Nov. 20, 2015).
28. Preston, L. Personal communication, September 14, 2015.
29. Hill, R. H.; Finster, D. C. *Laboratory Safety for Chemistry Students*; Wiley: Hoboken, NJ, 2010.

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Chapter 4

Is It Scholarly?

A Lesson Plan for Collaborative Chemistry Information Literacy

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This chapter describes a lesson plan that incorporates information literacy into an introductory chemistry course. The learning outcomes of the activity include becoming familiar with the peer-review process, knowing how to locate original research articles based on "clues" in a general news article, and differentiating between popular and scholarly periodicals. Students work in small groups in a collaborative classroom setting. The activities of the lesson plan are mapped to the Framework for Information Literacy for Higher Education. The lesson plan is supported by a literature review outlining the importance of collaborative, active learning in STEM courses, and highlights the correlation between information literacy instruction and student retention.

Introduction

Current trends in librarianship show a strong evidence-based preference for an active, collaborative learning process for acquiring information literacy skills. The Association of College & Research Libraries's revised Guidelines for Instruction Programs in Academic Libraries recommend that "instruction should employ active learning strategies and techniques that require learners to develop critical thinking skills in concert with information literacy skills (*1*)". These trends are not only mirrored, but perhaps more strongly reflected in the Science, Technology, Engineering, and Mathematics (STEM) education literature and best practices, including the American Chemical Society's Guidelines for

Chemistry in Two-Year College Programs. The American Chemical Society (ACS) pedagogy recommendations include "problem- or inquiry-based learning, peer-led instruction, group learning, learning communities or networks, writing throughout the curriculum, and technology-aided instruction (*2*)."

There is also growing evidence for the need for information literacy instruction in higher education in general. O'Kelly (*3*) demonstrates that at Grand Valley State University, for three consecutive years, 2012 -2014, there was a highly statistically significant correlation ($p < 0.0001$) between students having had library instruction and student retention. Although these results are a correlation, and the specific cause or reason for the link between library instruction and student retention is yet unknown, there is increasingly reason to consider information literacy instruction to be among high-impact educational practices (*4*).

Based on these trends and needs, as well as requests for information literacy instruction in an introductory chemistry course, I designed the following lesson plan for an introductory, non-majors chemistry course in a classroom designed specifically for collaboration with or without technology. The lesson plan focuses on finding known items and distinguishing popular from peer-reviewed/scholarly articles. This lesson plan was in part inspired by Kathleen Gregory's article in Issues in Science & Technology Librarianship "There is No Escape: What Google Can Teach Instruction Librarians (*5*)." In this commentary piece, she describes motivating factors embedded in Google's Advanced Power Searching online course and how they could be incorporated into STEM (Science, Technology, Engineering, Math) information literacy sessions. I had been intrigued by some of the methods she described, having taken the Power Searching course myself, and wanted to see if there were any way I could use some of the techniques in developing a lesson plan. That lesson plan is described in this chapter. It's a basic information literacy lesson plan, but it can serve as a springboard or scaffold to increasingly complex concepts in information literacy.

The lesson plan described here incorporates multiple active learning techniques, including problem-based learning, collaborative learning, and technology-aided instruction, to achieve the stated goals (see Table 1). Additionally, elements of the lesson plan are mapped to current trends and best practices based on a literature review, as well as mapped to threshold concepts according to the Association of College & Research Libraries' Framework for Information Literacy for Higher Education (*6*).

Lesson Plan: Is It Scholarly?

This lesson plan was developed for an introductory (non-majors) chemistry course, but could be adapted for a general chemistry majors course; ideally, this instruction would be used with freshmen and sophomore-level students because it focuses on lower-level information literacy skills. The lesson can be completed in a 50-minute class, although if students are very engaged and ask many questions, it could expand to 90 minutes or 2 hours. It is intended to take place in a library instruction room that is designed for collaborative learning (see Figure 1).

Table 1. Overview of Lesson Preparation

Suggested Materials:	• Computers or other internet-connecting devices • Copies of news article based on a peer-reviewed journal article, accessible through your institution. • Student handout. • Optional: whiteboards & markers • Optional: Steelcase Media:Scape (or similar) collaborative workstation, and corresponding projection capabilities
Learning Goals:	• Locate an original, scholarly research article from a "lead" in a popular periodical, newspaper or trade periodical article • Become familiar with the peer-review system and how it differs from other publishing models • Know the characteristics and features that differentiate scholarly and popular periodicals • Develop strategies for finding scholarly articles through library resources

Figure 1. Students engaged with the lesson plan in the collaborative classroom setting.

Anticipatory Set

The students are given a brief chemistry-related news article to read either prior to class, or at the beginning of the class session. The articles should be based on a study that appears in a peer-reviewed journal, specifically one to which the institution has access. To generate interest among the students, chosen articles could be humorous and/or timely, based on current headlines or topics currently covered in the chemistry course. Table 2 lists the articles used; articles may be selected to match a specific unit of chemistry, or for student engagement.

Table 2. Article Titles Used during Lesson Plan Execution

News Article Title	*Corresponding Journal Article Title*
First scientific method to authenticate world's costliest coffee, from the feces of the palm civet (*7*).	Selection of discriminant markers for authentication of Asian palm civet coffee (Kopi Luwak): a metabolomics approach (*8*).
Organic molecules found in Sutter's Mill meteorite, not previously found in any meteorites (*9*).	Processing of meteoritic organic materials as a possible analog of early molecular evolution in planetary environments (*10*).

In addition to the ScienceDaily news website used to obtain the two articles described here, Science News (*11*) and the "Seriously, Science (*12*)?" blog on the Discover Magazine website are good sources for science-related news items. Students are only shown the news article. On my campus, I use a print copy of the article in class because online access and our link resolver will automatically link to the journal article if students click on the DOI or other hyperlink in the journal citation. Part of this lesson is to gauge the students' ability to locate a known item, and allowing a simple click would defeat that purpose.

Input/Modeling

To engage students and prompt discussion of the article, students are asked to discuss among their table group whether the article is considered "scholarly," or peer-reviewed. Then the class is polled using an interactive polling website, such as Socrative (*13*). The differences between popular and scholarly are not discussed prior to this in the library session (though they may have been in their chemistry class). This step addresses prior knowledge and prompts discussion among students.

The librarian can use the student responses to lead a discussion about publication lifecycle and the peer-review process. Many students in an introductory science class are unaware of the scholarly publishing lifecycle, although some will have familiarity with the process.

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Once consensus is reached that the news article is not considered scholarly, the focus then shifts to identifying the peer-reviewed study on which the news item is based.

Students are asked to use any information in the news article to identify the more scholarly study. This is easily accomplished with ScienceDaily articles because the original study's citation is included at the end of the news article. Most students are able to identify this, and the librarian can ask a student to point this citation out using the Media:Scape workstations (individual laptops are connected to a large monitor at each table; screens from each table monitor can be projected onto large classroom screens for all to see).

Students are then asked to locate a PDF of the journal article. Students are encouraged to share with their table group their strategy for locating the journal article. On our campus, several paths can be used to gain full text access to these articles:

- Summon 2.0 search box on library home page
- DOI
- Article title/author
- Journal title search
- Database search
- Google Scholar search
- Google search

The Google search works because in order for a student (or anybody) to use the internet on our campus, they must first login with their university credentials, whether they are using Wi-Fi or a cable connection. The library link resolver works somewhat seamlessly to connect an authenticated user to our full-text content.

The purpose of this activity is three-fold:

1. Gauge prior knowledge about accessing known journal items.
2. Emphasize that not all of these methods would work from an off-campus setting unless the user were logged into the university website first.
3. Provide a challenge to solve.

After several students report locating the PDF, they are asked to share their method of access, and the librarian can explain the difference between on and off-campus access, and which of the above approaches will work better than others.

Students can at this point be instructed to use classroom whiteboards (if available) to summarize the differences between the peer-reviewed journal article and the popular news article. The librarian can lead a discussion of the key elements of a peer-reviewed science journal article, as well as the peer-review process itself. In particular, a discussion of publishing practices in the sciences, including open access opportunities and constraints could be included here.

The final part of the lesson plan is a modeling or guided practice component. The librarian can demonstrate for the students, while they follow along, how to use library resources, primarily Ulrichsweb, to verify whether a journal is peer-reviewed. This may also be verified by going to the journal's home page and locating submission guidelines and editorial policies.

Guided Practice/Check for Understanding

Students can then be given a poll/quiz that lists several journal titles and asks them to choose which one is not peer-reviewed, according to Ulrichsweb (or whichever method of verifying peer review is used).

Additional questions may be posed with the Socrative polling website, or by simply asking questions without the technology, for assessment purposes as desired.

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Threshold Concepts Addressed

This lesson plan can be mapped to the following threshold concepts presented as the frames of the ACRL's Framework for Information Literacy for Higher Education (*6*). Not every component of the frames will be addressed by the activities in the lesson plan, but this lesson touches on parts of the following concepts:

1. Authority is Constructed and Contextual (*6*)
   As students embark on a study within a discipline, they must soon understand who the experts of that discipline are. Level of expertise varies by discipline and information need. This lesson plan demonstrates this concept during the discussion about the news article "scholarliness," and the subsequent comparison with the peer-reviewed journal article.
2. Information Creation as a Process (*6*)
   The whiteboard activity and/or following discussion of the hallmarks of a peer-reviewed science article and a discussion about open access policies address the concept of information creation.
3. Information Has Value (*6*)
   A discussion of open access vs. traditional publishing addresses this concept.

Discussion

Active and Collaborative Learning in Librarianship:

This lesson plan supports current recommended pedagogy and best practices in both information literacy and STEM education. There is a nagging concern among librarians and academic faculty in general, that students entering higher education today are satisfied with superficial information literacy skills, courtesy of the ease of search engines such as Google and informational websites like Wikipedia (*14*). Indeed, Head and Eisenberg (2010), in their survey of college students' information-seeking behavior, discovered that "despite their reputation of being avid computer users who are fluent with new technologies, few students in our sample had used a growing number of Web 2.0 applications within the past six months for collaborating on course research assignments and/or managing research tasks (*15*).”

As discussed in the introduction, the ACRL’s Guidelines for Instruction Programs recommends an active learning approach to teaching information literacy (*1*). Likewise, although the new ACRL Framework for Information Literacy for Higher Education does not directly address pedagogy practices, the active language of the knowledge practices and dispositions associated with each frame/threshold concept strongly suggests active, collaborative learning (*13*). Megan Oakleaf has recommended employing active learning techniques to best assess student learning of information literacy using the new framework, pointing out: “What do all these examples have in common? They all employ active learning strategies (*16*).” The trend is becoming ubiquitous; in a recent study of information literacy pedagogy, Detlor, et. al., concluded “these findings suggest that ILI [Information Literacy Instruction] practitioners may wish to turn attention to the delivery of active ILI, and limit or even eliminate the delivery of passive ILI altogether (*17*).” This lesson plan supports this recent trend toward active learning of information literacy because there is very little lecture time included; students will be active participants throughout the session.

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Active and Collaborative Learning in STEM

The need for active/collaborative learning in STEM courses has been well-documented in recent years. In what is now considered a landmark study, Freeman, et. al. conducted a meta-analysis that examined 225 studies of student performance in STEM courses while comparing active versus passive pedagogy, the largest study of STEM education to date. Their findings showed that students in classes where the primary mode of instruction was active gained 6% on exam scores overall, and students in which the primary method of instruction was traditional lecture were 1.5 times more likely to fail (*18*). Moreover, Gregory suggests inserting information literacy into the most active part of a STEM course, the laboratory (*19*). Gregory examined two case studies in which information literacy was embedded into introductory chemistry and biology lab sections, respectively. Although scores on an Information Literacy (IL) assessment improved in both sections, results were not resoundingly significant. But these case studies provide the groundwork for future studies. Dolan and Collins assert that active learning “is when the instructor stops talking and students make progress toward a learning objective by actively doing something, such as working on a problem in a small group or using “clickers” to answer a conceptual question (*20*).”

The lesson plan described here, albeit brief and narrow in goals, does exactly that; students work collaboratively to solve a problem (locating a journal article based on clues in a news article), and answer questions with a clicker-type system (Socrative doesn’t require the use of clickers, just an internet-accessing device).

More specific to the field of chemistry, studies have also shown increased student learning when collaborative and problem-based teaching methods are applied. Process-Oriented, Guided-Inquiry Learning (POGIL) (*21*), a student-centered learning technique, has been increasingly adopted by chemistry departments at universities throughout the United States. Hein conducted a study comparing traditional lecture with POGIL techniques in a second-year organic chemistry course. She found that "the implementation of the POGIL method in the organic chemistry classroom has been shown to positively impact student proficiency on nationally standardized ACS organic chemistry exams (*22*)". Therefore, implementing an active, collaborative information literacy session into an active, collaborative chemistry course will maintain the learning style to which students have been acclimated.

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Future Applications/Scaffolding

Gregory's case studies imply another aspect of STEM information literacy that is pervasive in the literature: embedding IL instruction into STEM courses (*19*). The lesson plan described here was designed as a stand-alone, "one shot" session, however, it is poised to be built upon with increasingly complex levels of information literacy concepts and threshold concepts. Embedding – incorporating information literacy instruction throughout a course or curriculum, emphasizing point-of-need knowledge – is not a feature of this lesson plan. But this lesson plan could be part of a more comprehensive instruction plan that continues in future sessions that focus on the threshold concepts "Research as Inquiry," "Scholarship as Conversation," and "Searching as Strategic Exploration (*6*)."

The current lesson plan incorporates aspects of three of the threshold concepts of the ACRL Framework for Information Literacy, and is aimed at an introductory level in both the science and the information literacy. Scaffolding can be described as a process that allows a student new to a subject solve problems that they couldn't otherwise without assistance (*23*). Scaramozzino, in her article "Integrating STEM Information Competencies Into an Undergraduate Curriculum," includes a table mapping the ACRL Science & Technology Section's Information Literacy Standards into the information skills and learning objectives that each class level needs to achieve (*24*)." The table can be used to outline a scaffolding path for STEM IL, allowing for modifications to adapt to local needs. This could be applied to the lesson plan presented here if there were faculty agreement to embed the science librarian throughout the course (or over several years of a curriculum). For example, the activity in the current lesson plan that asks students to locate a scholarly journal article and compare it to a news article describing the same study certainly fulfills the "lower division student learning" criteria of the information skill:

"Information Channels: Demonstrate the function and uses of:

- General Web sources
- Mass-media sources
- Professional journal articles
- Academic databases
- Books (1.1, 1.2) (*24*)"

(Although books and general web resources are not part of this lesson plan.) Also included in current learning outcomes would be: "Describe peer-review process," under the upper-level student learning. This lesson could be built upon in future sessions, depending on course assignments and learning objectives, to include:

- "Locate conferences papers/posters (1.3)
- Recognize use of and find (1.2, 1.3):
    - subject specific peer-reviewed materials
    - standards
    - technical reports
    - patents
    - data sets and handbooks (*24*)"

These skills could be attained within the same course by adding a research paper requiring at least one of the sources in the list. A session introducing search strategies could also include an activity that focuses on developing search terms and narrowing a topic ("Searching as Strategic Exploration," in the ACRL Framework (*13*)).

This lesson plan could also act as a scaffold for more in-depth understanding of the scholarly communication/publishing lifecycle. Students could create annotated bibliographies to accompany a digital poster session (posters displayed electronically on monitors rather than printed on paper), for example, and the librarian could be embedded to consult on copyright and citation questions.

Conclusion

Studies are beginning to demonstrate the overall effectiveness of information literacy in a college curriculum, particularly with respect to student retention, and it appears likely that information literacy instruction will be included among the "high-impact practices" recommended for student retention and success. Presented here is a lesson plan for an introduction to scholarly communication in a single session of an introductory chemistry course. The lesson plan was designed with regards to current best practices of both information literacy and STEM education, both of which strongly encourage active, collaborative learning processes. Although this lesson plan only addresses a few of the threshold concepts found in the Framework for Information Literacy for Higher Education, it provides a basis for expansion to include all of the frames. Thus, this lesson plan can serve as a platform in an information literacy scaffold that can span a single course or an entire curriculum.

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References

1. Association of College & Research Libraries (ACRL). *Guidelines for Instruction Programs in Academic Libraries*; http://www.ala.org/acrl/standards/guidelinesinstruction (accessed Nov 29, 2015).
2. *ACS Guidelines for Chemistry in Two-Year College Programs*; http://www.acs.org/content/acs/en/education/policies/twoyearcollege.html (accessed Nov 24, 2015).
3. O'Kelly, M. *Correlation Between Library Instruction and Student Retention*; Presented at the Southeastern Library Assessment Conference, Atlanta, Georgia, November 16, 2015; ScholarWorks@GVSU.http://scholarworks.gvsu.edu/library_presentations/55/ (accessed June 6, 2016).
4. Murray, A. *Portal Libr. Acad.* **2015**, *15*, 471–487.
5. Gregory, K. *Issues in Science and Technology Librarianship* [Online] 2013, *Spring*; http://www.istl.org/13-spring/viewpoint.html (accessed June 6, 2016).
6. Framework for Information Literacy for Higher Education | Association of College & Research Libraries (ACRL). http://www.ala.org/acrl/standards/ilframework (accessed Nov 28, 2015).
7. First scientific method to authenticate world's costliest coffee, from the feces of the palm civet. *ScienceDaily*; http://www.sciencedaily.com/releases/2013/08/130821124552.htm (accessed Nov 30, 2015).
8. Jumhawan, U.; Putri, S. P.; Yusianto; Marwani, E.; Bamba, T.; Fukusaki, E. *J. Agric. Food Chem.* **2013**, *61*, 7994–8001.
9. Organic molecules found in Sutter's Mill meteorite, not previously found in any meteorites. *ScienceDaily*; http://www.sciencedaily.com/releases/2013/09/130910171440.htm (accessed Nov 30, 2015).
10. Pizzarello, S.; Davidowski, S. K.; Holland, G. P.; Williams, L. B. *Proc. Natl. Acad. Sci. U.S.A.* **2013**, *110*, 15614–15619.
11. Science News. https://www.sciencenews.org/ (accessed Jun 7, 2016).
12. Discover. *Seriously, Science?* http://blogs.discovermagazine.com/seriouslyscience (accessed Jun 7, 2016).
13. Socrative. http://www.socrative.com/ (accessed Jun 7, 2016).
14. Diekema, A. R.; Holliday, W.; Leary, H. *Libr. Inf. Sci. Res.* **2011**, *33*, 261–268.
15. Head, A. J.; Eisenberg, M. B. Truth Be Told: How College Students Evaluate and Use Information in the Digital Age. *Project Information Literacy Progress Report* [Online], November 1, 2010. ERIC. http://eric.ed.gov/?id=ED535166 (accessed June 6, 2016).
16. Oakleaf, M. *J. Acad. Libr.* **2014**, *40*, 510–514.
17. Detlor, B.; Booker, L.; Serenko, A.; Julien, H. *Educ. Inf.* **2012**, *29*, 147–161.
18. Freeman, S.; Eddy, S. L.; McDonough, M.; Smith, M. K.; Okoroafor, N.; Jordt, H.; Wenderoth, M. P. *Proc. Natl. Acad. Sci. U.S.A.* **2014**, *111*, 8410–8415.
19. Gregory, K. *Issues Sci Technol Libr.* **2013**, *10*, F49G5JSJ.
20. Dolan, E. L.; Collins, J. P. *Mol. Biol. Cell* **2015**, *26*, 2151–2155.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch004

21. Moog, R. S.; Spencer, J. N. *Process Oriented Guided Inquiry Learning (POGIL)*; ACS Symposium Series 994; American Chemical Society: Washington, DC, 2008.
22. Hein, S. M. *J. Chem. Educ.* **2012**, *89*, 860–864.
23. Kessinger, P. *J. Inf. Literacy* **2013**, *7*, 33–59.
24. Scaramozzino, J. M. *J. Libr. Admin.* **2010**, *50*, 315–333.

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Chapter 5

Chemistry in Context: Integrating Chemical Information Literacy, Scientific Writing, and Contemporary Issues in the First-Year Undergraduate Curriculum

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A broad range of information and communication competencies are required of science professionals and a scientifically literate populace. To systematically develop such knowledge, skills, and attitudes, undergraduate students must be exposed early and often to learning opportunities and instruction that explicitly embed these goals within and across disciplinary contexts. This chapter describes a successful example of chemical information instruction and writing practice in a large-enrollment General Chemistry lecture course populated by a diversity of science and engineering majors. Highlighted are the objectives, design, iterative implementations, outcomes, challenges, and future adaptations of a project titled "Chemistry in a Sustainable Context".

Introduction

Students earning an undergraduate degree in science are typically expected to: have knowledge of the ethical, historic, philosophical, and environmental dimensions of problems facing scientists, as well as the general public; make use of modern library search tools and strategies to locate and retrieve scientific information about a particular topic; and be able to critically evaluate and communicate the results of their findings to scientists and non-scientists alike (*1–5*). These information literacy skills, both general and discipline-specific, are widely recognized as essential to many professions (*6–8*) and the broader goals of science literacy (*9*).

General chemistry, which is a required course for most science and engineering majors, offers a fertile ground for the early integration of information instruction. Information competencies and learning standards are well-delineated by the Association of College & Research Libraries (ACRL) for all disciplines (*10*, *11*) and for Science and Engineering/Technology (*12*), and further distilled by the Chemistry Division of the Special Libraries Association (SLA) and the American Chemical Society (ACS)'s Division of Chemical Information (*13*). Alignment of the standards and teaching, however, often places chemical information instruction in the later part of the college curriculum (*14*). In fact, published examples at the introductory level are few and typically involve laboratories or non-majors courses (*15–26*). Various factors (*27*), including class sizes, time, resource availability, relevance to coursework, and librarian support, can present significant barriers for university instructors and programs aiming to develop "sustainable, transferrable" information literacy (*28*) starting in the first year of study.

Despite these challenges, the author has introduced and refined a "Chemistry in a Sustainable Context" project in the third course of a three-quarter general chemistry lecture sequence for science and engineering majors, as well as pre-professionals in health-related studies, at a large, research-intensive public university. The capstone project incorporates elements of the first-year experience – critical inquiry, writing, information literacy, and collaborative learning – that are listed among the American Association of College & Universities (AAC&U)'s ten "high impact educational practices" shown to increase rates of student retention and engagement (*29*). There is precedent for these outcomes in chemistry. For more than two decades, intentionally designed writing assignments in general chemistry have been used as a tool to augment students' understanding, critical thinking, and motivation and interest (*30–32*). More recently, longitudinal data have confirmed that exposure to the scientific literature and information competencies in a first-year chemistry (laboratory) course promotes students' performance and persistence in the sciences (*22*, *23*).

Project Motivation

From materials, infrastructure and transportation, to energy, climate and the environment, agriculture and food, lifestyle and health, chemistry impacts every aspect of our daily life (*33*). By connecting real-world issues with scientific theories and advances, one heightens her/his awareness and ability to make informed decisions as citizens and consumers (*34*). The general chemistry capstone project, "Chemistry in a Sustainable Context", is intended to introduce a diversity of science and engineering majors at an early stage in their university education to the library and scientific literature, and to engage them through explanatory writing in the application of general chemistry-level concepts to broader contexts and contemporary science issues of particular interest to them. More specifically, a student completing this project is expected to gain:

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(1) knowledge of the scientific research process and methods for conducting a scientific literature search effectively and efficiently;
(2) practice in science communication skills, including the ability to collect and condense material from different sources, to write (or speak) in a professional style appropriate to the readership, and to convey information logically, accurately and persuasively;
(3) a greater social awareness and appreciation of the integral relationship between chemistry and society, as well as a student's chosen career path.

That such knowledge, skills, and attitudes are transferrable to other classes, undergraduate research/internships/employment, and a range of professions is also underscored.

Project Design and Delivery

At the University of California, San Diego, there are typically four to five high-enrollment (300+ students) sections of general chemistry that are offered concurrently each academic quarter. The project was conceived by the author, an instructor for one of the *General Chemistry III* course sections, in response to calls for chemistry education reform (*35*, *36*). Since its first implementation in 2010, the project theme has shifted from a specific chemical compound to encompass a more widely appealing set of topics (loosely) associated with sustainability, a major research and education focus of the university and its local community (*37*, *38*), as well as the global enterprise (*39*). Informed by the literature and students' experiences, the project has also evolved in terms of the course-integrated instruction in chemical information that has been designed to support it. In its current format, students are required to select and explore - in written or video (or other creative) format - a question of their choice, using the chemical principles introduced in the general chemistry course sequence.

The project is completed in three stages over the ten-week academic quarter as students: (1) become acquainted with the research process (non-graded); (2) select a topic, conduct a preliminary literature search, and receive teaching assistant (TA)/instructor feedback (40% of project grade); and (3) compose and submit their final research essay/video (60% of project grade). The learning outcomes, assessment criteria, and detailed instructions are circulated via the course website, and emphasized in lectures. To further reinforce the project's value – by demonstrating chemistry's central perspective within science, its role in society, and its connection to various professions – each lecture is launched with a "Chemistry in Context" literature example related to the day's topic (see Figure 1).

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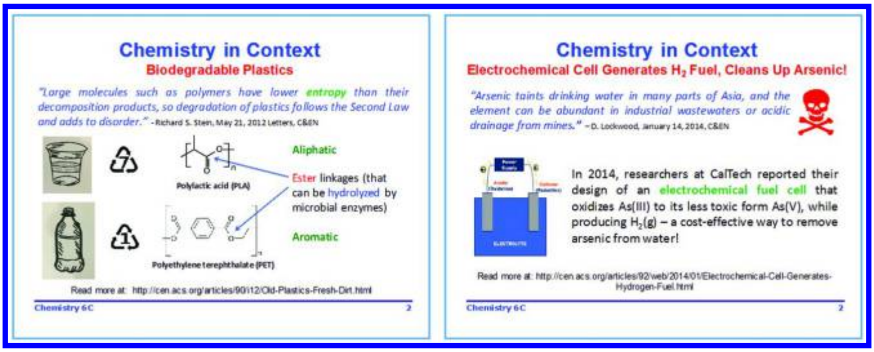

Figure 1. Examples of "Chemistry in Context" slides featuring innovations and innovators in chemistry, drawn from both the scientific and popular literature, that are projected at the beginning of a lecture.

Part 1. Learn about the Nature of Scientific Information and the Research Process.

Before they compose their capstone essays, students should be introduced to and afforded opportunities to apply basic information literacy competencies. These include knowledge of library tools and services, the flow of scientific information, the nature and purpose of different types of scientific literature, the methods that can be used to construct a search, and the need to evaluate the authority and credibility of different sources (*13*). Through the various iterations of the project, the chemistry faculty has tried several approaches to integrating this information and practice within the course, working within the constraints of limited class time and an already full curriculum.

Critical to all revision cycles has been the participation of the Chemistry & Biochemistry librarian, who has made herself available for student consultations and contributed to the development of instructional materials (*17*, *21*). At the onset, the librarian provided input on a Research Guide designed by the course instructor, and then created a complementary online Library Guide for the class (see Figure 2) (*40*). In early project renditions, the librarian also gave a brief presentation during one of the regularly scheduled *General Chemistry III* lectures. It was valuable for the students to become acquainted with the librarian – putting a 'face to the name', and lowering barriers to seeking assistance in later stages of the project (*17*) – but the session was too dense in content and not very participatory.

To address these deficiencies, the librarian helped the course instructor to create and refine a collaborative learning exercise that was intended to be facilitated by the graduate TAs in their weekly 50-minute discussion sections, which have an enrollment cap of 40 students. In advance of this literature tutorial, the librarian and course instructor met with the TAs to discuss both content and pedagogical strategies. Given a general interest article, the activity required students to define a research topic, to create a relationship diagram (described vide infra) and list of searchable terms, and to use databases (specifically, Web of

Science and Academic Search Complete) to find and retrieve from the primary, secondary, and tertiary literature more detailed and current information about the chemistry highlighted. Students were encouraged to bring their own computers so that they could participate fully in the exercise.

Overall, this tutorial proved to be more effective than a lecture in engaging students in a literature search, but section attendance was generally sporadic and students' preconceptions of the tutorial's utility was mixed (likely because it was conducted by the TAs and there was no grade associated with it). In the most recent generation of the project, a 1-hour interactive workshop on the research process was hosted by the course instructor outside of the regularly scheduled class time. In this adaptation of the TA-led tutorial, the students are guided through the steps they will take to complete the capstone project – how to prepare, search, read, and write - starting with their topic of choice. The demonstration and discussions were captured by podcast, enabling as broad participation as possible.

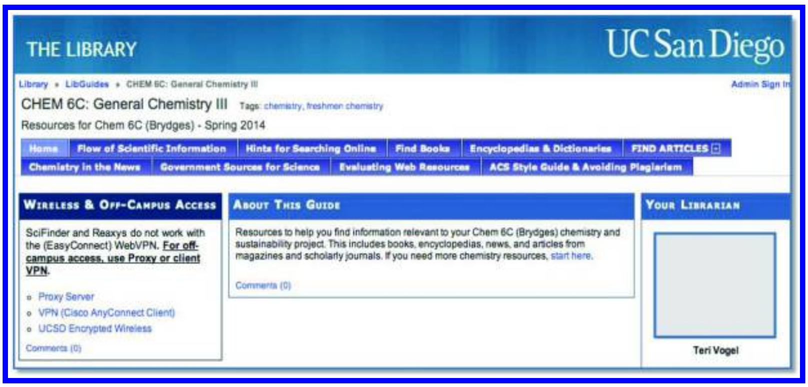

Figure 2. A screen capture of the Library Guide for the course (see: http://libguides.ucsd.edu/chem6c). During the Spring 2014 academic quarter, the site received a total of 4589 hits to its various pages (cf. 3550 in 2012). Reprinted with permission from Ref. (40). Copyright 2010 Regents of the University of California.

Part 2. Select a Topic and Conduct a Literature Search.

Students are expected to use the tools and strategies modeled in Part 1 of the project when conducting their independent literature search. To begin, they must select their research topic of interest. Students are encouraged to consider: What are you curious about? What is your major? Is there a topic that links to this or your future career goals? Would you like to get involved in undergraduate research, and if so, in what area? Any or all of these prompts can lead a student to a topic choice, but to enhance perspectives and seed ideas, an extensive list (50+) of questions is provided. Topics are grouped according to the International Year of Chemistry

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(IYC) themes (*33*) and the United Nation's Sustainable Development Goals (*39*); many are purposely broad and flexible so that students can modify their focus as interest and necessity dictates. Questions include: How "green" are our cleaning products? What is clean coal technology? How can plastics be made of renewable materials like starch and cellulose feed stocks? and, What is a promising example of targeted drug delivery?' Other sample questions are featured in Figure 3.

Figure 3. Some of the more than fifty suggested questions provided to students at the start of the project. The topic list is updated regularly to reflect recently published advances in the chemical sciences. Overall, the project's sustainability theme extends from chemistry to students' knowledge and interest thereof.

Next, students develop a relationship diagram for their research topic (see Figure 4). By brainstorming and reading background information, students are better able to refine their research question – moving from a general topic to a more clearly defined research path. To help in this process, students generate a list of ten searchable terms and/or phrases related to their question/topic. Ultimately, they are required to find, cite (in ACS format), and summarize the key points and relevance

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of, *at minimum*, one background reference, one scholarly article that provides an accurate and current description of the relevant chemistry, and one popular/trade-related article, book, website, *etc.* that lends real-world context. The first or most germane page of each reference (typically the abstract) is attached to the literature search assignment. As these will constitute the main literature sources that students use and reference in their essays, they are encouraged to invest the time in advance to find the most relevant and current information. Between this stage and writing, TA/instructor feedback is provided.

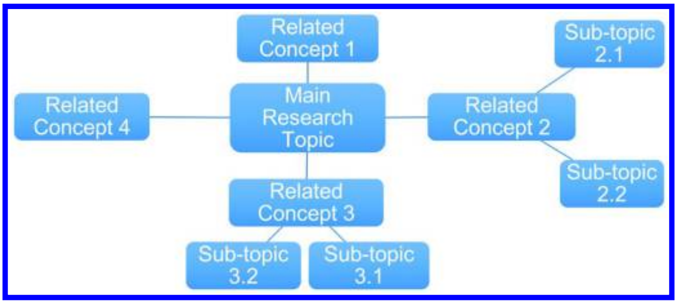

Figure 4. A generic relationship diagram featuring the main topic in the middle and branches and sub-branches linking related concepts. In the process of developing this map, students identify what they know and don't know about a particular topic, and broaden or narrow their research focus accordingly.

Part 3. Compose a Research Essay (Written, Video, or Other Creative Format).

The research essay itself is intended to be a short exposition of a chemistry topic. Students can choose to write for print (750-1000 words), create a video (5-7 minute footage), or make use of other communication approaches and tools. In general, students are encouraged to imagine themselves as a 'science journalist', that is, someone who is not an expert in the field associated with the topic, but who has familiarized her/himself with the area of research and societal connections to the extent that (s)he can write or deliver an interesting, informative and comprehensive story (i.e. informed expertise). Kovac and Sherwood have emphasized how important it is to specify for students the topic, audience, and rhetoric form (*31*). Accordingly, explanatory rather than persuasive writing is recommended, allowing students to focus their efforts on identifying, understanding, and synthesizing the key ideas from their literature sources. The target audience is students' peers, individuals who have a good command of general chemistry and related sciences, but little or no prior knowledge of the topic/issues (i.e. scientifically educated non-experts rather than general readers/viewers).

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Elements of scientific argumentation – the claim, the evidence, and the rationale, referencing credible scientific resources – are reinforced in the essay outline and rubric, which are provided at the project onset (see Figures 5 and 6, respectively). Written essays are formatted using a manuscript-style template adapted by the author/course instructor from *The Journal of the American Chemical Society (JACS)*. In addition to length, (scientific) language, and ACS formatting requirements, an article must contain at least one figure (molecular structures, chemical equations, graphics, or other image) that enhances the discussion and a reader's understanding. This underscores the importance of visual representations in chemistry, and helps to align the written and video essays, which are obviously more visual in nature. Students who elect to produce a video essay are provided with storyboard examples and directed to the Library's Digital Media Lab. Ultimately, students submit their written essays and video scripts electronically; video files are uploaded separately to an external drive. Students who collaborated on a video essay must also complete a self and peer evaluation form.

Given the class size (300-440 students), it is pertinent at this point to mention the grading structure and associated workload. Undergraduate tutors and graduate TAs, who have served as valuable consultants and collaborators on this project, have played a particularly key role in grading. To be effective, they have required additional coaching in applying rubrics and giving constructive feedback (*31*, *41*). And since the range of topics is so extensive, it has worked best for TAs to select and grade projects – from literature search to final essay/video submission – based on their content knowledge and interest.

Project Outcomes

From "Paint the Town 40-Red" to "Burdensome. Big Tickets. Biofuels", the print and video works produced by students have been of significant quality and creativity. The data captured from the most recent end-of-term anonymous surveys (Spring 2014, $N = 410$; and Spring 2015, $N = 333$) reveal interesting trends in student experiences with and perceptions of the "Chemistry in a Sustainable Context" project.

Prior to starting the project, the frequency by which students enrolled in *General Chemistry III* read about science in either the popular press (internet, magazines, newspapers, books) or the peer-reviewed literature (i.e. scientific journals) was very low (53% and 73% Never or Rarely, respectively). And of the 78% of the class who claimed to have used at least one scientific search engine, the use varied for Google Scholar (66%), Web of Science (28%), Academic Search Complete (25%), SciFinder Scholar (7%), and PubMed (1.5%). Accessing and engaging with science are important for science literacy. According to the Science and Engineering Indicators 2016, the internet is now the primary information source for science and technology (47%) and science-specific issues (67%) for all Americans, and Google is the most common means by which individuals seek information online (*42*). Remarkably, students' self-reported use of scientific search engines shifted to 98% upon project completion.

Chemistry in a Sustainable Context: A CHEM6C Essay Collection

I NSERT YOUR TI TLE

INSERT AUTHOR'S NAME.* Use first names, initials, and surnames (e.g., Jane R. Smith) or first initials, second names, and surnames (e.g., J. Roberta Smith).

Insert your Major, University of California, San Diego. La Jolla, CA 92093, United States

ABSTRACT. The chemical principles and real-world issues associated with insert your topic are explored.

KEYWORDS. Insert here 3-5 key words that could be used in an article query/search. Separate each key word by commas.

The body of your article should be placed here. You can type your essay directly into this template, or you can copy and paste it from word processing software. There is no need for you to include headings such as "Introduction", et cetera, as this is a thesis-driven essay rather than a research manuscript. Font: Arial 10. Spacing: 0 pt before/after text.

In general, your essay should be a short exposition of your chosen chemistry topic. Imagine yourself as a "science journalist", i.e. you are not an expert in the field associated with your topic, but you have familiarized yourself with the area of research and related societal issues to the extent that you can write/deliver an interesting, informative and comprehensive story (i.e. informed expertise). Explanatory rather than persuasive writing is recommended; focus your efforts on identifying, understanding, and synthesizing the key ideas from your literature sources. Assume that your audience is your peers - individuals who have a good command of general chemistry and related sciences, but little or no prior knowledge of the topic/issues (i.e. scientifically educated non-experts rather than general readers/viewers).

Before you compose your written or video essay, be sure that you have developed a thesis statement that is clear and concise. While the "*Suggested questions to explore*" that were listed on TritonEd were purposely broad (to give you the flexibility and freedom to delve into whatever aspect(s) of the topic were of interest to you), remember that you are NOT composing a lengthy review of an area of research, so you'll need to distill only the essential points that support your thesis. Your organizational diagram that you prepared during your literature review should help you distinguish the more general and specific ideas upon which you'll focus. The elements of scientific argumentation – the claim, the evidence, and the rationale, referencing credible scientific resources – are reinforced in the essay outline below.

As noted in the Capstone Project Description posted on TritonEd, the key essay components are:

An **introduction** that catches reader's attention, moves from general to specific topic, and provides a strong thesis statement. *Length:* Typically 1-2 paragraphs.

A ***main body* (background and analysis/argument)** that provides the information for understanding the context of the thesis, emphasizing underlying chemical concepts and highlighting any socioeconomic, health, environmental or other sustainability issues that are relevant. Importantly, it develops ideas logically and factually, and shows evidence of points. Length: Typically 3-6 paragraphs.

A **conclusion** that provides a summary and briefly explores outstanding questions, potential pitfalls, or future directions in the area of study. *Length:* Typically 1 paragraph.

A ***reference*** section (see below). This section will be ordered numerically, corresponding to the order you cite the corresponding sources in your essay. Your in-text citations should appear as italic numbers in parentheses (1) or subscripts[1].

If you have questions, please contact Prof. Brydges or your TA. See also the list of hints and suggestions provided on our TritonEd course site (Figure 1).

CHEMISTRY OF LIFE

General Chemistry 6C

Spring 2015

Figure 1. CHEM6C Spring 2015 Course Website.[1] (Image credit: ACS Spring 2012 National Meeting & Exposition)

Spring 2015 *Author's Last Name 1*

Chemistry in a Sustainable Context: A CHEM6C Essay Collection

You are also encouraged to include molecular structures, chemical equations, graphics, or other visuals to enhance your exposition and a reader's understanding of your topic. Each figure must have a caption that includes the figure number and a brief description, preferably one or two sentences. The caption should follow the format shown below. All figures must be mentioned in the text consecutively and numbered with Arabic numerals. The caption should be understandable without reference to the text. To insert the figure into the template, be sure it is already sized appropriately and paste before the figure caption.

Figure 1. Figure caption. Adapted (or reprinted) from Ref. XX (page #), with permission.

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Note that permission is necessary if the image is copyrighted (unless there is a statement about use for educational purposes); you should be able to supply a note from the author. If there are no copyright restrictions, you can use the word 'courtesy' in the credit.

A few additional pointers about editing:
View "Header and Footer" and update the author's last name.

Highlight the body of your essay, and then select Format "Paragraph", Line and Page breaks, and "Don't hyphenate".

REFERENCES. References will be placed here, at the end of your essay. Authors are responsible for the accuracy and completeness of all references. For example:

1. UC San Diego General Chemistry 6C (Section B00, Brydges, Spring 2015) Course Website, https://ted.ucsd.edu/ (Accessed May 1, 2015).

Word count (Essay body): 750-1000 words. The word count will be the last feature of your article.

Spring 2015 *Author's Last Name 2*

Figure 5. The ACS-styled essay template (with embedded instructions) provided to students.

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"CHEMISTRY IN CONTEXT" ESSAY RUBRIC					
	2 = Excellent	***1.5 = Good***	***1 = Acceptable***	***0.5 = Marginal***	***0 = Poor/Omitted***
Introduction and Title	**Title** accurately, clearly, and concisely reflects the emphasis and content of the paper. It is professional *and* creative, while also being brief and grammatically correct.	**Title** captures essence of paper and is professional but not very creative.	**Title** fits with topic but is not sufficiently descriptive or creative.	**Title** is vague and too simplistic.	**Title** is lacking.
	Intro is well-structured (general to specific), includes a clear and succinct thesis statement and sufficient, relevant background (in 1-2 paragraphs), and is compelling.	**Intro** meets 3 of 4 criteria: (1) it is well-structured (general to specific); (2) it includes a solid thesis statement; (3) it has sufficient and relevant background (in 1-2 paragraphs); (4) it is not attention-grabbing.	**Intro** may have minor organizational issues and may contain a somewhat ambiguous thesis statement or lack minor background details. It may or may not be captivating.	**Intro** contains a poorly constructed thesis and the background is insufficient or irrelevant.	**Intro** is missing a thesis statement; No background is provided.
Content and Organization	**Body of the essay** links well to the main thesis/overall topic, has a logical flow, and features good idea/ paragraph separation.	**Body of the essay** links to the main thesis, and most information is presented in an orderly fashion; a few minor points may be confusing.	**Body of the essay** is generally (but not always) linked to the main thesis, and while structure is mostly logical, paragraph transitions are lacking.	**Body of the essay** is not well-constructed; ideas are presented in a mostly disjointed fashion and only weak links to the thesis are made.	**Body of the essay** is very poorly organized; no links to thesis are provided, and information is presented in a disjointed and confusing way.
	Descriptions of relevant chemical principles are accurate, in sufficient detail, and at an appropriate level for the readership/viewer.	**Descriptions of relevant chemical principles** are correct and sufficiently comprehensive, but not always linked to other parts of the essay.	**Descriptions of relevant chemical principles** are mostly correct and/or somewhat lacking in detail.	**Descriptions of relevant chemical principles** are often erroneous and/or vague or missing.	**Descriptions of relevant chemical principles** are missing altogether.
	Context for the issue is provided; references to at least one recent and relevant (<2-3 years old) research study *and* real-world issues (documented in the secondary or tertiary literature) are made.	**Context for the issue** is provided; references to at least one recent and relevant (<2-3 years old) research study is made but real-world issue(s) are less detailed.	**Context for the issue** is provided but insufficient; references to at least one research study is made, albeit in insufficient detail and/or citation is outdated; and/or connection to societal issue is lacking.	**Context for the issue** is scarce; links to current research and/or societal issue are minimal, outdated, or not entirely relevant.	**Context for the issue** is missing.
	Conclusion links to thesis, provides a concise summary of the research presented, and highlights unresolved questions, future directions, etc.	**Conclusion** meets 2 of 3 criteria: (1) it links to thesis and provides a cogent summary of the research presented; (2) it outlines unresolved questions; and (3) it specifies future directions.	**Conclusion** links to thesis, summary is sufficient but not impactful and/or future directions are weak or not addressed.	**Conclusion** does not link to thesis; summary is short and vague, and future directions/questions are lacking.	**Conclusion** is not provided.
	ALL sources are used, cited, and formatted correctly within the body of the essay.		**Most (but not all) sources** are referenced; there are minor errors in citation format throughout the body of the essay.		**Sources** are not cited within text (Note: not necessary for videos).
	Works cited/References are reputable and appropriate, match citation format used in text, and follow ACS guidelines. Citations for pictures are given either within text or at end of essay/video.		**Works cited/References** are mostly reputable and appropriate (including visuals); there are minor errors with formatting (ACS or style of citations used in text).		**Works cited/References section** is missing.
Presentation and Enhancements	**Language** is appropriately formal; sentences are clear, concise and direct, and the essay is essentially free of grammatical errors.		**Language** is generally formal and sentence structure mostly clear and concise; some grammatical errors are noted.		**Language** is too informal; many sentences are unclear and/or the essay contains several grammatical errors and typos.
	Graphics/visuals reinforce content, are placed appropriately (ie. close to relevant text or voice), and are referenced within text (i.e. refer to Figure x)		**Graphic(s)/visuals** are somewhat superfluous, and/or may be placed incorrectly, and/or may or may not be referenced within the text.		**Graphics/visual** are missing.

TOTAL SCORE: ________

Figure 6. The research essay (written, video) grading rubric.

The careful construction of research assignments to favor use of these more powerful tools over the internet (and engines such as Google) has been noted by Jacobs *et al*. (*43*) With respect to the research and writing process, *General Chemistry III* students were almost equally divided on whether they found it challenging: to search for and locate appropriate articles related to their topic (42% strongly agreed/agreed; 16% were neutral; 42% disagreed/strongly disagreed); to understand the articles related to their topic (36% strongly agreed/agreed; 31% were neutral; 33% disagreed/strongly disagreed); and, to summarize the articles related to their topic (43% strongly agreed/agreed; 23% were neutral; 34% disagreed/strongly disagreed). Students in a first year chemistry course reported by Forest and Rayne also struggled with primary literature summaries, but to a much greater degree; locating and deciphering a relevant article was deemed to be difficult by 85% and 63% of students, respectively (*18*). These results suggest

Flener Lovitt et al.; Integrating Information Literacy into the Chemistry Curriculum
ACS Symposium Series; American Chemical Society: Washington, DC, 2016.
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that having specific instructions and a preliminary literature search assignment helped to alleviate some of the common issues associated with selecting and researching a topic.

Moving from the critical reading to writing process, the students' difficulties matched those outlined by Oliver-Hoyo in terms of content, relevance, organization, and sources (*32*). This was not surprising, given that nearly half of all *General Chemistry III* students (46%) reported having never written a scientific essay beforehand. The degree to which students were able to transfer the research and writing skills they developed in their university writing courses, which are an integral part of the general education requirements of UC San Diego, to this discipline-specific assignment was not probed. Regardless, the data underscore a need for more practice and formative feedback at all project stages. This may be possible if participation in the information literacy tutorials is enforced via a grade, and the submission of multiple writing drafts is implemented (*32*, *43*).

In terms of relevance, enjoyment, and perceived benefits, 80% of students indicated that they selected a topic to explore that was of personal or career interest to them, whereas 16% were neutral about their project theme despite the broad range of options provided, including the opportunity to pursue a topic not listed. Students enjoyed learning about the topic that they selected (85% strongly agreed/agreed; 14% were neutral; only 1% disagreed/strongly disagreed), though only 51% expressed firm intentions to continue to read about their topic in the future. That the project increased their interest in chemistry, and its application to everyday life was reported by 64% of students (another 27% were neutral). And finally, a majority of students believed that the skills and knowledge acquired from the project will be of benefit to them in subsequent courses (70% strongly agreed/agreed; 22% were neutral) and undergraduate research (77% strongly agreed/agree; 16% were neutral).

When asked what they found to be the most rewarding aspect of the project, students' free responses were varied. For some students, the research and writing process was gratifying: "*Seeing how, through hard work, I could understand and grasp a professional-level article was rewarding.*"and "*I can now say I've written a scientific paper!*" Other students appreciated its relevance, as the following comments relate: *"I was able to look at chemistry from a different perspective, aside from just chemical equations in a classroom"* and "*The capstone project introduced us to interesting real-world applications of chemistry which we would probably never have looked at or researched had it not been part of the curriculum. I did mine on food dyes, and the research I found was very interesting and made me look for additional articles to by myself that were not part of the project."* And yet for other students, the project proved to be transformative: *"I found a new appreciation for chemistry;"* and *"Thank you for challenging me to think outside the box and learn more than I would have otherwise. I am now a chemistry minor."*

In spite of the added work that such a project brings to an already demanding course, after its latest implementation (Spring 2015), 85% of students advocated for featuring the project in its current format and/or with slight modifications, whereas 8% suggested that we offer a different type of project and 7% indicated a preference for no project of any type. Each year, students have provided their recommendations for future general chemistry courses, and these have been

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used in successive iterations to improve upon the project, as also documented by Mandernach *et al.* (*44*), and Jacobs and colleagues (*43*). In alignment with their perceived challenges, students have suggested more training in reading scientific papers and writing scientifically, increased weighting of the project in the overall course grading structure, and a project timeline that is less condensed.

Conclusions and Future Work

Overall, the "Chemistry in a Sustainable Context" project has served as a creative outlet, providing a new window to chemistry for students with diverse interests, and allowing for a broad range of scientific and professional skills to be practiced in a first-year undergraduate chemistry lecture course. Despite the additional effort and time required of students (especially compared to other course sections which do not feature the project), the overall course ratings (*45*) have remained at 90% and above since the project implementation. As student dissatisfaction with writing assignments has been noted previously (*31*, *43*), these ratings indirectly reaffirm that students do value student-centered, course-integrated opportunities to engage with writing and information literacy. Beyond the affective domain, improvements in students' scientific research and writing abilities have not yet been quantified. The author also intends to conduct a longitudinal study to determine whether any benefits to science and engineering majors persist (or become more apparent) as they progress through their undergraduate studies.

Meanwhile, the project continues to evolve, informed by student feedback and an ongoing faculty-library collaboration. Future versions will include 'just-in-time" online tutorials focused on chemical information literacy (*46*), peer review of essay drafts, and the establishment of a means to showcase students' efforts. Having demonstrated that chemical information instruction and science communication practice can be embedded in a large-enrollment general chemistry lecture, the next goal is to make the project, or elements thereof, more adaptable to other course sections and/or lower-division courses at the home institution and beyond. Ultimately, the pursuit of science literacy in undergraduate education is a shared enterprise, as underscored by the ACRL framework:

> *"**Students** have a greater role and responsibility in creating new knowledge, in understanding the contours and the changing dynamics of the world of information and in using information, data, and scholarship ethically. **Teaching faculty** have a greater responsibility in designing curricula and assignments that foster enhanced engagement with the core ideas about information and scholarship within their disciplines. **Librarians** have a greater responsibility in identifying core ideas within their own knowledge domain that can extend learning for students, in creating a new cohesive curriculum for information literacy, and in collaborating more extensively with faculty (10)."*

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Notes: (1) All data reported in this study were approved for publication by the institutional review board. (2) Interested readers may contact the author to obtain digital versions of Figures 3, 5, and 6.

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References

1. ACS Committee on Professional Training. *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs*; American Chemical Society: Washington, DC, 2015. http://www.acs.org/content/dam/acsorg/about/governance/committees/training/2015-acs-guidelines-for-bachelors-degree-programs.pdf (accessed Dec. 2016).
2. ACS Committee on Professional Training. *Chemical Information Skills*; American Chemical Society: Washington, DC, 2015. http://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/chemical-information-skills.pdf (accessed Dec. 2015)
3. American Association of Physics Teachers. *Guidelines for Self-Study and External Evaluation of Undergraduate Physics Programs*; AAPT: College Park, MD, 2005. http://www.aapt.org/Resources/upload/Guide_undergrad.pdf (accessed Dec. 2015)
4. National Association of Biology Teachers. *Guidelines for the Evaluation of Four-Year Undergraduate Biology*; NABT: Warrenton, VA, 2008. http://www.nabt.org/websites/institution/File/docs/Four%20Year%20Guidelines.pdf (accessed Dec. 2015).
5. American Association for the Advancement of Science. *Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future*. 2015. http://visionandchange.org/files/2015/07/VISchange2015_webFin.pdf (accessed Dec. 2015).

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch005

6. Hart Research Associates. *Falling Short? College Learning and Career Success. Prepared for the* Association of American Colleges & Universities: Washington, DC, 2015. https://www.aacu.org/sites/default/files/files/LEAP/2015employerstudentsurvey.pdf (accessed Dec. 2015).
7. Hart Research Associates. *It Takes More than a Major: Employer Priorities for College Learning & Student Success*; Association of American Colleges & Universities and Hart Research Associates: Washington, DC, 2013. https://www.aacu.org/sites/default/files/files/LEAP/2013_EmployerSurvey.pdf (accessed Dec. 2015).
8. Head, A. J. *Learning Curve: How College Graduates Solve Information Problems Once They Join the Workplace*; Project Information Literacy Report. 2012. http://projectinfolit.org/images/pdfs/pil_fall2012_workplacestudy_fullreport_revised.pdf (accessed Jan. 2016).
9. Glynn, S. M.; Muth, K. D. Reading and Writing to Learn Science: Achieving Scientific Literacy. *J. Res. Sci. Teach.* **1994**, *31*, 1057–1073.
10. Association of College and Research Libraries. *Framework for Information Literacy for Higher Education*; American Library Association: Chicago, IL, 2015.http://www.ala.org/acrl/sites/ala.org.acrl/files/content/issues/infolit/Framework_ILHE.pdf (accessed Dec. 2015).
11. Association of College and Research Libraries. *Information Literacy Competency Standards for Higher Education*; American Library Association: Chicago, IL, 2000. http://www.ala.org/acrl/sites/ala.org.acrl/files/content/standards/standards.pdf (accessed Dec. 2015).
12. *ALA/ACRL/STS Task Force on Information Literacy for Science and Technology. Information Literacy Standards for Science and Engineering/Technology*. http://www.ala.org/acrl/standards/infolitscitech (accessed Dec. 2015).
13. Special Libraries Association, Chemistry Division AdHoc Committee on Information Literacy. *Information Competencies for Chemistry Undergraduates: The Elements of Information Literacy*; Craig, C., Maddux, L., Eds.; May 2011. http://chemistry.sla.org/wp-content/uploads/cheminfolit.pdf (accessed Dec. 2015).
14. Currano, J. Teaching Chemical Information for the Future: The More Things Change, the More They Stay the Same. In *The Future of the History of Chemical Information*; McEwen, L. R., Buntrock, R. E., Eds.; ACS Symposium Series 1164; American Chemical Society: Washington, DC, 2014. pp 169–196.
15. Beall, H. Literature Reading and Out-of-Class Essay Writing in General Chemistry. *J. Chem. Educ.* **1993**, *70*, 10–11.
16. Sherman, L. R. Using the chemical literature to write an interesting freshman term paper. *J. Chem. Educ.* **1988**, *65*, 993–994.
17. Sommerville, A. N.; Cardinal, S. K. An Integrated Chemical Information Instruction Program. *J. Chem. Educ.* **2003**, *80*, 574–579.
18. Forest, K.; Rayne, S. Incorporating Primary Literature Summary Projects into a First-Year Chemistry Curriculum. *J. Chem. Educ.* **2009**, *86*, 592–594.
19. Gawalt, E. S.; Adams, G. A Chemical Information Literacy Program for First-Year Students. *J. Chem. Educ.* **2011**, *88*, 402–407.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch005

20. Peters, M. C. Beyond Google: Integrating Chemical Information into the Undergraduate Chemistry and Biochemistry Curriculum. *Sci. Technol. Libr.* **2011**, *30*, 80–88.
21. Locknar, A.; Mitchell, R.; Rankin, J.; Sadoway, D. R. Integration of Information Literacy Components into a Large First-Year Lecture-Based Chemistry Course. *J. Chem. Educ.* **2012**, *89*, 487–491.
22. Bruehl, M.; Pan, D.; Ferrer-Vincent, I. J. Demystifying the Chemistry Literature: Building Information Literacy in First-Year Chemistry Students through Student-Centered Learning and Experiment Design. *J. Chem. Educ.* **2015**, *92*, 52–57.
23. Ferrer-Vinent, I. J.; Bruehl, M.; Pan, D.; Jones, G. L. Introducing Scientific Literature to Honors General Chemistry Students: Teaching Information Literacy and the Nature of Research to First-Year Chemistry Students. *J. Chem. Educ.* **2015**, *92*, 617–624.
24. Yeagley, A. A.; Porter, S. E. G.; Rhoten, M. C.; Topham, B. J. The Stepping Stone Approach to Teaching Chemical Information Skills. *J. Chem. Educ.* **2016**, *93*, 423–428.
25. Pence, L. E. A Chemical Information Assignment for Nonscience Majors. *J. Chem. Educ.* **2004**, *81*, 764–768.
26. Walczak, M. M. Using News Assignments To Develop Skills for Learning about Science from Public Information Source. *J. Chem. Educ.* **2007**, *84*, 961–966.
27. Garritano, J. R.; Culp, B. F. Chemical Information Instruction in Academe: Who is Leading the Charge? *J. Chem. Educ.* **2010**, *87*, 340–344.
28. Jacobs, D. L.; Dalal, H. A.; Dawson, P. H. Integrating Chemical Information Instruction into the Chemistry Curriculum on Borrowed Time: The Multiyear Development and Evolution of a Virtual Instructional Tutorial. *J. Chem. Educ.* **2016**, *93*, 452–463.
29. Kuh, G. *High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter*; Association of American Colleges & Universities: Washington, D.C., 2008. http://www.aacu.org/leap/hip.cfm (accessed Dec. 2015)
30. Beall, H. In-Class Writing in General Chemistry: A Tool for Increasing Comprehension and Communication. *J. Chem. Educ.* **1991**, *68*, 148–149.
31. Kovac, J.; Sherwood, D. W. Writing in Chemistry: An Effective Learning Tool. *J. Chem. Educ.* **1999**, *76*, 1399–1403.
32. Oliver-Hoyo, M. T. Designing a Writing Assignment to Promote the Use of Critical Thinking Skills in an Introductory Chemistry Course. *J. Chem. Educ.* **2003**, *80*, 899–903.
33. *American Chemical Society. International Year of Chemistry 2011 (IYC 2011)*; http://www.acs.org/content/acs/en/global/iyc2011.html (accessed Dec. 2015).
34. Feinstein, N. W.; Allen, S.; Jenkins, E. Outside the Pipeline: Reimagining Science Education for Nonscientists. *Science* **2013**, *340*, 314–317.
35. Cooper, M. The Case for Reform of the Undergraduate General Chemistry Curriculum. *J. Chem. Educ.* **2010**, *87*, 231–232.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch005

36. Mahaffy, P. Moving Chemistry Education into 3D: A Tetrahedral Metaphor for Understanding Chemistry. *J. Chem. Educ.* **2006**, *83*, 49–55.
37. University of California San Diego. *Sustainability*; http://sustain.ucsd.edu (accessed Jan. 2016).
38. *The City of San Diego Sustainable Community Program*; https://www.sandiego.gov/environmental-services/sustainable (accessed Jan. 2016).
39. United Nations Development Programme. *Sustainable Development Goals 2015*; http://www.undp.org/content/undp/en/home/sdgoverview/ (accessed Jan. 2016)
40. Vogel, T. *UC San Diego LibGuide - CHEM 6C: General Chemistry III: Home*; http://ucsd.libguides.com/chem6c (accessed July 2014).
41. Seymour, E. *Partners in Innovation: Teaching Assistants in College Science Courses*; Rowman & Littlefield Publishers: Lanham, MD, 2005.
42. National Science Board. *Science & Engineering Indicators 2016, Chapter 7. Science and Technology: Public Attitudes and Understanding*; National Science Foundation: Arlington, VA. 2016.
43. Jacobs, D. L.; Dalal, H. A.; Dawson, P. H. Integrating Chemical Information Instruction into the Chemistry Curriculum on Borrowed Time: A Multiyear Case Study of a Capstone Research Project for Organic Chemistry. *J. Chem. Educ.* **2016**, *93*, 444–451.
44. Mandernach, M. A.; Shorish, Y.; Reisner, B. A. The Evolution of Library Instruction Delivery in the Chemistry Curriculum Informed by Mixed Assessments Methods. *Issues Sci. Techol. Libr.* **2014**, *77* DOI:10.5062/F46H4FDD.
45. University of California, *San Diego's Course and Professor Evaluation (CAPE)*; https://cape.ucsd.edu (accessed Jan. 2016).
46. Pritchard, P. P.; Thomas, D. Inspiring Writing in the Sciences: An Undergraduate Electronic Journal Project. *Collect. Essays Learn. Teach.* **2010**, *3*, 54–59.

Chapter 6

Incorporating Chemical Information Literacy into Large Organic Chemistry Classes through the Laboratory

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A structured chemical information literacy curriculum for the organic chemistry laboratory was developed through a collaboration between a laboratory instructor and a physical science librarian from 2007-2014. Class sizes were about 350 (over 50% freshmen) and 250 for semester 1 and 2, respectively. In the two-semester sequence, the instructor and librarian taught the literature of chemistry through library course guides, pre-lab lectures, library assignments, and laboratory reports. The students learned how to use online handbooks, databases, and journal articles to find the experimental values of physical and spectroscopic properties and how to cite the resources. Students demonstrated their learning by successfully completing the library assignments and finding and comparing literature values in the laboratory reports. Learning objective accomplishments were reflected in data collected in 2012-2013.

Since comparing experimental physical and spectroscopic properties to literature data can be an important component of most organic chemistry laboratory reports, students must have resources to obtain these values. The reliability and origin of the information that is to be used as references is not always apparent to the beginning student. The undergraduate organic chemistry laboratory provides an opportunity to familiarize students with authoritative resources and databases that are used by chemists. For the past several years at Brown University, a "faculty-embedded-librarian partnership" (*1*) between the physical sciences librarian and the instructor of the organic chemistry laboratories resulted in the development of assignments that allowed students to actively apply and build their confidence in utilizing these resources.

The program in the chemistry department was conceived between the instructor and the librarian to provide the students with a structured curriculum of chemical information literacy (CIL). The CIL literature is full of approaches that faculty (*2–4*), librarians (*5–7*), and faculty-librarian collaborations (*8–11*) have published on methods to introduce CIL to different student populations in small and large chemistry departments. Workshops (*12*), for-credit classes (*3*, *13*, *14*), online tutorials (*15*), and seminars (*1*) are just some examples of these approaches. Authors have also focused on using the organic chemistry course and/or laboratory to develop information literacy skills (*9*, *16–18*).

This chapter presents the strategy implemented at Brown University to conduct CIL training of large classes of organic chemistry students through the graded laboratory requirement of the courses. Using the focus of obtaining physical and spectroscopic properties of compounds in the experiments, the authors introduced students to a methodology for extracting property data from the tertiary (handbooks), secondary (databases) and primary literature (journal articles) of chemistry. In addition, the students learned and practiced the use of a customized style guide to cite references consistently. Examples of communication and assessment tools are given. Data collected for 2012 and 2013, when the curriculum was in its final refinement, are provided. The authors believe that the two-semester scaffolding of information literacy into a large classroom through the laboratory has provided the students with an opportunity to recognize the importance of the library in science.

Background

The organic chemistry course sequence at Brown University offers the first semester of the course (Chem0350) in the spring and the second semester (Chem0360) in the following fall. For the laboratory, students attend a pre-laboratory lecture once a week for 50 minutes and attend laboratory once a week for 4 hours.

Most students complete one semester of general chemistry before taking the organic chemistry sequence. Table 1 summarizes the average enrollment for each course and the number of semesters in which the course contained the CIL content. In addition, Table 2 shows the percentage of students from the different academic ranks that took the courses over the period of the collaborative effort. Notable for both courses is that first-year students and sophomores are the majority of the population. Given that Brown University does not have a requirement for information literacy, the authors believed that they had an opportunity to introduce chemical information literacy early to a population of students who could potentially apply the skills and knowledge to future science courses.

Table 1. Average Enrollment for Courses during the Collaboration*

Course	*Average Enrollment*	*Number of Semesters*
Chem0350 (first semester)	386	7
Chem0360 (second semester)	258	5*

* For two semesters, the instructor was not assigned to teach the Chem0360 laboratory.

Table 2. Population of Students by Academic Rank Completing the Course from Spring 2009 through Spring of 2014*

Course	*% First-year*	*% Sophomore*	*% Junior*	*% Senior*	*% Other*
Chem0350 (first semester)	50.3	37.7	9.9	1.5	0.6
Chem0360 (second semester)	---	50.9	37.9	11.5	--

* Data was not available for spring of 2008.

The science librarian and the instructor established learning objectives as shown in Table 3 for each semester of the two-semester course. By 2012, an established curriculum was developed that incorporated online resources in all work.

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Table 3. Learning Objectives for the Organic Chemistry Laboratory Sequence

Semester	*Learning Objectives*
Chem0350	Students will • collaborate with the embedded science librarian throughout the semester. • learn how to search for compounds in tertiary resources and the primary literature. • utilize authoritative resources for obtaining required physical properties for compounds in experiments. • cite all resources in a designated format for physical properties in laboratory reports. • learn how to obtain physical properties in the primary literature of chemistry by using a database, Reaxys® (*19*) • be introduced to the organization of a chemistry journal article to locate specific physical properties from the paper. • use the library course guide to access all resources for the laboratory.
Chem0360	Students will • continue the collaboration with the embedded science librarian throughout the semester. • continue to use the resources provided in the library course guide to obtain physical properties of compounds in experiments. • utilize the library course guide to access resources for spectroscopic properties. • learn how to search the primary literature to obtain spectroscopy data for compounds in experiments. • use two databases, Reaxys® and SciFinder (*20*), to search the primary literature for spectroscopic data for compounds in experiments • continue to cite the resources in the designated format for all library assignments and laboratory reports.

First Semester Organic Chemistry Laboratory

Resources Introduction and Library Course Guide

To establish the relationship between the students and the science librarian, the librarian was invited to give a pre-laboratory lecture at the start of the semester. Using an online presentation from the librarian's custom-designed library course guide, the librarian introduced the resources to the students. The university's course management system made the library guide readily accessible online.

During the presentation, the science librarian outlined the most effective ways to search for compounds based on the searching capabilities of the university's resources for the course. Students were informed that searching by structure was the most reliable, followed by Chemical Abstract Service Registry Number (CAS-RN). The challenges of searching by name were emphasized because using name as a search term can have ambiguous results. For example, a compound may have multiple chemical names and/or common names.

Using the library course guide, the science librarian demonstrated search features in the three tertiary resources (handbooks) that the students would be using throughout the course: CRC Handbook of Chemistry and Physics (*21*), Knovel Library's Critical Tables (*22*), and the Merck Index (*23*). The class was instructed in the searching capabilities of all three and provided with examples to illustrate the information that could be obtained from each resource.

To introduce the chemical literature database, Reaxys®, a live example using structure searching was presented. Students learned how to use the database, which compiles the primary literature and extracts physical properties into a table. Students needed to register to use the licensed database and all pertinent information about registration was conveyed through the course guide. Figure 1 is an example of a table from Reaxys® that illustrates the extent of data compiled from published articles. Students were shown how to obtain articles online from the university's ejournal subscriptions.

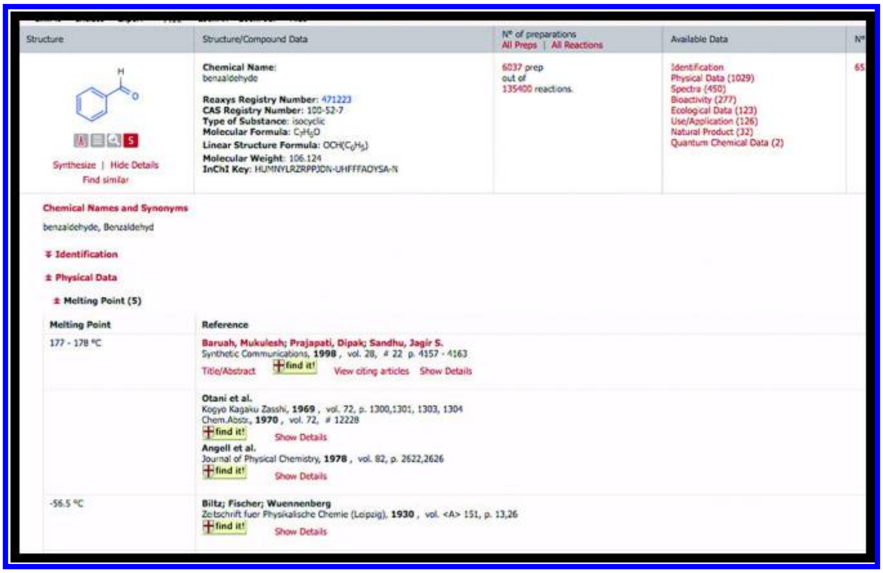

Figure 1. Example of the table feature from Reaxys®. Credit: Reaxys is a trademark of RELX Intellectual Properties SA, used under license.

The science librarian demonstrated how to locate the structure of the desired compound in the journal article. To begin, the librarian outlined the format of a typical organic chemistry journal article. Since many of these articles contained a large number of structurally related compounds, it was noted that the molecules were cataloged in a systematic fashion by authors to keep track of the compounds. The librarian invented the label "author identification code" to give a common name to the cataloging system. The code could be a letter, number, or letter/number combination that served as a shorthand representation for each molecule in the article. Students were told to find the first instance of the structure of the desired compound and determine the author identification code. This code was then used

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to locate the experimental value of the corresponding physical properties in the article. For example, the structure of 2,3-dimethylphenol may be given the label 4a, which is the designated author identification code for 2,3-dimethylphenol in the article. Within the article, students would find additional information, such as a physical property, for 2,3-dimethylphenol by browsing for 4a.

Finally, the librarian introduced the citation style guide that would be used throughout the semester. The citation style guide for the laboratories was customized to capture specific information from the resources used for the course. A special tab on citing the literature was available in the library course guide. There were detailed examples for the class to utilize.

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Development of an Assignment for Library Resources

To provide an opportunity for students to engage actively with the library resources relevant to the course, a Chemical Literature Assignment was developed by the instructor and the science librarian. Students were asked to obtain physical properties from each resource using the various searching methods demonstrated by the librarian. The main learning goal of the assignment was to familiarize students with authoritative library resources for the semester and the type of information that each resource could provide. The assignment was specifically designed with a single correct answer for each question for two main reasons. The first reason was to reduce the amount of time that the students would spend on the assignment. The second reason was to make grading of these questions by the many graduate teaching assistants (TAs) for the course straightforward. With courses that have large enrollments and the majority of grading being completed by graduate students, the ability of TAs to grade assignments proficiently must be taken into consideration when designing course materials.

The Merck Index questions on the assignment were the only ones that required searching by name. From the selected handbooks for the course, the Merck Index provided information that was not readily available in the other two. For instance, the questions for the Merck Index focused on the biological information that Merck could provide such as LD_{50} and therapeutic use of the compound. In addition, the name search also preserved the historical "encyclopedia" format of the resource. It is only in the most recent online edition of the Merck that searching by structure has become possible.

Questions for the tertiary resources evolved to include a specific table within the resource to obtain the necessary information. This specification was needed to eliminate the possibility of students searching in other tables within a resource and obtaining different information.

Since three tertiary resources were being used for the assignment, a summary question to compare the tertiary resources was incorporated into the assignment. This question helps the students become aware of the different types of physical property data that can be obtained from each title. The goal of this question was to guide students to make informed decisions for using specific resources in future laboratory reports. Figure 2 is an example of the summary questions on the assignment.

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5. Complete the data for CARBON TETRACHLORIDE using the 3 different Handbooks. Follow the guidelines given for the tables to use for each Handbook in the previous exercises. If a reference source does not have the data, write N/A in the column. If a reference source does not have the complete information, write all that is available. DO NOT assume information! (9 pts)

Handbook	CAS-RN	Density@T (°C), Include units	Physical form	Miscible with (list only one solvent)	Refractive index@ T(°C)	LD_{50} Orally in mice, g/kg
Knovel Critical Tables						
Merck Index						
CRC						

6. Based on the information presented in the table for question 5, answer the following questions. (9 pts)
a) Which Handbook(s) is(are) not the correct reference if the experimental refractive index is reported to 4 decimal places? ______ __________
b) Which Handbook(s) is(are) the correct reference if the temperature of the density value must be included? ___ __________
c) Which Handbook(s) cannot be used to obtain solubility data? ___ _________
d) Which Handbook(s) can be used to obtain the CAS-RN for a substance? ______ ______
e) Which Handbook(s) can be used to obtain the physical form of a substance? _____ ____________

Figure 2. Example of summary questions from the Chemical Literature Assignment.

A specific question requiring the use of the Reaxys® database was also included in the Chemical Literature Assignment. Students were given a structure of a compound and asked to obtain a physical property of the compound. After completing a structure search of the compound using the Reaxys database, students were able to identify a journal article that provided the requested physical property of the compound. The journal article was retrieved through the ejournal subscriptions. They were expected to find the specific structure in this article and use the author identification code to obtain a physical property. Students had to provide a page number in the article to demonstrate that the paper was actually accessed. Figure 3 is an example of a Reaxys® question for the assignment.

4. Perform an exact structure search using the *Reaxys Database* for this question. (9 pts)
***Cite* the reference:**
a) Complete the information below for identifying this compound in the paper.
i) Table # ____ ________
ii) Exact page number for table ____ _____
iii) Author identification code _____ ______
b) Complete the table below.

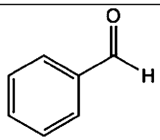
Structure	CAS RN	Boiling point, °C	Page number in paper for boiling point
			

Figure 3. Example of a question requiring searching the Reaxys® database.

Like the questions for the tertiary resources, the Reaxys® questions had a single correct answer. Students were given strict criteria to find a "correct" paper for the question in the assignment. In order to narrow the possibilities of potential papers, a final criterion of using an article with the most current year of publication in the database was implemented. This information was provided to the students through a specific tab in the library course guide dedicated to the Chemical Literature Assignment. As shown in Figure 1, the correct journal article to use for the structure, in the Reaxys® table, would be the 1998 paper in *Synthetic Communications*. In developing the assignment, a compound was chosen that resulted in a single article fitting all the criteria. This question in particular required vetting by both the instructor and the science librarian to ensure that the physical property data and the structure of the compound were readily apparent in the published paper.

Figure 4 illustrates the information available in the tab for the Chemical Literature Assignment of the library course guide. Learning goals for the students were provided to help students understand the assignment. During the pre-laboratory lecture by the science librarian, all this information was reviewed with the students.

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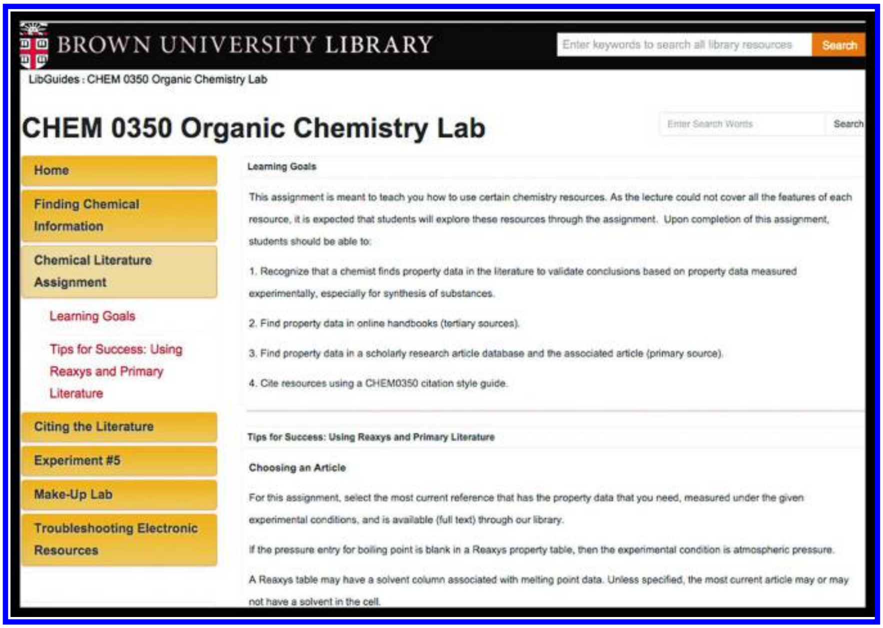

Figure 4. Information in the tab for the Chemical Literature Assignment available in the library course guide. Credit: By permission of the Brown University Library (http://libguides.brown.edu/CHEM0350L).

Citing the Library Resources

The requirements for citing the library resources evolved as new resources were used and as the authors realized that the citations needed to be more specific. For example, citations for the tertiary resources included the name of the table used and the Chemical Abstract Service Registry Number (CAS-RN) of all compounds searched. This requirement was to make the citation specific and also to deter students from simply copying and pasting in the citation from one report to another. The librarian adapted the style from the 3rd edition of the ACS style manual (*24*). With the emergence of online versions of scientific journals, citations were updated to include the Digital Object Identifier (DOI) and the title for the journal article. Table 4 summarizes the major changes in the citation style throughout the CIL curriculum implementation.

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Table 4. Significant Changes Made to the Citation Format for the Library Resources

Year	*Handbooks*	*Database Or Primary Literature*	*Formal Citation Required in Assignments and Reports*
2007	Edition only	No clear specificity	No
2008	No changes	No changes	No
2009	*Book title,* edition (# ed.); Publisher Name: Publication Location, Year of Publication; Pages (pp range or p single).	Same format as for print EXCEPT use the citation details if provided; especially the URL; Date accessed must be provided	Yes
2010	No changes	Reaxys®: cut & paste from property table (no formatting)	Yes
2011	Include name of table for properties	Reaxys®: citation formatted	Yes
2012	Include name of compounds	Include DOI	Yes
2013	Include CAS-RN of compounds	Include title of paper	Yes
2014	Same as 2013	Same as 2013	Yes

Extension of Library Resources to Laboratory Reports

With the introduction of the information resources through the Chemical Literature Assignment, subsequent laboratory reports contained sections that required students to obtain literature values for various physical properties of compounds. Students used the library course guide to access all the available resources. Students were required to use the correct citation format for all entries that required literature values. For most laboratory reports, students utilized the tertiary resources. Figure 5 shows an example of an entry in a laboratory report that requires information from a tertiary resource.

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4. a) Complete the table below for the melting point analysis of the pure combined samples. (4 pts)

List of fractions combined	CAS-RN of Compound	Mass recovered, g	Experimental Melting Point, °C	Literature Melting Point, °C

b) Cite the reference source(s) used for the literature values in the table. Do not use Reaxys for this assignment. (2 pts)

Figure 5. Example of a section of a laboratory report requiring information from a tertiary resource.

For an experiment synthesizing alkyl chloride, the physical properties of these compounds could not be found in the available tertiary resources. Reaxys® was therefore used as the tool to obtain the physical properties. Information about searching the compounds was introduced in the library course guide through a specific tab, Experiment 5, as shown in Figure 4. For some of these compounds, articles were quite old and students would not have been able to access these papers through the ejournal subscriptions. As a result, students were only required to use the table feature of Reaxys® to obtain the desired physical properties of the alkyl chlorides and not access the paper. However, in the library course guide, students were taught that reading the original paper was a best practice for extracting property data. An example of a physical properties table is shown in Figure 1.

To manage these types of assignments in a large class, it was essential to be highly organized. For example, the Reaxys® database was constantly being updated and the most recent paper was subject to change as a result. The generation of a spreadsheet by the science librarian for all assignments with papers from the chemistry literature allowed for monitoring of changes occurring in the database. It was necessary to verify the papers for all assignments before grading keys were prepared for TAs.

Second Semester Organic Chemistry Laboratory

During the second semester of the organic chemistry sequence, the instructor and the science librarian focused on resources that would give the students experience extracting spectroscopic properties of organic substances from handbooks, databases, and journal articles. The goal was to build on the knowledge and skills that students had acquired in the first semester. The learning objectives for this semester are outlined in Table 3.

Development of Library Assignment 1

For the first pre-laboratory lecture of the semester, the science librarian introduced students to the current semester's library course guide, again using an online presentation. The major change to the guide was the inclusion of information to help students find various spectroscopic data in the primary literature using the Reaxys® database. This library course guide also contained the resources available to the students from Chem0350. Citing the resources was still a learning objective for this semester.

The science librarian instructed the students to use a substance structure search in Reaxys® to find the following spectroscopy: Nuclear Magnetic Resonance (NMR), ^{1}H and ^{13}C, Infrared (IR), and Mass spectrometry (MS). The table feature of Reaxys®, which identified the type of spectroscopic data available, was highlighted. As shown in Figure 1, spectra are listed under the column heading of "Available Data." The class learned how to read the Reaxys® table to obtain the experimental conditions (temperature, pressure, NMR frequency, etc.) for the various data.

Since students were required to obtain information from within a journal article, the librarian explained how to find spectroscopic data in the content. Spectroscopic data is often presented in the Supporting Information (SI) section of papers. Therefore, the organization of SI to find spectroscopic data was reviewed. Various ways in which papers present spectroscopic data was taught. For example, NMR data can be presented in chemical shift tables or a full spectrum can be included in the paper. The students were shown how to navigate a paper to extract brand name and instrument models of the various instruments that were used to obtain spectra.

To have students actively engaged in learning to find spectroscopic data in journal articles, Library Assignment 1 was developed. Students were required to use the Reaxys® database to complete a structure search to find an article with the most recent date of publication that had properties corresponding with those listed in the question. From the library assignments using Reaxys® in Chem0350, the class was already familiar with searching based on this criterion. Each of the five questions consisted of a structure of an organic substance and a certain type of spectroscopic data to find through the search. A requirement of the assignment was to access the paper and retrieve specific information with page numbers. Figure 6 illustrates an example question for Library Assignment 1 that requires searching the Reaxys® database to obtain spectroscopic information.

Although the format of the questions remained constant, the instructor changed the compounds in Library Assignment 1 each semester. Questions with single correct answers were used for this assignment for similar reasons as described in the Chemical Literature Assignment. As with all assignments that used a dynamic database such as Reaxys®, it was imperative that the answers be validated just before preparing an answer key.

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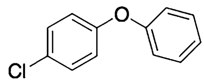
1. Find a reference with a proton NMR spectrum for  in Chloroform-d1 at 400 MHz..

a) Provide the CAS-RN number for this compound _________________

b) Complete the information for identifying this compound in the paper.

i) Table # _________

ii) Exact page number for structure of compound in paper _______

iii) Identification number/letter in paper ___________

c) Complete the information for the instrument:

i) Specific Model __________________

ii) Exact page number(s) for Model and Frequency __________________

d) Cite the literature paper.

e) Attach a copy of the full spectrum.

Figure 6. Example of a question from Library Assignment 1 requiring searching the Reaxys® database.

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Extension of Library Resources to Laboratory Reports

With the library's subscription to Reaxys® and the ability to obtain spectroscopy data from the database, new tabs with goals and tips for success were added for one or more experiments in the semester. As for the synthesis experiment in Chem0350, the Reaxys® database was used to obtain information about compounds that were not readily available in the tertiary resources. Depending on the experiment, students were required to find a paper in the chemistry literature that provided the melting point or the melting point and proton NMR (^{1}H) for the synthesized product of the experiment.

If a melting point was the only physical property data required, the class could use the melting point value available in the table feature of Reaxys® as the literature value for their report. While students did not have to read the paper, they were expected to click the URL (Uniform Resource Locator) in the citation cell on the table to get the details for the reference including the DOI. As indicated in Table 4, the DOI was part of the citing standards for an online paper. This approach was taken because many of the papers were not included in ejournal subscriptions. As with Chem0350, it was critical that the students' work could be accomplished using online articles to which the library had access. Locating a paper in a print volume was out of the scope of the course goals. Therefore, before the assignments were put on the library course guide, the librarian vetted all potential journal articles for each experiment.

With experiments that required the proton NMR (^{1}H) for a certain compound, students had to access a journal article to retrieve the information. The completion of Library Assignment 1 was invaluable for assisting students with this type of requirement in the laboratory report. Students were expected to use the NMR data to help guide them in the interpretation of their experimental compound. Figure 7 gives an example of a section of a laboratory report that required NMR data from a published paper. In most cases, the NMR data could only be located after applying all the strategies used for Library Assignment 1, such as finding the author identification code of the specific compound.

8. Proton NMR analysis of the product.

a) Draw (use ChemBioDraw) the structure of the product below and label the protons for identification in the tables below. (2 pts)

b) Complete the table below using NMR analysis from the *reference* paper obtained using the Reaxys Database. Add more lines as you need them! (3 pts)

Proton	Chemical shift, ppm	Splitting	Integration

c) Cite the reference PAPER obtained from the Reaxys Database used for part 8b. (3 pts)

d) Complete the table for your experimental proton NMR. (3 pts)

Proton	Chemical shift, ppm	Splitting	Integration

Figure 7. Example of a section of a laboratory report requiring NMR data from a published paper.

Development of Library Assignment 2

Besides using the Reaxys® database for literature searches, it was desired to introduce the students to another tool extensively used by chemists to search the primary literature, SciFinder. An experiment was modified from a published paper (*25*) that used SciFinder to search for properties of various analogs of a specific compound with the common name "chalcone." This chalcone synthesis experiment provided structures of compounds that allowed students to search using SciFinder and was the basis for Library Assignment 2.

The second pre-laboratory lecture given by the science librarian focused on explaining how to search using SciFinder and discussing Library Assignment 2. Students were required to register to obtain access to SciFinder (the university no longer had seat limitations by 2012). During the science librarian's presentation, the information from the Library Assignment 2 tab on the library course guide was used. Substance searching, including opening the structure editor, was demonstrated. Using an example chalcone, the librarian explained the CAS Registry record and the experimental properties available. In the lecture, students learned about the rich content in such a record. To obtain articles from the references on the Registry record, downloading a PDF was explained to the students.

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To facilitate the students' access to SciFinder, the lecture given by the science librarian was video recorded. The link to the video was posted on the course management system for students to view as they completed the assignment.

Students were assigned one of 16 chalcones to synthesize for the experiment. For Library Assignment 2, the class was required to obtain the following data from a literature paper for their assigned chalcone: melting point, IR (band or spectrum), proton (^{1}H) and carbon (^{13}C) NMR (chemical shift or spectrum), and MS (parent ion or spectrum). Using SciFinder, students completed a structure search of their chalcone to find one paper that contained all five of the required properties to characterize the chalcone. The SciFinder results on the Registry record for experimental properties were categorized by spectroscopic and physical. The student could deduce which paper was the one to select by identifying the property with the most references. By reviewing the other four, a common citation could be found. As always, the final criterion for selecting the paper was that the article had the most recent publication date.

The instructor selected the chalcone analogs and the librarian determined which ones met all the criteria. Only chalcones that had an associated paper available in SciFinder were chosen for the experiment.

An online submission for Library Assignment 2 to the course management system was mandatory. Table 5 lists the questions the students were required to answer for the assignment. The literature paper and the SI were uploaded in PDF format as part of the assignment. After the closing of the submission date, the instructor and the science librarian graded the assignment together.

Table 5. Questions for the Online Submission for Library Assignment 2

What is the number of your assigned chalcone? (1 through 16)
What is the CAS-RN of your assigned chalcone?
What is the melting point value or range from the attached literature paper?
In the Registry record of your assigned chalcone from SciFinder, what is the number of the citation of the attached literature paper in the reference list?
List the specific NMR brand name and frequencies for both ^{1}H and ^{13}C nuclei from the attached literature paper

Survey for Reflection on Chemical Information Literacy

At the end of the semester for 2012 and 2013, students were surveyed to provide an opportunity for reflection on their personal learning outcomes from the chemical information literacy component of the laboratory. The results are shown in Figure 8. In 2012, 201 students completed the survey while in 2013, 256

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students completed it. As a small incentive to complete the survey, students were given a couple of bonus points toward their quiz grade (the quiz grade was 32% of the overall lab grade). Not all students enrolled in the course completed the survey. The university's Institutional Review Board (IRB) determined that IRB review was not required for this survey.

As shown in Figure 8, the results for the five questions were consistent for the two years of surveying. The first two questions asked the students to assess their personal growth in using the library resources and using published papers to find data. Consistently, the sum of the responses of "Strongly Agree" and "Agree" were in the range of 85-90%.

Survey question 1: *In doing library assignments and finding papers for lab reports, my confidence using chemistry resources, provided by the library, has grown since the beginning of the semester.*

Year	% Strongly Agree	% Agree	% Neither	% Disagree	% Strongly disagree
2012	30	59	7	3	1
2013	26	59	8	13	1

Survey question 2: *My ability to use published papers in organic chemistry to find data has grown since the beginning of the semester.*

Year	% Strongly Agree	% Agree	% Neither	% Disagree	% Strongly disagree
2012	33	57	5	4	1
2013	26	63	6	4	1

Survey question 3: *The library course guide was useful for successfully completing the assignments in the laboratory reports and library assignments.*

Year	% Strongly Agree	% Agree	% Neither	% Disagree	% Strongly disagree
2012	30	44	17	5	5
2013	35	46	11	7	5

Survey question 4: *Integrating library resources into the laboratory curriculum enhanced my understanding of the way chemists use the chemical literature.*

Year	% Strongly Agree	% Agree	% Neither	% Disagree	% Strongly disagree
2012	14	50	19	12	5
2013	13	50	22	12	3

Survey question 5: *Using library resources for chemistry will help me navigate resources for other disciplines.*

Year	% Strongly Agree	% Agree	% Neither	% Disagree	% Strongly disagree
2012	9	27	36	19	10
2013	6	31	32	22	9

Figure 8. Survey results from second semester organic chemistry students for two different years.

The third and fourth questions focused on how the students felt about using the library course guide and having library resources as part of the laboratory curriculum to help them become familiar with the tools of chemists. The sums of the two highest ratings ("Strongly Agree" and "Agree") were 74% and 81% for question 3 and 64% and 63% for question 4, respectively for 2012 and 2013.

The last question sought feedback on whether the students recognized that they were gaining transferable skills when they learned how to use chemistry resources. The response in both years showed that about one-third of the respondents were grouped in the following combined ratings: "Strongly Agree and "Agree", "Neither Agree" or "Disagree", or "Disagree" and "Strongly Disagree".

The authors consider that the feedback for the first four questions indicated that the students, over two semesters of organic chemistry, personally felt the impact of the authors' inclusion of CIL into the curriculum of the laboratory. On the other hand, with the responses to question 5, it was clear that students did not recognize that learning one discipline of electronic information resources would give them transferable skills in the use of the online resources for other disciplines.

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Discussion

The strategy that was refined over the six plus years of collaboration is reflected in the two years of data presented by the survey. By 2012, the authors were satisfied with the content and presentation of the curriculum of the two semesters. The authors' learning objectives in Table 1 remained the same throughout the collaboration.

The objectives regarding the student use of the library course guide indicated success in the response to Question 3 in the reflective survey. While it is not possible to say that all the students used the customized webpages for each library assignment or laboratory report, the numbers suggest that overall the library course guide was an important tool for students in the courses.

The students' interactions with the librarian through in-person, email, telephone, and chat communications are anecdotal evidence of the "embeddedness" of the librarian into the courses when it came to CIL. The library course guide provided the link to the librarian throughout the semester. Therefore, students learned from the librarian in lectures, by the course guide, via videos, and in communications that satisfied the first learning objective for each semester.

While the authors did not accumulate data testing the success of each objective, they believe that the final forms of the assignments and laboratory reports gave students the confidence (whether they recognized it or not) to use the chemical literature for more than property search. Through their curriculum they have found an approach to introduce to first-year and second-year undergraduate students to some of the research resources of the chemist.

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Lessons Learned

During the years of the collaboration, the authors learned lessons from experience with the activities and iteratively revised the course each semester. The authors, however, would like to note the following important lessons for those considering information chemistry literacy education via a large laboratory course. Working with a large population of students using the resources has taught the authors many things:

- Each semester, the instructor's role is to change the graded assessments, and assign the experiments and the librarian's is to verify answers and advise on the suitability of compounds for students to find results from sources.
- Assignments are improved with students' questions.
- Limitations in resources require flexibility.
- Answers should be verified before grading begins because online content is updated continuously.
- A video of the science librarian's pre-lab lecture facilitates the learning of the library resources; students can replay the sequence of steps.

Conclusion

At the time the authors began their CIL collaboration in 2007, the American Chemical Society's Committee on Professional Training's 2003 version of the *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs* provided recommendations for student skills in chemical literature. The guidelines stated that "students preparing for professional work in chemistry must learn to retrieve specific information" and they should "gain experience with online, interactive database searching." To achieve this, instruction should include library and computer exercises (*26*). In the CHEM0350 and 0360 assignments and reports, the authors sought to meet these general guidelines. However, other standards pointed to more specific expectations for skills that students needed to work successfully with the chemical literature.

In 2000, the Association of College Research Libraries (ACRL), a Division of the American Library Association (ALA), had already published standards for information literacy for higher education (*27*). Then the Science and Technology Section (STS) of ACRL formed a Task Force on Information Literacy for Science and Technology. By June 2006, this group had created a modification of the ACRL document with the focus on undergraduates in science and engineering/technology (*28*). Certain performance indicators of the five STS standards mapped to the content and goals of the chemical literature teaching for both semesters of the organic chemistry sequence described in this chapter. For example, according to Standard One, students need to be able to recognize primary, secondary, and tertiary resources in a discipline. The students in both courses were required to be skilled with online handbooks (tertiary), literature databases (secondary), and extracting required data from journal articles (primary). In Standard Two, a performance indicator includes using structure search in a discipline's information retrieval systems, a requirement of the courses described in this chapter. Standard Five, indicator 1c, is to "apply information access skills learned in one subject area to another." The student responses to the Reflection survey question 5 suggested to the authors that most of the students did not recognize the potential for this transferable knowledge.

In 2007, the Ad Hoc Committee on Information Literacy in the Division of Chemistry (DCHE) of the Special Libraries Association produced *Information Competencies for Chemistry Undergraduates: the elements of information literacy* (*29*). One of the authors was on that committee. This document outlined specific outcomes for a chemistry student. Part 1-1 states that students need to get help from "librarians, faculty, and teaching assistants." According to Part 1-3, they should understand systems to identify chemical information including CAS RN and apply chemical structures to find information. Properties, Part 2-1, and spectra, Part 2-3, recommends using basic property sources such as handbooks like CRC, Merck, and Knovel Critical Tables and complex compendia, now called SciFinder and Reaxys®. The organic students in semester 1 started with handbooks and physical properties and progressed to one of the compendia. The students in semester 2 focused on spectroscopic data in the two complex sources and the primary literature including supporting information documents associated with some journal articles. Finally, Section 4 emphasizes that a student can cite using the appropriate format. Throughout the assignments and laboratory reports, using the courses' citation style was a must.

As a result of these correlations with the standards, as outlined by the ACS, ALA/ACRL/STS, DCHE, and the most recent ACS Committee on Professional Training's (CPT) document "Chemical Information Skills" (*30*), the pedagogy presented in the chapter is applicable to other institutions that are developing CIL curricula. The assignments and extensions to the laboratory reports can be adapted to the library holdings available at other institutions. First-timers to chemical information literacy should find guidance and useful tips in the chapter for creating their own content. Librarians or faculty could teach the curriculum presented in this chapter. On the other hand, the authors found that their collaboration was essential to the implementation of the chemical information literacy.

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Chemical Abstracts Service customer support for training log-ins from 2008-2011

Brown University Chemistry Department

Brown University Organic Chemistry Laboratory students from 2007-2014

RELX Intellectual Properties SA for permission to include the Reaxys® screen capture in Figure 1.

Brown University Library for permission to include Figure 4.

Dr. Eric Victor for technical help with figures.

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References

1. Tucci, V. K.; O'Connor, A. R.; Bradley, L. M. A Three-year Chemistry Seminar Progam Focusing on Career Development Skills. *J. Chem. Educ.* **2014**, *91*, 2071–2077.
2. Forest, K.; Rayne, S. Incorporating Primary Literature Summary Projects into a First-year Chemistry Curriculum. *J. Chem. Educ.* **2009**, *86*, 592–594.
3. Ridley, D. Introduction to Searching with SciFinder Scholar. *J. Chem. Educ.* **2001**, *78*, 557–558.
4. Rosenstein, J. A Literature Exercise using SciFinder Scholar for the Sophomore-Level Organic Chemistry Course. *J. Chem. Educ.* **2005**, *82*, 652–654.
5. Currano, J. N. Learning to Search in Ten Easy Steps: A Review of a Chemical Information Course. *J. Chem. Educ.* **2005**, *82*, 484–488.
6. Peters, M. C. Beyond Google: Integrating Chemical Information into the Undergraduate Chemistry and Biochemistry Curriculum. *Sci. Technol. Libr.* **2011**, *30*, 80–88.
7. Somerville, A. N.; Cardinal, S. K. An Intergrated Chemical Information Instruction Program. *J. Chem. Educ.* **2003**, *80*, 574–579.
8. Gawalt, E. S.; Adams, B. A Chemical Information Literacy Program for First-Year Students. *J. Chem. Educ.* **2011**, *88*, 402–407.
9. Jensen, D.; Narske, R.; Ghinazzi, C. Beyond Chemical Literature: Developing Skills for Chemical Research Literacy. *J. Chem. Educ.* **2010**, *87*, 700–702.
10. Mandernach, M. A.; Shorish, Y.; Reisner, B. A. The Evolution of Library Instruction Delivery in the Chemistry Curriculum by Mixed Assessment Methods. *Issues Sci. Technol. Libr.* [Online] 2014, No. 77. http://www.istl.org/14-summer/refereed3.html (accessed Jan 23, 2016).
11. Thompson, R. Q.; Ricker, A. S. Teaching Chemical Information in a Liberal Arts Curriculum. *J. Chem. Educ.* **1999**, *76*, 1590.
12. Tomaszewski, R. The Concept of the *Imploded Boolean* Search; A Case Study with Undergraduate Chemistry Students. *J. Chem. Educ.* **2016**, *93*, 527–533.
13. Greco, G. E. Chemical Information Literacy at a Liberal Arts College. *J. Chem. Educ.* **2016**, *93*, 429–433.
14. O'Reilly, S. A.; Wilson, A. M.; Howes, B. Utilization of SciFinder Scholar at an Undergraduate Institution. *J. Chem. Educ.* **2002**, *79*, 524–526.
15. Jacobs, D. L.; Dalal, H. A.; Dawson, P. H. Integrating Chemical Information Instruction into the Chemistry Curriculum on Borrowed Time: The Multiyear Development and Evolution of a Virtual Instruction Tutorial. *J. Chem. Educ.* **2016**, *93*, 452–463.
16. Gallagher, G. J.; Adams, D. L. Introduction to the Use of Primary Organic Chemistry Literaure in an Honors Sophomore-Level Organic Chemistry Course. *J. Chem. Educ.* **2002**, *79*, 1368.
17. Swoger, B. J. M.; Helms, E. An Organic Chemistry Exercise in Information Literacy Using SciFinder. *J. Chem. Educ.* **2015**, *92*, 668–671.

18. Tomaszewski, R. A Science Librarian in the Laboratory: A Case Study. *J. Chem. Educ.* **2011**, *88*, 755–760.
19. Reaxys® (RELX Intellectual Properties SA). https://www.reaxys.com (accessed Nov 20, 2015).
20. SciFinder (Chemical Abstracts Service). https://scifinder.cas.org (accessed Nov 20, 2015).
21. *CRC: Handbook of Chemistry and Physics* (Taylor & Francis Group, LLC); http://www.hbcpnetbase.com/ (accessed Nov 20, 2015).
22. *Knovel Library: Critical Tables* (Knovel Corporation); https://app.knovel.com/web/index.v (accessed: Nov 20, 2015).
23. *Merck Index Online* (Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc. licensed to Royal Society of Chemistry); https://www.rsc.org/merck-index (accessed Nov 20, 2015).
24. *The ACS Style Guide: Effective Communication of Scientific Information*, 3rd ed.; Coghill, A. M., Garson, L. R., Eds.; American Chemical Society: Washington, DC, 2006.
25. Vyvyan, J. R.; Pavia, D. L.; Lampman, G. M.; Kriz, G. S. Preparing Students for Research: Synthesis of Substituted Chalcones as a Comprehensive Guided-Inquiry Experience. *J. Chem. Educ.* **2002**, *79*, 1119–1121.
26. Committee on Professional Training. *ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs* [Online]; American Chemical Society: Washington, DC, Spring 2003. https://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/2003-acs-guidelines-for-bachelors-degree-programs.pdf (accessed June 14, 2016).
27. Association of College and Research Libraries. *Information Literacy Competency Standards for Higher Education* [Online]; American Library Association: Chicago, 2000. http://www.ala.org/acrl/standards/informationliteracycompentency (accessed June 12, 2016).
28. ALA/ACRL/STS Task Force on Information Literacy for Science and Technology. *Information Literacy Standards for Science and Engineering/Technology* [Online]; American Library Association: Chicago, June 2006. http://www.ala.org/acrl/standards/infolitscitech (accessed June 12, 2016).
29. Ad Hoc Committee on Information Literacy of the Chemistry Division. *Information Competencies for Chemistry Undergraduates: the elements of information literacy* [Online]; Craig, C., Maddux, L., Eds.; Special Libraries Association: New York, January 2007. http://chemistry.sla.org/il/ (accessed June 12, 2016).
30. Committee on Professional Training. *ACS Guidelines & Supplements* [Online]; American Chemical Society: Washington, DC, August 2015. https://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/chemical-information-skills.pdf (accessed July 14, 2016).

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Chapter 7

Integrating Information Literacy and Research Strategies into a Sophomore Chemistry Course: A New Collaboration

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Librarians at the State University of New York College of Environmental Science and Forestry (SUNY ESF) teach a one-credit information literacy course, which is required for several majors. For many years, a section of this course was integrated into a senior level professional chemistry course. Students in this course work with chemistry faculty to develop a research proposal, and spend five weeks with the chemistry liaison librarian learning library and information research skills related to their topics. Recognizing that students need to begin learning research and career skills sooner than their senior year, chemistry faculty approached the library to work with them in integrating information literacy skills into a new sophomore level course. During this new course's pilot semester, the chemistry liaison librarian was invited to teach two class sessions and to develop an assignment for students to help them write a paper on a chemistry topic. This chapter discusses specific outcomes, topics covered, assignments, observations, and future directions of the information literacy instruction in this new sophomore level course.

Introduction

Information literacy has a long history at the State University of New York College of Environmental Science and Forestry (SUNY ESF), and librarians have taught a one-credit course on information seeking skills for many years. Historically, this course has been integrated in the senior year of the chemistry curriculum. In recent years, chemistry faculty recognized the need for chemistry majors to learn information literacy skills sooner in their college career. This chapter presents a new collaboration between chemistry faculty and a librarian to develop a new chemistry course with an information literacy component.

In the published literature, librarians and chemistry faculty have reported on their collaborations, many of which go beyond the "one-shot" library information sessions and move towards integrating library and research information skills into course content and assignments. Information literacy skills taught by a librarian as part of chemistry labs have involved students working through guided exercises (*1*, *2*). Jensen, Narske and Ghinazzi also reported on efforts made at Augustana College to develop what they call "chemical research literacy" into the organic chemistry course sequence (*3*). This effort included a presentation by the science librarian and three assignments that guided students through "evaluat[ing], interpret[ing], and incorporat[ing] chemical literature when communicating (*3*)." A deeply integrated approach from the University of Rochester has developed over several years into a chemical information instruction program spanning all four years of an undergraduate experience in lecture and laboratory courses (*4*). A one-credit chemical information literacy course was implemented at Goucher College with the purpose of developing chemistry major sophomores' skills in information literacy to better prepare them for course work in upper-division chemistry courses (*5*). Librarians and chemistry faculty partnered together at James Madison University to update a Literature and Seminar course in which chemistry faculty and librarians team teach chemical information literacy skills (*6*). In this case, faculty and librarians indicated that the research skills needed by students have changed to not just searching skills, but to filtering and evaluating skills, as there is much more information to sift through (*6*). The chemistry faculty and librarians at SUNY ESF also made this observation, which was a major factor leading to the development of a new course for chemistry major sophomores.

Librarians are familiar with using the Information Literacy Competency Standards for Higher Education from the Association of College and Research Libraries (ACRL) to develop learning objectives for their library instruction sessions (*7*). Regarding chemistry and information literacy, most of the models in the literature refer to the Information Competencies for Chemistry Undergraduates developed by the Special Libraries Association (SLA) and the American Chemical Society (ACS) (*8*). Both the ACRL standards and the SLA and ACS competencies were consulted as part of the development of the information literacy component of the new course described in this chapter. The most common competencies referred to include:

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- Understand how information is organized in the library (databases, catalog, research guides, etc.) and the basics of how scientific information is communicated (i.e. peer-review process in publishing) (*8*).
- Know how to search for and find chemical information such as background information and journal articles (*8*).
- Clearly present research in an ethical manner, particularly as it relates to proper citation and formatting and use of a citation manager (*8*).

Librarians at SUNY ESF have also worked to integrate information literacy into the broader chemistry curriculum. The SUNY ESF campus community consists of about 2,000 students and 200 faculty and is situated adjacent to Syracuse University in Syracuse, New York. Librarians at Moon Library at SUNY ESF hold liaison responsibilities for each of the academic departments on campus. Each librarian teaches at least one section every semester of a one-credit information literacy course. Several of the undergraduate degree programs require completion of this information literacy course (often called ESF 200), and the chemistry Bachelor of Science degree is no exception.

The first exposure to information literacy concepts and library resources for chemistry major students at SUNY ESF is through the first-year orientation seminar. This required course introduces first-year and transfer students to the chemistry major program and orients them to various campus services (student affairs, career services, library resources, etc.) to help them be successful in their chemistry major and college in general. The chemistry liaison librarian (henceforth referred to as the CLL) is invited each year to a class period to introduce library services, databases (including SciFinder), and other informational resources. Historically, students have been advised to take the one-credit information literacy course (ESF 200) during their senior year in conjunction with the professional chemistry course. ESF 200 has been taught by SUNY ESF librarians since its inception in 1973 (*9*). This 200-level course, populated mostly by sophomores, meets three hours a week for five weeks each semester and is required by several degree programs. ESF 200 incorporates learning outcomes developed in accordance with the ACRL information literacy standards (*7*). Re-visioning of the course to reflect the new ACRL Framework for Information Literacy for Higher Education is currently in progress (*10*). The course is organized around five units, which include: Catalog Searching, Database Searching, Internet Searching, Topic Selection, and a Final Project. Each of these units has a specific graded assignment to assess student learning. Students also complete a final project of which examples include bibliographies (sometimes annotated) of a variety of sources on a research topic, or posters of recommended books, journals, databases, and websites on a specific research topic.

In 1977, ESF 200 was made a requirement for chemistry students as part of the Professional Chemistry course (FCH 495) (*11*). And, since the 1990s, there has been a specialized section of ESF 200 integrated with FCH 495. The CLL has taught these specialized sections and linked them to the corresponding course. As part of the senior year professional chemistry course, students write a research proposal that is the basis of their research project in the following

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semester. These proposals require literature reviews and are submitted for a round of reviews by chemistry faculty before final grading. The intent for integrating the information literacy course with this professional chemistry course was to teach students literature searching skills to aid them in preparing their research proposals.

Table 1 shows the progression of information literacy instruction for chemistry students at SUNY ESF along with the changes that are discussed in this chapter. Based on the examples in the literature, the long history of information literacy at SUNY ESF, and the need to revise instruction to better meet students' needs, this chapter focuses on how the CLL and chemistry faculty members have worked together to integrate information literacy into a new sophomore level chemistry course, Career Skills for Chemists (FCH 232). In this new course, students are introduced to various aspects of chemistry, including career information, which they will need to work towards as they continue their studies and look for employment. FCH 232 does not replace ESF 200 because each has a different focus. Both courses are still a requirement for chemistry majors.

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Table 1. Progression of Information Literacy for Chemistry Majors at SUNY ESF

	First Year	*Sophomore Year*	*Senior Year*	
Course	FCH 132: Orientation Seminar	FCH 232: Career Skills for Chemists	FCH 495: Professional Chemistry	ESF 200: Information Literacy
Notes	CLL visits class each fall	-CLL teaches two classes and grades library assignment -New course since 2013 -Beginning 2015, students also take ESF 200		-Taught by CLL and previously integrated in FCH 495 -As of 2015 no longer integrated in FCH 495; students take first year or sophomore year

A Need for Change

Although integrating the one-credit information literacy course with the senior professional chemistry course was valuable, this arrangement was ultimately not the most helpful to students since they were not learning searching and information retrieval skills until their senior year. Chemistry faculty who taught the professional chemistry course and other lower-division chemistry courses realized that students lacked basic skills needed to locate literature for lab courses, independent research experiences, and term papers in various science and engineering courses. There was too much of a gap between the CLL visiting the freshman chemistry orientation seminar class and students taking the information literacy course during their senior year. Chemistry major seniors would indicate on the end-of-course surveys that they wished they had learned these skills and taken the course sooner. Librarians and chemistry faculty at SUNY ESF were in agreement that information literacy skills are valuable throughout an undergraduate's time in college; and these concepts should be taught in the freshman or sophomore year. This chapter focuses on one solution that began in the fall semester of 2013.

Chemistry faculty noted that students' main source of information was the internet and the information students were finding was not peer-reviewed, often biased, and frequently incorrect. They also observed that students would typically find one research article from a Google search that may or may not have been recent or peer-reviewed. Students then assumed this was sufficient to proceed with a project. They lacked the ability to do a structured search focused on key words or concepts and they generally did not use critical thinking when evaluating the relevance of prior work that they found. Upper-division chemistry courses require proper citation of sources, and students lacked knowledge of the elements of a citation and a specified citation style. Often they would copy and paste a citation from the internet into their papers without properly using in-text citations and a correctly formatted bibliography.

To address the undergraduate students' need for certain skills earlier in the chemistry curriculum, the chemistry faculty authors of this chapter decided to design a new sophomore-level course called Career Skills for Chemists (FCH 232). Reasons for starting this course included the following:

- Faculty wanted students to start thinking about chemistry as a career rather than simply an academic subject.
- Chemistry students needed to become familiar sooner in the curriculum with skills that had been historically taught in the senior year so they could utilize and practice them. These skills include various aspects of technical writing and public speaking, information literacy, concepts in academic integrity and professional ethics, and the ability to find jobs and internships coupled with interviewing skills.
- The development of *esprit de corps* within the cohort taking the course (mainly sophomores and transfer students) to enhance retention in the chemistry curriculum.
- To facilitate student interaction with successful alumni of the chemistry program who have pursued a diversity of careers.

To assist with teaching information literacy skills, chemistry faculty asked the CLL to lead two class sessions in the new course. Those sessions focused on locating literature to inform a position paper, one of the course's assignments. Chemistry faculty recognized that the librarian's knowledge and experiences in teaching the required information literacy course for chemistry seniors would benefit the development of this new course. Chemistry faculty also recognized that librarians are far more familiar with current databases, search techniques,

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availability, and location of information; and by working with librarians who know the newer resources and techniques, they have been informed of the multitude of databases that are easier to use. Furthermore, chemistry faculty recognized that librarians are more adept at teaching and explaining the fundamentals of literature searches and citation styles whereas chemistry faculty indicated that, in many instances, they assume a much greater understanding of students' knowledge of web searching for specific information.

A New Collaboration

In the summer of 2013, the two chemistry faculty who were developing this new course for chemistry sophomores began working with the CLL to develop the information literacy portions of the course. One demonstrable outcome of this new course would be that students would be able to develop skills in information literacy to facilitate conducting a survey of technical publications for the purpose of writing a position paper on a subject in polymer, environmental, biochemistry, or natural products chemistry. The librarian visited FCH 232 twice, once each in the sixth and seventh weeks of the 14-week-long semester, to discuss literature searching and formulating citations for the position paper assignment. There were eight students enrolled in this course. Each class was fifty minutes long and met once a week. The CLL developed an assignment to guide students through a research strategy, and graded it to gauge their success (see Figure 1).

Information Literacy Class Sessions

The information literacy class sessions took place in a computer lab so that students could actively work on their assignments. PowerPoint and live database demonstrations were used by the CLL to teach during these sessions. The authors of this chapter collaborated to decide on the desired outcomes for these information literacy sessions. These outcomes (listed below) were informed by the ACRL Information Literacy Competency Standards and the Information Competencies for Chemistry Undergraduates as discussed earlier.

- Outcome 1: Students will be able to develop a search strategy to find literature on a topic.
- Outcome 2: Students will be able to search in designated library databases.
- Outcome 3: Students will be able to identify a peer-reviewed article.
- Outcome 4: Students will be able to correctly format literature citations according to APA style.

The first class session introduced strategies for finding a topic in which students were interested and then locating a corresponding news article that they could use as they developed their position for their paper. The CLL reviewed databases such as Opposing Viewpoints from Gale and Newspaper Source Plus

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from EBSCO as places to help students begin to refine a topic and find a popular news source. The New York Times Science section and Scientific American were also suggested as sources for the news article. Also during this first information literacy class session, the librarian introduced basic search strategies such as developing a list of keywords and concepts, using connectors (Boolean and other), and applying limiters within databases. Students would begin to use these strategies in the next class as they searched for scholarly articles on their topics.

Name ______________________________

FCH 232 Library Assignment - Develop a Search Strategy

INSTRUCTIONS: Fill in the blanks below and answer the questions about how you conducted your search strategy for your position paper. Using APA style, please list at least 8 citations of articles and/or sources you found for your paper. Add more lines or another sheet of paper if you need more room. See the FCH 232 Research Guide (http://libguides.esf.edu/FCH232) for more information. This assignment is due October 15, 2013 and is worth 100 points.

What is your research topic? Write a short paragraph describing your topic.
List keywords relating to your topic:

Describe, in detail, how you combined your keywords to search for articles on your topic.

List at least two (2) databases you searched and explain why you chose each one.

Which database did you like searching best? Why? What did you not like?

According to what you learned in class, what is a peer-reviewed article or journal? (Remember most of your sources must be peer-reviewed!)

Source Citations: Format in APA style as you would in your references page at the end of your paper. You must have at least eight (8) sources listed and six (6) of those must be peer-reviewed.

Figure 1. Library Assignment for FCH 232 in Fall 2013. These questions were spaced out over two pages.

The second information literacy class session built upon the search strategies taught in the first session and required that students apply them by using databases to locate peer-reviewed articles. Chemistry faculty had asked that only two databases be discussed as they had observed students being overwhelmed

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with the number of databases available to them. The two databases discussed were SciFinder, from Chemical Abstracts Service, and ScienceDirect, from Elsevier. SciFinder was requested by the chemistry faculty because students will use it throughout their time as chemistry undergraduates and in their careers. ScienceDirect was chosen by the CLL because it contains a wide range of science and chemistry related publications. Students were instructed on the basics of searching each of these databases to retrieve relevant articles. The CLL then taught students the essentials of APA style (which was the required style for this course), particularly for journal articles, and provided a two-page guide with examples. The CLL also created an online guide via LibGuides to reiterate some of the information taught in class and point students to relevant resources such as citation managers (*12*). Students were given about ten to fifteen minutes at the end of the second class session to work on searching for articles in the databases. This time of searching was unstructured, but students asked questions and the CLL and chemistry faculty were able to provide assistance. At the end of the session, the CLL told students they were welcome to seek help from her, or other librarians, as they completed their assignments. Only one student of the eight-person class asked the CLL for assistance outside of class.

Library Assignments

The chemistry faculty asked the CLL to create and grade a library assignment to help students work towards what was needed for the position paper. The library assignment was due one week after the second information literacy class session and each student completed their own assignment. The assignment asked students to:

- Write a short paragraph describing their topic
- Write down keywords they planned to use for searching databases for literature on their topics
- Demonstrate how they planned to combine and search those terms
- Identify which databases they searched and any problems they encountered
- Give a definition of a peer-reviewed journal article
- Include a list of references formatted according to APA style

Figure 1 shows the full library assignment as given to students. Table 2 shows the library assignment questions and point values as they correspond to the outcomes for the information literacy class sessions. Initial observations indicated that students encountered the most trouble generating a correctly formatted references list, even when using citation manager software; however, most students were able to find relevant sources for their paper.

The Position Paper

For the position paper assignment, students were asked to locate a current event or issue reported on in a newspaper or popular magazine on a topic related to environmental chemistry, biochemistry, natural product chemistry, or polymer chemistry. This topic needed to be something arguable so that students could take a stance on the subject matter. Students were then asked to find 8-10 scholarly, peer-reviewed articles to help develop their argument in a written paper. A correctly formatted APA references list, including the popular news article, was also required for the paper. Position papers were due six weeks after the information literacy sessions.

Table 2. Information Literacy Outcomes and Library Assignment

Corresponding Outcome	*Library Assignment Question*	*Grade Value (100 points possible)*
Outcome 1: Students will be able to develop a search strategy to find literature on a topic.	What is your research topic? Write a short paragraph describing your topic.	5 points
Outcome 1: Students will be able to develop a search strategy to find literature on a topic.	List keywords relating to your topic.	5 points
Outcome 1: Students will be able to develop a search strategy to find literature on a topic.	Describe, in detail, how you combined your keywords to search for articles on your topic.	15 points
Outcome 2: Students will be able to search in designated library databases.	List at least two (2) databases you searched and explain why you chose each one.	5 points
Outcome 2: Students will be able to search in designated library databases.	Which database did you like searching best? Why? What did you not like?	5 points
Outcome 3: Students will be able to identify a peer-reviewed article.	According to what you learned in class, what is a peer-reviewed article or journal?	10 points
Outcome 3: Students will be able to identify a peer-reviewed article. Outcome 4: Students will be able to correctly format literature citations according to APA style.	APA References List with at least eight sources, six of which must be peer-reviewed.	55 points: -30 points for at least 8 sources -5 points for "References" title -20 points for APA formatting

Evaluating the Information Literacy Class Sessions in FCH 232, Fall 2013

The CLL assessed the students' achievement of the information literacy outcomes by grading the library assignments and sending the grades to the chemistry faculty. The CLL and chemistry faculty discussed students'

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performance on the assignments later in the semester. Overall, students did well on the assignment and achieved grades in the range of 80-100 percent. Students were able to articulate variations of search terms and how they combined those terms to search for sources on their topic (Outcome 1). They struggled, however, with correctly titling their references list in accordance with APA style, which relates to Outcome 4. Even though it was discussed in class that the correct list title is "References," most students did not title their lists. This further indicates that students did not use (or correctly use) a citation manager/generator as suggested in class.

The library assignments were graded according to the point values shown in Table 2. Rather than using a rubric, the CLL assigned grades for each question based on whether the student answered the question correctly and included a description of their thought process, particularly for the more open-ended questions. Students lost points if they consistently missed elements of citations, such as not listing references alphabetically, not listing enough authors, missing publication titles, volume, and issue numbers, etc. Because APA style was the required format for this part of the assignment and the elements of APA style were discussed in class, it was important that students be able to employ this style.

Students achieved similar grades on the position paper as they did on the library assignment. Formal mapping and assessment of the information literacy outcomes was not done with the position papers. However, chemistry faculty observed that students still struggled with properly citing their work and formulating their reference lists. It was also evident that students did not completely understand the position paper genre as many students did not find a news source that informed the student authors in taking a stance on the topic. Many students wrote typical research papers, with no discussion of the pros and cons of the topic they wrote about.

At the end of the semester, the chemistry faculty and the CLL discussed how the course and the information literacy sessions went. All had positive reactions regarding the new course and the information literacy class sessions as a whole. As the CLL later reflected on the experience and discussions with the chemistry faculty, a few issues rose to the surface to address in the future. First, it would be beneficial to have more time in class for students to work on searching the literature and have the librarian there to help. Second, instruction on citations needed to be more specific on each piece of a citation and give more of an indication of what is expected of students by way of correct citation format. Lastly, the assignment should be reformatted to include more critical thinking questions, such as discussing why it is important to cite sources correctly and how to determine what type of source (popular, scholarly, newspaper, peer-reviewed, etc.) is needed or has been found. With only observations (no data) on the background of skills that students possessed before taking the Career Skills for Chemists course, the authors were not able to truly assess improvement of information literacy skills. The next section discusses the method addressing this issue the chemistry faculty and librarian are presently working towards.

FCH 232 and Information Literacy since Fall 2013

The Career Skills for Chemists course (FCH 232) was offered again in Fall 2015. Between 2013 and 2015 the course was made a requirement for the sophomore chemistry majors. Additionally, the one-credit information literacy course (ESF 200) is no longer integrated into the Professional Chemistry course for senior chemistry students, but it is still a required course for the chemistry program. Students are advised to take ESF 200 as first-years or sophomores.

Fourteen students enrolled in FCH 232 in the Fall of 2015, and the CLL again visited the class twice in the middle of the 14-week-long semester. Much of what was done in the Fall of 2013 was repeated as described above, but some changes were made based on the CLL's reflections on the first course. Instead of one library assignment, students were given two assignments to complete. Students partially completed these assignments during the class sessions taught by the librarian. The questions were similar to the original assignment from 2013, but split into two groups. The first assignment focused on finding a popular news source and brainstorming keywords and developing a search strategy. The second assignment focused on searching for scholarly articles and putting together a reference list in APA style. The librarian graded the assignments and by having two assignments, students were able to get feedback throughout the process of beginning to research for their position paper. Students did well on the assignments much like the students two years prior. Grading of the library assignments was similar to what was described above, and grades were better overall compared to the grades given in Fall 2013. Position paper grades were also better than the first time the course was offered, particularly the pro/con arguments and use of peer-reviewed articles. The authors discussed how the Career Skills for Chemists course went this second time and observed that the information literacy class sessions were useful for the students and they were better able to complete the position paper assignment. By having two library assignments, students were able to receive some feedback before moving to the next library assignment, which likely helped them work through their research process for finding sources for the position paper.

As the Career Skills for Chemists course continues with the information literacy component, more and better assessment is needed to determine its effectiveness formally. Developing a better rubric for grading the library assignments and matching that to the outcomes for the information literacy component is critical and is currently in progress for Fall 2016. As students move through the chemistry curriculum after taking the Career Skills for Chemists course (and the one-credit information literacy course), it will be necessary to develop a process to see how students' information literacy skills improve. This might be accomplished by developing a metric that measures senior students' success in research proposals from the Professional Chemistry course and how that compares to what they learned as sophomores, or through a departmental graduation or exit survey. It would also be prudent to link the Career Skills for Chemists information literacy assignment to those used in the one-credit information literacy course assignments that chemistry majors also complete.

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Conclusion

From the CLL's perspective, this collaboration with chemistry faculty in working with the new Career Skills for Chemists course has been valuable. It was important to get to know the chemistry major students earlier in their time at SUNY ESF. It was also valuable to begin to assist them with information literacy skills that not only help them in their studies, but are also skills they will use throughout their careers. From the faculty's perspective, this collaboration strengthened students' use of literature sources and library resources. In particular the relevance of literature that was cited in papers was of a higher level than in previous classes. A few students who were in the pilot FCH 232 class in 2013 took a graduate level course with one of the authors of this chapter in the Spring 2016 semester. He observed that those students' term papers were more inclusive of peer-reviewed journal papers compared to website citations as seen in the past. One student even included a section on search strategy. Clearly, these students better understand the quality distinction between peer-reviewed articles versus openly sourced (website) information. Instruction in chemistry-specific library resources was particularly helpful for students as they are often overwhelmed by the abundance of databases available and invariably rely on Google, whereas through this collaboration with the CLL these students used scientific databases more extensively. As the course continues in future semesters, it will be essential to formally assess students' learning, possibly in conjunction with the one-credit information literacy course and the senior professional chemistry course. An assessment of this nature would be useful to see how information literacy skills are needed and developed throughout the chemistry undergraduate experience at SUNY ESF.

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References

1. Peters, M. C. *Sci. Technol. Libr.* **2011**, *30*, 80–88.
2. Loo, J. L. *J. Acad. Librariansh*. **2013**, *39*, 252–259.
3. Jenson, D.; Narske, R.; Ghinazzi, C. *J. Chem. Educ*. **2010**, *87*, 700–702.
4. Somerville, A. N.; Cardinal, S. K. *J. Chem. Educ*. **2003**, *80*, 574–579.
5. Greco, G. E. *J. Chem. Inf.* **2016**, *93*, 429–433.

6. Mandernach, M. A.; Shorish, Y.; Reisner, B. A. *Issues Sci. Technol. Librariansh.* [Online] 2014, 77, DOI: 10.5062/F46H4FDD. http://www.istl.org/14-summer/refereed3.html (accessed Nov 16, 2015).
7. Association of College & Research Libraries. *Information Literacy Competency Standards for Higher Education*; http://www.ala.org/acrl/standards/ informationliteracycompetency (accessed Nov 16, 2015).
8. *Information Competencies for Chemistry Undergraduates: The elements of information literacy*; Special Libraries Association, Chemistry Division and American Chemical Society, Divison of Chemical Information, 2012; https://en.wikibooks.org/wiki/Information_Competencies_for_Chemistry_Undergraduates (accessed Nov 16, 2015).
9. Morris, J. M.; Elkins, E. A. *Library Searching: Resources and Strategies with Examples from the Environmental Sciences*; Jeffrey Norton Publishers: New York, NY, 1978.
10. Association of College & Research Libraries. *Framework for Information Literacy for Higher Education*; http://www.ala.org/acrl/sites/ala.org.acrl/files/ content/issues/infolit/Framework_ILHE.pdf (accessed Mar 11, 2016).
11. SUNY ESF. *Undergraduate Studies Bulletin, Part One of the Catalog of the SUNY College of Environmental Science and Forestry*; Syracuse, NY, 1977.
12. Owens, R. *FCH 232 - Career Skills for Chemists*; http://libguides.esf.edu/FCH232 (accessed Mar 14, 2016).

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Chapter 8

Reading, Writing, and Peer Review: Engaging With Chemical Literature in a 200-Level Analytical Chemistry Course

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The 200-level analytical chemistry course has been one of the few science courses designated as writing intensive (WI) in the Oberlin College curriculum. In this course, students develop their chemistry writing skills in tandem with their ability to find, read, evaluate, and understand the intellectual relationship of two research articles reporting current advances in analytical chemistry. This exercise includes learning the process of subject and cited reference searching in scholarly databases, peer review of the first draft of a paper examining the two articles, followed by revision, self-reflection and a final paper, all in the context of learning to communicate research findings and understand conventions of science writing. A portion of the exercise takes place in the science library computer lab with instruction from the science librarian. In a related guided inquiry exercise, students in each lab section work together to compare and evaluate specific aspects of three additional journal articles. Professional reading, group discussion, and the writing component of the class have been found to help develop student understanding of analytical techniques while strengthening abilities as scientific writers. This chapter describes the rationale and objectives of the literature review and writing assignments, as well as informal evaluation of the efficacy of the exercises.

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Introduction

The practice of teaching chemistry information has greatly changed over the past three decades, most notably with the astonishing transformation of the venerable *Chemical Abstracts* into the present day SciFinder. Through the intervening steps of library-mediated searching and products aimed at end users (CAS on CD-ROM, STN Express, STN Web, SciFinder Scholar), a systematic approach was considered important for teaching undergraduates how to access, assess, and utilize chemical data and literature (*1*). Whether in the context of a dedicated chemical information course (*2*, *3*) or integrated throughout the curriculum (*4–7*), journal literature remains an essential part of the chemistry undergraduate program (*8–12*). Improving laboratory reports in both content and level of writing has been the intent of some pedagogical exercises (*11*, *13*, *14*) while others strengthen students' critical thinking and abilities to find and understand experimental data (*9*, *15–18*). The skills needed to write a journal article or literature review have been taught to upper-level students (*19*, *20*) and in introductory courses alike (*8*, *10*). Approaches for using journal articles as a teaching tool seem limitless; the rapid growth of open access as a publishing model, open data repositories, and sophisticated searching capabilities of the internet have given instructors wide latitude for creativity (*6*).

This evolving landscape of open access and unfettered searching creates both opportunities and challenges. Undergraduate chemistry students need a solid introduction to firmly established conventions for scholarly communication in the discipline, including reliable databases and indexes for finding and using chemistry literature. They must also develop the intellectual acumen for reading and contributing to that body of knowledge. The 2015 ACS Committee on Professional Training (ACS CPT) *Guidelines and Evaluation Procedures for Bachelor's Degree Programs* recommend that "Students' ability to read, analyze, interpret, and cite the chemical literature as applied to answering chemical questions should be assessed throughout the curriculum (*21*)." Regarding effective communication, the *Guidelines* are unequivocal, stating, "The chemistry curriculum should include critically evaluated writing and speaking opportunities so students learn to present information in a clear and organized manner, write well-organized and concise reports in a scientifically appropriate style, and use relevant technology in their communication (*21*)."

Developing writing skills for the discipline undeniably belongs in the undergraduate curriculum along with knowledge of chemical literature as scholarly communication. Finding meaningful and effective ways to integrate that experience into chemistry courses has given rise to the multiplicity of approaches noted here. This paper describes another model for a writing-intensive practice that also advances learning in chemistry.

Past Practice

From 1993 through 2008 Oberlin College offered the stand-alone course Chemical Information, team-taught by chemistry faculty and the science librarian (*2*, *3*). During that period, the format changed from a semester-long course to a module lasting just seven weeks. We devoted less attention to data sources while emphasizing searching, finding and assessing journal literature accessed through SciFinder Scholar and other scholarly databases. Over time, both students and faculty began to question the relevance of a stand-alone course. Key factors that contributed to the end of the Chemical Information course are summarized in Table 1.

Table 1. Contributing Factors for Discontinuing Chemical Information Course

1. **Topics were not immediately relevant to student interest**. The topics students were required to choose for their literature research, while timely and interesting on some level, were not directly related to either their honors research or to work underway in faculty research labs. Students wanted to devote their literature research skills to those more immediate concerns.
2. **New skills and expectations of incoming students**. Students were arriving at Oberlin College with greater knowledge of search engines and enthusiasm for using online sources, meaning less time was needed to teach students how to find chemical data.
3. **Lack of time for meaningful improvement through repetition**. The course was not structured to critically assess written or oral communication in a process that would encourage reflective improvement through multiple drafts and/or peer review. The final presentations were at the end of the semester or module, with little opportunity for feedback.
4. **Sources for chemical data were more prevalent**. As data became both easier to find and more relevant to assignments in required lower-level courses, students were gaining valuable experience earlier in their college career.

Current Practice

Discontinuing the course necessitated incorporation of some of its exercises and objectives into other courses. In the introductory general chemistry course students delve into the literature with a practice called "science Friday" that shares research news reports from *Nature* and *Science*. Organic Chemistry students are introduced to SciFinder and learn the basics of finding data and structure searching. The honors students become adept at literature searching for their specific research area, often with the guidance of their advisor or lab mentor. First-year seminar (FYS) courses are a natural place to introduce information literacy and writing skills (*22*) but few of the first-year seminars at Oberlin College have focused on chemistry. FYS courses that are taught by chemistry faculty have not emphasized detailed study of primary research articles in the discipline. The combination of these approaches left something of a gap in writing instruction for students continuing in chemistry, despite the fact that the writing goals for students at Oberlin College (see Table 2) dovetail nicely with the ACS CPT *Guidelines* (*21*).

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Table 2. Writing Goals for Oberlin College Students. Oberlin College Rhetoric and Composition Department (*23*)

1. Communicate effectively in writing.
2. Understand writing as a process.
3. Engage in writing as a form of critical thinking.
4. Demonstrate rhetorical flexibility by addressing various audiences and purposes in their writing.
5. Demonstrate their awareness of the conventions and forms of particular disciplines.

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Writing Intensive (WI) courses offer explicit instruction in writing and are limited in size to allow such instruction. WI courses require multiple writing assignments with mechanisms for students to receive feedback on their work and to incorporate this feedback into their writing for the course (reflective work). In addition, completing the writing requirement is strongly encouraged by the end of the second year so students are better prepared for advanced writing in upper-level courses. With these expectations in mind, Associate Professor Rebecca Whelan drew upon her experience at Stanford University (*24*) to integrate writing instruction into Analytical Chemistry, a 200-level course required of all chemistry and biochemistry majors. Whelan described her approach in some detail at the Dreyfus Foundation's 2012 Symposium *Research Frontiers in the Chemical Sciences* (*25*).

Writing in Analytical Chemistry

Whelan asserts that the writing component of the course serves multiple goals: the students deepen their understanding of analytical techniques as they learn how to communicate research findings and gain knowledge of rhetorical conventions of science writing. The process of investigating an instrumental technique in the chemical literature, coupled with writing a review paper, advances both learning the chemistry content of the course while preparing the student for technical writing. Students have affirmed these outcomes in their course evaluations; they report that the writing and literature investigation assignments were valuable components of the course and increased their confidence to find and evaluate chemical literature.

The assignment, as outlined in the *Lab Assignment Notebook* (*26*), involves several steps, with opportunity for feedback and revision (see Table 3).

Methods – Beginning the Assignment

The students and course instructor meet with the science librarian in the science library computer lab during their regularly scheduled lab time in the third week of the semester. The timing of the session ensures that the students and instructor already know each other and are comfortable with give and take between instructor and student. Students feel empowered to ask questions, to explore and compare research possibilities with each other, and to seek advice from both peers and instructors. This leads to an exchange of ideas and builds tolerance for ambiguity when the relevance between research articles is not entirely obvious and careful reading is required for comprehension.

Table 3. Analytical Chemistry Writing Assignment

1. Find, read, and understand a journal article describing an important recent development in analytical chemistry
2. Use SciFinder to search for other papers using the same analytical method described in the first article, but in a different context.
3. Write a paper discussing both articles.
4. Swap drafts and enter in discussion with a classmate for review of each draft.
5. Based on that feedback, submit a revised version.

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The session begins with approximately 45 minutes of instruction from the librarian, focused on the use of SciFinder and Thomson Reuters' Web of Science. Students are shown a comparison between a cited reference search and topic or keyword search. The assignment directs students to search SciFinder for the analytical method of interest by topic or keywords. The demonstration of cited reference searching is offered to illustrate the benefits of using and understanding multiple ways of finding related research.

Choosing a research topic is a guided process that begins with the standard textbook *Quantitative Chemical Analysis* by Daniel Harris (*27*). Students may use either the 7th or 8th edition of the Harris textbook, made available in the computer lab. Harris begins each chapter with an engaging explanation of a specific analytical tool or method, some of which are already familiar to the students. The faculty member suggests ten different options from the text, but students are free to choose any one of the tools or methods highlighted at the chapter beginnings. They study a figure, table, or illustration that explains a specific analytical tool or method, identify the original source cited by Harris, and begin a search to find the cited paper.

One example is Harris' discussion of microdialysis for measuring drug metabolism, which cites a 1991 paper from *Analytica Chimica Acta*. The article is older than any of the current students, which is an interesting starting point, and the text description of the process yields a number of terms useful for searching (such as chromatogram, pharmacokinetic, dialysate, HPLC, and blood microdialysis, among others), in addition to the article citation. The students are thus primed with both contextual information and a specific paper to locate, easily searched in SciFinder or Web of Science. They spend the rest of their time in the session, up to three hours total, finding the cited paper and a second paper that relates directly to the analytical method.

Library Session Challenges and Opportunities

The seeming simplicity of this process is heavily dependent on the cited publication source and date. Students learn necessary skills for recognizing parts of a scholarly citation, interpreting journal abbreviations and how to access the cited paper, working from a print source. This can be challenging for students accustomed to relying on online sources; novice readers frequently overlook details of volume, issue and page numbers, and may even lack direct experience using science journals in print to understand the relevance of those parts of a citation. Students also learn to identify different types of publications since they are directed to use a primary research article for their first choice. Recognizing differences among various types of sources (journal article, technical report, monograph, review, etc.) is not intuitive. Teaching those distinctions promotes information literacy and understanding various forms of scholarly literature.

Successfully completing this first step is surprisingly time-consuming for some students and their obstacles can be shared with the entire group to illustrate typical hurdles in the literature research process. Contrasting a relatively easy pathway from an online database to an article online with a seemingly dead end (that is, an online source that cannot be accessed or identified) gives some students their first experience of tracking a reference to an older print journal in the library stacks – a hallmark of the shifting landscape of chemical literature. This process is directly relevant to the assignment; that, and the students' interest in the analytical methods described, provides incentive, even when the hunt for a paper published some years earlier proves challenging.

The library session is dynamic and informal. Each student works independently at a computer, at tables arranged side by side along both walls and in the center of the room. The room arrangement fosters peer-led instruction, as students confer with one another on their topics and compare relative success of different search strategies. During the session, both the librarian and faculty member work individually with students and respond to questions as they occur, an approach that avoids the tedium of demonstrating in advance every possible scenario for finding articles. It seamlessly leads to instruction about interlibrary loan and varied ways to access scholarly literature: within a leased database or at a publisher's site based on subscription, archival vs. current access, consortium or institutional access, online vs. print only. Open access and "moving wall" concepts are also explained, along with the costs of publishing and purchasing scholarly resources.

Answering questions in the moment keeps students engaged, as the discussion stays focused on their specific interests rather than hypothetical problems. This approach requires flexibility by the librarian and faculty member when working with students individually in order to pause and address the entire group as opportunities arise. Students experience searching the literature as a non-linear process grounded in perseverance and attention to detail – not unlike research in the analytical lab.

Significant attributes of the assignment that contribute to its success include: the well-defined beginning with a familiar source; actively working together with both the faculty member and librarian; participating in peer review, and reflective

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work. Table 4 outlines these and other important aspects of the assignment. The related activity of reading and discussing other journal articles as a group enriches understanding of scholarly communication and helps prepare students for their participation in that discourse.

Table 4. Elements of Success

1. Begin with the familiar.
2. Work cooperatively in-class to select a method for study.
3. Focus on a method or tool that relates to learning in lab or personal interests.
4. Timing in the semester: late enough to establish both knowledge of some instrumental techniques and good rapport with peers and faculty.
5. Searching for related papers with librarian present for assistance.
6. Exceedingly clear expectations and guidelines for the entire process.
7. In-class exercise gives students a feeling of success and progress, with both papers selected, if not in hand, before the end of class.

An approach to this assignment in previous semesters asked students to find the second paper by following the links in SciFinder or Web of Science to citing papers. That gave them an opportunity to see *why* other researchers cite papers and they quickly observed (with some frustration) that many citing papers are irrelevant to the method they are researching. Since methodology is the focus of this assignment, they had to explore the citing papers carefully. Searching by keywords or subject terms, combined with the ease of linking to citing papers and learning the potential for expanding search results with an explicit cited reference search, gave students a deeper understanding of the comprehensiveness and complexity of these two important databases.

Methods – Reading, Analysis, and Discussion

Locating the two required papers during the lab session gives students a good start on this assignment and practice with using databases. More importantly, the assignment develops transferable skills for other science courses, as has been observed in the upper-level analytical chemistry course that is also taught by Whelan (one of two upper-level analytical courses taught at Oberlin College). This successful first step is just the beginning. Reading for comprehension and writing a first draft that compares and summarizes the relationship between the papers takes significantly longer. Guided reading of the papers is an important aspect of the assignment. The goal is not to amass many papers for a systematic review, selecting some data and observations from each, but to read two articles in depth and understand fully the relationship between them. A series of questions from the *Lab Assignment Notebook* (*26*) (Table 5) provides the framework for this evaluation, prefaced with the instructions, "Your goal is to understand what the article is reporting and the significance of the results. Use the following questions to guide your reading."

Table 5. Guided Reading Questions

1. What have the authors accomplished?
2. Are they reporting a new technique, instrument, or method?
3. Did they apply an existing method to an important chemical, biological, or environmental problem?
4. Have they improved an existing method?

Further engagement with the chemical literature occurs later in the course and gives students insight into the process of writing, peer review and publishing in chemistry. In instructor-facilitated group discussions, students examine three journal articles, typically published in *Analytical Chemistry*. Focusing on that journal gives students knowledge about one of the most prestigious and impactful publications in the discipline, and generates discussion about editorial practice and professional peer review. The elements and characteristics common to all three research papers (title, abstract, methods, analysis, conclusions, cited references) are evaluated. By doing this, students gain understanding of the relative significance of the sections of a research article and how to evaluate each article on those merits. If there is an obvious error in one of those papers, an invaluable discussion on the implications for authors, editors and peer reviewers can occur. This type of discussion prepares students to read and assess their chosen papers with a more critical eye and prepares them for their role as peer reviewer later in the semester.

Methods – Writing and Peer Review

Preparing a draft for peer review places a certain amount of tension and expectation on students. They understand the level of critique that will be applied to their paper, based on the group analysis of journal articles just experienced and the questions on a peer-review worksheet distributed in advance (see Table 6), developed from Oberlin College Rhetoric and Composition guidelines.

Table 6. Questions to Guide Peer Review

1. What do you think the piece says? How would you describe the main idea?
2. What are the strengths of the paper? Please explain or elaborate.
3. What are the weaknesses? Please explain and also offer suggestions for improvement.

All of the student authors ask their peer-review partner to answer the questions in Table 6. They formulate three additional questions that pertain specifically to their paper, for example, "Did I use enough illustrations in defining the conditions for fluorescence resonance energy transfer on p.4?" The six questions and reviewer comments are written on worksheets that become part of the completed assignment.

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An expectation of rigorous review by their peers motivates students to submit a first draft that is well organized and documented. The writing assignment grading rubric further motivates students to prepare carefully for peer review: to earn the highest grade, papers must include documentation from peer review that reveals that the review process was "thoughtfully undertaken." If the peer-review process was not completed, or "clearly not taken seriously," the paper is more likely to earn a failing grade.

Students exchange their first drafts with another student in the class and devote an entire class period to reading, commenting, and responding to each other. This is a good use of course time and worthwhile for the students, who learn that "getting feedback, responding to feedback and revising" is an integral part of scholarly communication (*25*). Their revised papers are submitted to the professor two weeks later, accompanied by the peer review worksheets described in Table 6. "Writing once is not done," is a message the professor shares with the class, saying, "everybody has to revise, everybody has to give feedback" to underscore the collaborative effort behind scholarly writing (*25*). When guided appropriately, the peer-review process results in papers that are better prepared and easier to read, relative to students who lacked that experience. The professor benefits by being able to focus more on the content of the writing and less on poor composition or grammatical errors.

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Conclusions

The assignment described in this chapter asks students to critically read two articles that are directly related to one another and write a paper about them, in a multi-step process that includes both lab and lecture experience. Despite its relatively narrow focus, this assignment helps students gain insight into the entire arc of research and publishing in chemistry. By examining and evaluating the parts of journal articles and experiencing the function of peer review, students acquire an understanding of scholarly communication as constructed and contextual.

By completing this assignment, students develop as writers and obtain valuable, transferable skills in researching chemical literature, as observed in higher-level courses when those students are compared with others who lack the earlier experience. Students with library research and writing experience in the 200-level course are better prepared than their peers for more intensive use of the chemical literature and writing assignments in upper-level analytical courses. These conclusions are based on the observations of the professor who teaches both the 200-level course and one of the upper-level courses, and self-assessment by the students. Students' anonymous comments on course evaluation documents indicate increased confidence in their ability to search, find, and critically read scientific articles, as well as their development as scientific writers.

Such positive outcomes from a relatively simple assignment are supported by the writing-intensive nature of the course. Writing, and the thoughtful reading and discussion that comes with it, has been shown to be a powerful pathway for learning in chemistry (*20*, *28–31*). Adding the guided peer-review and revision components can both deepen subject learning while improving writing and communication skills (*32*, *33*). Incorporating writing into the course, even on the relatively modest scale of one five- to six-page paper, promotes success through the chemistry curriculum. This conclusion is bolstered by Alaimo and Langenhan (*34*), who redesigned their organic chemistry curriculum from writing lab reports to teaching students to write scientific papers. They observed, "writing like a chemist means thinking like a chemist." The assignment described in this chapter is an effective method for making that connection.

References

1. Currano, J. N. Teaching Chemical Information for the Future: The More Things Change, the More They Stay the Same. In *The Future of the History of Chemical Information*; McEwen, L. B., Buntrock, R. E., Eds.; ACS Symposium Series 1164; American Chemical Society: Washington, DC, 2014; pp 169−196.
2. Ricker, A. S.; Thompson, R. Q. Teaching Chemical Information in a Liberal Arts Curriculum. *J. Chem. Educ*. **1999**, *76*, 1590–1593.
3. Ricker, A. S. Chemistry Information for the Undergraduate in a One-Credit Course: Faculty/Librarian Team Teaching. In *Chemical Librarianship: Challenges and Opportunities*; Somerville, A. N., Ed.; Haworth Press: Binghamton, NY, 1997; pp 45−67.
4. McKenna, J. F.; Gregory, D. D.; Jeannot, M. A.; Mechelke, M. F. An Integrated Writing/Research Component in the Undergraduate Chemistry Curriculum at St. Cloud State University. Abstracts of Papers, 232nd ACS National Meeting, San Francisco, CA, Sept 10−14, 2006; American Chemical Society: Washington, DC, 2006; CHED-471.
5. Guo, S. Integrating Library Instruction into SAGES Seminars at Case Western Reserve University for Undergraduate Chemistry Students: A Strategic Plan. Abstracts of Papers, 239th ACS National Meeting, San Francisco, CA, March 21−25, 2010; American Chemical Society: Washington, DC, 2010; CINF-5.
6. Cardinal, S. K.; Newsom, C. L. Creation of an Instructional Module for Small College Science Librarians Highlighting Free Chemistry Resources and Their Use in Undergraduate Instruction. Abstracts of Papers, 233rd ACS National Meeting, Chicago, IL, March 25−29, 2007; American Chemical Society: Washington, DC, 2007; CINF-035.
7. Walczak, M. M.; Jackson, P. T. Incorporating Information Literacy Skills into Analytical Chemistry: An Evolutionary Step. *J. Chem. Educ*. **2007**, *84*, 1385–1390.
8. Bennett, N. S.; Taubman, B. F. Reading Journal Articles for Comprehension Using Key Sentences: An Exercise for the Novice Research Student. *J. Chem. Educ*. **2013**, *90*, 741–744.
9. Roecker, L. I. Introducing Students to the Scientific Literature. *J. Chem. Educ*. **2007**, *84*, 1380–1384.

10. Rosenstein, I. A Literature Exercise using SciFinder Scholar for the Sophomore-Level Organic Chemistry Course. *J. Chem. Educ.* **2005**, *82*, 652–654.
11. Tilstra, L. In the Classroom: Using Journal Articles to Teach Writing Skills for Laboratory Reports in General Chemistry. *J. Chem. Educ.* **2001**, *78*, 762–764.
12. Jensen, D., Jr.; Narske, R.; Ghinazzi, C. Beyond Chemical Literature: Developing Skills for Chemical Research Literacy. *J. Chem. Educ.* **2010**, *87*, 700–702.
13. Rosenthal, L. C. Writing Across the Curriculum - Chemistry Lab Reports. *J. Chem. Educ.* **1987**, *64*, 996–998.
14. Deiner, L. J.; Newsome, D.; Samaroo, D. Directed Self-Inquiry: A Scaffold for Teaching Laboratory Report Writing. *J. Chem. Educ.* **2012**, *89*, 1511–1514.
15. Tomaszewski, R. A Science Librarian in the Laboratory: A Case Study. *J. Chem. Educ.* **2011**, *88*, 755–760.
16. Henary, M.; Owens, E. A.; Tawney, J. G. Creative Report Writing in Undergraduate Organic Chemistry Laboratory Inspires Nonmajors. *J. Chem. Educ.* **2015**, *92*, 90–95.
17. Gupta, T.; Burke, K. A.; Mehta, A.; Greenbowe, T. J. Impact of Guided-Inquiry-Based Instruction with a Writing and Reflection Emphasis on Chemistry Students' Critical Thinking Abilities. *J. Chem. Educ.* **2015**, *92*, 32–38.
18. Burke, K. A.; Greenbowe, T. J.; Hand, B. M. Implementing the Science Writing Heuristic in the Chemistry Laboratory. *J. Chem. Educ.* **2006**, *83*, 1032–1038.
19. Gragson, D. E.; Hagen, J. P. Developing Technical Writing Skills in the Physical Chemistry Laboratory: A Progressive Approach Employing Peer Review. *J. Chem. Educ.* **2010**, *87*, 62–65.
20. Schepmann, H. G.; Hughes, L. A. Chemical Research Writing: A Preparatory Course for Student Capstone Research. *J. Chem. Educ.* **2006**, *83*, 1024–1028.
21. American Chemical Society, Committee on Professional Training. *2015 Guidelines for Undergraduate Professional Education in Chemistry*; Washington, DC, 2015; pp 18−19.
22. Oberlin College. *First Year Seminar Program*; http://new.oberlin.edu/arts-and-sciences/fysp/ (accessed June 2, 2016).
23. Oberlin College. Rhetoric and Composition Dept. *Writing Requirement*; https://new.oberlin.edu/arts-and-sciences/departments/rhetoric/writing-req/ (accessed June 21, 2016).
24. Whelan, R. J.; Zare, R. N. Teaching Effective Communication in a Writing-Intensive Analytical Chemistry Course. *J. Chem. Educ.* **2003**, *80*, 904–906.
25. Whelan, R. J. *Getting it "Write": Envisioning Science Writing Pedagogy Beyond the Laboratory Report*; Presented at Research Frontiers in the Chemical Sciences, Dreyfus Foundation Symposium, Oct 26, 2012. http://www.totalwebcasting.com/view/?id=dreyfus (accessed Nov 15, 2015).

26. Whelan, R. J. *Lab Assignment Notebook, CHEM 211 Analytical Chemistry*; Oberlin College, Oberlin, OH. Unpublished work, 2015.
27. Harris, D. C. *Quantitative Chemical Analysis*, 8th ed.; W.H. Freeman and Co.: New York, 2010; pp 1−719.
28. Sherwood, D. W.; Kovac, J. Writing in Chemistry: An Effective Learning Tool. *J. Chem. Educ.* **1999**, *76*, 1399–1403.
29. Stewart, A. F.; Williams, A. L.; Lofgreen, J. E.; Edgar, L. J. G.; Hoch, L. B.; Dicks, A. P. Chemistry Writing Instruction and Training: Implementing a Comprehensive Approach to Improving Student Communication Skills. *J. Chem. Educ.* **2015**, *93*, 86–92.
30. Vázquez, A. V.; McLoughlin, K.; Sabbagh, M.; Runkle, A. C.; Simon, J.; Coppola, B. P.; Pazicni, S. Writing-to-Teach: A New Pedagogical Approach to Elicit Explanative Writing from Undergraduate Chemistry Students. *J. Chem. Educ.* **2012**, *89*, 1025–1031.
31. Weaver, C. L.; Duran, E. C.; Nikles, J. A. An Integrated Approach for Development of Scientific Writing Skills in Undergraduate Organic Lab. In *Addressing the Millennial Student in Undergraduate Chemistry*; Potts, G. E., Dockery, C. R., Eds.; ACS Symposium Series 1180; American Chemical Society: Washington, DC, 2014; pp 105−123.
32. Nilson, L. B. Improving Student Peer Feedback. *Coll. Teach.* **2003**, *51*, 34–38.
33. Bean, J. C. *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*; Jossey-Bass: San Francisco, 2011; pp 295−302.
34. Alaimo, P. J.; Bean, J. C.; Langenhan, J. M. Eliminating Lab Reports: A Rhetorical Approach for Teaching the Scientific Paper in Sophomore Organic Chemistry. *WAC J.* **2009**, *20*, 17–32.

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Chapter 9

Research Strategy for Searching the Literature More Effectively

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Confusion and frustration are two of the emotions often felt by undergraduates when they are expected to do library research. They often do not know where to start, and are often unable to select appropriate terms or sources to search. Furthermore, instructors overestimate the literature research skills of their students. In CHEM 23201, a required one-semester course, we introduced a research strategy worksheet as a way to guide students in searching the literature. We assumed that they would need more help in using the unique features of the discovery tools than in selecting search terms. Our assumptions were wrong. An examination of the tenets of Bloom's Taxonomy of Learning Domains and its explanation of higher-order thinking skills, which include asking questions, could have predicted the difficulty the students initially had with the worksheet.

Practicing chemists must possess a certain level of chemical information literacy. Verifying physical constants, finding preparation methods or finding review articles are a few examples of the types of information chemists may need to use when completing a research project. They need to consult the literature; therefore they need to know how to search the literature. Searching the literature is such an important skill that the Office of Professional Training at the American

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Chemical Society in their *Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs* includes a section that specifically addresses chemical information skills. The ACS notes the need for students to be able to, "...retrieve information efficiently and effectively...and manage many types of chemical information…" (*1*).

To search this literature as effectively and efficiently as possible, students need to construct a search with good search terms. A search with poor search terms will bury the good results in a stack of unwanted results, which may cause the student to miss relevant documents or cause them to recreate previously published research (*2*).

Unfortunately, dread and feeling overwhelmed are two of the emotions expressed by undergraduates when they are expected to complete this research (*3*). While instructors overestimate the literature searching skills of students (*4*), students are poor at selecting the right search terms and sources (*5*, *6*). Instructors conjecture that students, as "digital natives," are sophisticated users of technology (*4*, *7*). They also assume that students understand what a database is, and that students have internalized the basics of searching online databases (*4*). Instructors have forgotten what it was like to search a database when they may not have been fully aware of what a database was, much less how to search it. Additionally, students don't think of librarians as a resource to help them with their research, nor do they consider them as experts in the organization of information (*4*). All of these assumptions and misunderstandings on the part of students and teachers result in students continuing negative reaction to library research.

Reflecting on our knowledge of the negative reactions to library research, we decided to introduce the research strategy worksheet as a guide for undergraduate chemistry students to use when they searched the literature in a required seminar course. The worksheet has appeared to help the students gain a better understanding of the steps to employ when searching the literature. However, the worksheet and how it was deployed needed improvements as it did not seem to help students think about their research topic in terms of key concepts. Initially, we assumed that students would need more instruction on the mechanics of searching databases and were surprised when we found that it was their inability to write a good thesis statement and to select good key concepts that was the source of their frustration. An examination of the tenets of Bloom's Taxonomy of Learning Domains (*8*) and its explanation of higher-order thinking skills, which include asking questions, could have predicted the initial difficulty the students had with summarizing their topic and selecting effective search terms. Additionally, the process of searching the literature has analogies to other activities in life such as orienteering, teleporting and cooking.

Anyone giving a single instruction session, usually a librarian, may not realize the difficulty undergraduates have with selecting effective search terms nor of their habit of using a search term from just one key concept. Therefore, no time will be spent discussing with the students the importance of selecting good search terms nor of using terms from more than one key concept. These analogies could be used to help those single session instructors understand that picking multiple good search terms will help the student be a more efficient and effective searcher of the chemical literature.

Course Overview

The University of Notre Dame is a research university in the Midwest. There are roughly 8,500 undergraduates and 3,400 graduate students. The University Libraries has a main library, 5 branch libraries, and 3 information centers. The Chemistry-Physics Library is a branch serving the information needs for anyone with an interest in astronomy, biochemistry, chemistry, and physics. Many of the chemistry and biochemistry undergraduate majors work in labs with faculty and graduate students supervising their research. Faculty members want their students to be productive members of their group so it is important for the students to know how to find chemical information. Many of those students will have co-authored a paper or two before graduating.

For the past 12 years Thurston Miller has taught a required 1-credit undergraduate chemistry seminar, CHEM 23201 (Finding and Presenting Chemical Information) for the Chemistry Department at the University of Notre Dame. The course introduces students to the library and information sources in chemistry. Each year there are 35-55 students in the seminar. Most of the students are sophomores and a few are juniors.

Kathleen Fleming co-taught the course in 2013.

Most of the students at the University of Notre Dame were raised in an environment where compters, other technology, and access to the internet is so common and well established, that they match the description of "Digital Natives" (*7*). Unfortunately, while these "natives" are comfortable with technology, this does not mean they intrinsically know how to use the technology, or search technology, *well* (*9*, *10*). Furthermore, many students do not realize that they do not know how to find information (*9*).

An assessment of student knowledge of resources in the form of a pretest was administered between 2004-2010. The pretest showed that all the students enter the class frequently searched Google and infrequently searched the library catalog or library website. It also showed that they had used such sources as Academic Complete, EBSCOhost and JSTOR. However, when it came to sources for finding chemical information, most students have not used sources such as SciFinder, Reaxys, or Web of Science. Most of the students regard their ability to use chemical information resources to find chemical information as ineffective. Of course, this poor estimation of their own ability is not an unexpected response because the very need for the class reflects the view of the Chemistry Department regarding undergraduate library research skills.

For this course we cover skills in four areas: knowing what resources are available, knowing how to use the tools within each resource, selecting concrete and unambiguous search terms, and evaluating the search results to modify the search terms. Some of the chemistry-specific skills used in finding chemical information, such as structure searching or reaction searching, require more instruction and practice than this course provided.

At the beginning of the semester each student selects a compound from a list we provide. Every student has a different compound. Juglone, folic acid, DEET, sucrose and tetradotoxin are examples.

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The first 10 weeks of the 15-week-long semester are focused on finding chemically interesting information about their compound. We defined "chemically interesting" to mean things like a synthesis and a characterization, conformation affecting taste, the compound's role in apoptosis or ATP, etc. These examples of chemically interesting and others were given to students early in the semester.

The sources we cover in these 10 weeks included SciFinder, Reaxys, Web of Science, several of the NCBI databases, free patent databases (USPTO, Esp@cenet, SureChem), and Google (including Google Books, Google Patents, and Google Scholar). We also cover some print versions of resources, such as the *Merck Index*, *CRC Handbook of Chemistry and Physics*, and *The Dictionary of Organic Compounds*. In addition, we give an introduction to reading citations, copyright, and citation searching. We ask the students to use any citation manager of their choosing and most students select RefWorks because it is the one we explain how to use. The students also learn about some conventions of the chemical literature such as CAS registry numbers, InChI Keys and the Hill format of the molecular formula.

We also provide students with a list questions they need to ask of every database/search engine they use. These questions are:

- What subject is covered by the database?
- What dates does the database cover?
- Can Boolean operators be used in the database?
- Are truncation symbols used in the database?
- Can wildcards be used?
- How can a phrase be searched in the database?

In-class practices help the students apply the skills they learn and use the databases/search engines while a librarian is present to help them with any difficulties. In addition, there are seven assignments designed to help students find the information they need for their presentation and help them navigate the library system. As part of each assignment, the students print their search history for the database and we provide feedback on their search strategy.

As they would do for any ACS Conference presentation, students write an abstract for their talk. The 75- to 125-word abstract also helps them connect the individual assignments to their end-of-semester presentation. Two drafts of the abstract are submitted as part of assignments two and five before the final abstract is submitted as part of assignment seven.

In the five remaining weeks of the semester, students gave 10-minute presentations explaining their compound and what they have learned about it. A faculty member from the Chemistry Department joins the class to listen to the presentations and provides feedback on the explanation and understanding of the chemistry content of the presentation. We provided feedback on the mechanics of the presentation.

In addition, each student in the audience provides written feedback for the presenter. Most of the questions on the written feedback form include a five point Likert-type scale as well as one open ended question. The feedback is handed in at the end of the class session and is graded based on whether it was done or not done.

The presentation is followed by a question and answer session with their classmates. The presentations are videotaped.

Finally, after-action reports are written by each student concerning their presentation. After-action reports are reviews used at the end of a project to help the author reflect upon their performance against some standards, lessons learned and areas for improvement. The first part of the report asks them to give their reflections of what they feel they did well and what they feel went poorly. For the second part the student watches their video and comments on what they observed. These comments are guided by a series of questions focused on the mechanics of the presentation.

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Research Strategy Worksheet

The research strategy worksheet (Figure 1) was used in the course to give the students some structure when conducting library research. It reminds them to find key concepts and compile synonyms and related terms for each concept. It also codified an approach to searching that they naturally execute, but may not be aware of. The worksheet we used was a version of what Thurston Miller had used when he learned how to give bibliographic instruction sessions while he was a graduate student at the University of Washington.

We introduced the worksheet in the second class session with an explanation of the first three steps and an in-class exercise. Following this session the next three weekly assignments asked the students to update the information they provided for the first three steps during the in-class exercise as they learned more about their topic.

We thought the students would find the worksheet helpful in reducing student frustration with library research. However, we feared that it was so basic that the students would feel insulted if we spent too much time explaining the worksheet. We had two reasons for our concerns.

First, in class we would show the class sample summary statements (step 1), such as, “I want to find information on the resistance to antibiotics in pigs and poultry.” and asked the students to identify the key concepts (step 2) and identify related terms & synonyms for each key concept (step 3). Based on their in class responses, it was apparent they had no difficulty identifying key concepts and thinking of related terms & synonyms. Consequently, we spent our time training them on the use of Boolean operators, truncation, phrases, etc. and navigating each database (step 4).

Second, generally when faculty members asked us to speak to their class, they did not think it was necessary to include what they viewed as basic ideas (identifying key concepts and finding related terms & synonyms). As a result, we focused the bulk of our sessions on identifying resources and building a search (step 4).

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Research Strategy Worksheet

1. Summarize your topic.

How would you describe it to family members gathered around the dinner table?

2. Identify key concepts.

Two concepts are a minimum. Must be as concrete and unambiguous as possible. Prioritize them. For print resources use the most important concept when looking in the index.

Concept 1	Concept 2	Concept 3

Concept 4	Concept 5

3. Find related terms and synonyms.

Do this every time. Time spent on this step will reduce frustration & increase quality of results.

4. Build a search

Select at least two databases.

5. Run your search.

6. Examine results and Refine your research strategy.

Do this every time. Searching for information usually fails, except by accident. So be flexible. Don't give up too soon.

Figure 1. Research Strategy Worksheet.

Prior to 2012, we had the students take the aforementioned pretest on the first day of class. This helped us determine what they knew about reading citations, what search engines they used frequently, what they understood about using Boolean operators in a search, and whether they had taken any library instruction sessions, etc. The results remained consistent from one year to the next.

Then in 2012, we replaced the pretest with a series of open-ended questions in order to learn about student experience with library research. The questions were:

- Describe your approach to doing library research when you were in high school or as a freshman.

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- Where did you go to find information?
- What resources did you consult?
- How successful were you?
- How did you measure success?

Students answered these questions and shared with us how they felt about doing library research (even though we didn't ask them that question).

Here are three typical responses we had from the students:

- "In high school, I found library research extremely overwhelming."
- "Up to this point in my life, my approach to library research has been to avoid it at all costs."
- "I often felt frustrated whenever I had to do research. I was never sure if I was getting everything I needed, and sometimes would have trouble finding sources."

Each student had more to say than this but it was their expression of frustration and feeling overwhelmed that made us wonder if we were reducing or contributing to their angst when faced with doing library research? We liked to think that we are helping rather than hurting. Our pre-2012 pretests had focused on what they knew and based on conversations we learned of their frustration with library research. We assumed that their frustration would be reduced if they knew about the different search engines, truncation symbols, and Boolean operators. But was that true? We decided to change something because we were concerned we were not helping them.

As a result, we decided to more fully integrate the research strategy worksheet into the course by including it in assignment two (finding background and overview information using encyclopedias, books, and Google) and assignment three (finding articles using SciFinder and Web of Science). Prior to 2012, we gave the students the worksheet as a guide but didn't require the students to complete it in an assignment.

First Attempt Using the Worksheet

We had the students complete the first three steps in the worksheet. What follows is an example of the type of answers we got in assignment two when they completed the first two steps:

Step 1 (summarize your topic)

"I want to find information on the chemical and physical properties and uses of aspirin."

Step 2 (identify a minimum of two key concepts)

Concept 1: Aspirin

Concept 2: Uses

Concept 3: Properties, Chemical & Physical

Concept 4: Pain

Concept 5: Analgesics

As noted earlier, when we provided the summary statement, students were successful in identifying synonyms and related terms, but we had to supply the statement. But when we looked at their answers in assignment two, we could see some problems of which we were previously unaware.

It has been our experience when looking at student search histories that the majority of students will use just one search term and stop looking at the results after one or two screens of results. And rarely will those students refine their searches with new terms. Therefore, we want those one or two screens of results to contain as many entries as possible that are of interest to the student. Hence our focus on the search terms used by the students.

In general, we observed that the students had difficulty posing a research question in step one. The students didn't seem to understand the characteristics of a key concept and that those concepts should be as concrete and unambiguous as possible. In addition, the students didn't seem to understand that the key concepts came from the research question.

We discussed the summary statement and the key concepts in class when we returned assignment two. We used the above example as a generalization of what we saw in the assignment and what changes could be made to improve the worksheet in preparation for assignment three. Assignment three had the students revising steps one through three of the worksheet.

As part of our in-class discussion, we did a word association with the students to demonstrate the importance of using key concepts that are as concrete and unambiguous as possible and that using a second key concept in conjunction with the first gives results that are more focused on their topic. We asked the students to write down the first word that comes to their mind when we say "trunk" and then share what they wrote with the class. The shared list usually amazes the students because the list was not unanimous with the term they selected. We will get furniture, elephant, tree, part of the body, swimsuit, automobile, etc. Therefore, just using "trunk" will retrieve results associated with each term. If "tree" "trunk" had been used, then the results would be unlikely to include results associated with other aspects of trunk.

Likewise, in our aspirin example above, if the second concept, "uses," is replaced with "stroke" or "arthritis" or "blood thinner" then the search results will be more focused on the research interest of the individual student. When the results are more focused then the student can do their research quicker. For some students saving time is a very compelling reason to change how they search library databases.

Some students agreed that "uses" was too broad and ambiguous. They wondered if it would be acceptable to change the concept from "uses" to "medical uses" or "health." These terms are better than "uses" but they are still broad. This wouldn't be a problem if the students viewed literature research as an iterative process and that this was just the next step of the process. However, it has been our experience that the students, especially undergraduate students, want it to be the final step.

Abstract and Worksheet Connection

We realized there was a connection between the abstract that the students are assigned to write and the research strategy worksheet. The abstract was a compilation of the answers to these five questions.

- Attention Grabber – What is the big picture? Why should the reader care?
- Research Question – What question are you trying to answer?
- Approach – What are you doing to find the answer?
- Results – What did you learn from the approach you took?
- Perspective – Are there any implications of what you learned?

The research question of the abstract is the same as step one, summarizing your topic, of the research strategy worksheet. The worksheet was assigned early in the semester. The second draft and final version of the abstract were later in the semester. We could see improvement as the semester progressed. At the start of the semester we saw worksheet answers such as:

- "I want to find information on the chemical and physical properties and uses of aspirin."

By the time we got to the middle of the semester we saw abstract answers such as:

- "How do the chemical and physical properties contribute to aspirin being an effective drug in combating blood clots associated with stroke."

This statement in their abstract was better for two reasons. First, the statement helped them focus their research. Second, the statement had an impact on the key concepts selected and ultimately on the terms used as part of their search strategies.

At the end of the semester we asked the students to describe how their approach to gathering information had changed. While there was one student out of fifty that said nothing had changed, many said their approach had changed. Common student responses included:

- "I also will never again search ONE key concept in Google. Total research faux-pas."
- "One useful thing I understand better is how important it is to search using multiple concepts and synonyms. If you don't have good search terms it is really difficult to find the information you want."
- "My approach to gathering information has changed from just searching with one key term to search with two or three. This has made me more efficient because my search results are better, resulting in a decrease in time spent searching. I still have to put in the time, but now I continuously find the articles that I am looking for."

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The usefulness of this worksheet and our focus on key concepts has been demonstrated to be applicable across disciplines. Kathleen Fleming held an instructional session with a political science class that was based on the level of detail included on the research strategy worksheet used in CHEM 23201. The political science session was well-received by the Instructor, and Kathleen Fleming was invited to teach the political science class again and the Instructor requested that it be taught at the same level of detail.

Search Strategy Evolution

As we looked at the search strategies on the search histories the students submitted with their assignments we realized we could divide the search strategies into three groups that we will call: 20th century, Y2K, and 21st century. And this division evolved through the semester. Most of the students had 20th century search strategies at the beginning of the semester. By the middle of the semester we saw a lot of Y2K search strategies in the search histories the students included in their assignments. The goal was to see 21st century search strategies by the end of the semester.

Example 1 is the search strategy that fits our definition of a "20th century search strategy." The 20th century information environment was dominated by print indices such as *Reader's Guide to Periodical Literature*. With a print index the literature searcher was limited to a single concept in a particular time period, such as the most recent index year, and if the concept was sufficiently large or diverse then the searcher could use sub-headings supplied by the index to narrow the search. If the researcher needed to look at the most recent 10-15 years then the researcher had to look through 10-15 index volumes. It was a time-consuming process.

Example 1 from Web of Science (WoS):

Results	Search
49,183	Topic = Aspirin
7,876	Refined by WoS Categories = Cardiac Cardiovascular Disease
279	Publication Year = 2015

Most of the students entering our class were using the search strategy one would use for a print resource when they were using an online search engine. In addition, they were not taking advantage of the search capabilities the search engine provided such as truncation, Boolean operators, etc. They were frustrated because they had to wade through a lot of results they didn't want, to find the ones they did want. It was a time-consuming process and they didn't have confidence that they had found the information they needed to complete the research project. In other words, they were doing a lot of work when they could have been letting the search engine work for them.

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Example 2 is the search strategy that is in transition. Improvements can be seen but there are also remnants of the 20th century search strategy. We called this search strategy "Y2K" because Y2K was a transition between years beginning with 19** to years beginning with 20**. The Y2K search strategy exemplifies the transition from searching print to using search engines. The students using this strategy know they can and should use multiple concepts to focus their search results but are not sure what makes for a good concept. Sometimes they use a more effective second concept and other times they don't. Using ambiguous concepts gives them mixed results. As a result, they fall back on techniques that worked in the print environment, such as limiting by year or by system supplied sub-headings.

It is sometimes difficult for students to think of how a concept can take on different meanings. It is helpful remember the word association exercise we had the students perform when asked what word they associated with "trunk"? When we asked students we got Elephant, Automobile, Piece of Furniture, Tree, Clothing, Body Part, Traveling, and a Railroad or Phone line. Trunk is an example of an ambiguous concept. Sometimes you can't avoid concepts that are vague or have multiple meanings but having another concept in your search strategy gives the vague term some focus or context.

In Example 2, the Y2K search strategy used the ambiguous concept of "uses". The students were making the transition from searching with one concept to searching with two or more concepts in an attempt to focus their search, but one of the terms used didn't improve their search results. We also saw "medical uses" or "health" replacing "uses" in the search.

They were doubly frustrated because they had followed the guidelines given by us on using a minimum of two concepts and they still had to wade through unwanted results to find the ones they wanted.

Example 2 from SciFinder:

Results	Search
23,204	Research Topic = uses of aspirin
1,273	Publication Year = 2015

Example 3 is the search strategy that fits our definition of a "21st century search strategy." The 21st century information ecosystem is dominated by search engines of all kinds, from Google to SciFinder to Web of Science. The search strategy should change as a result of the new environment.

Searches with one concept should be replaced with searches using two or more concepts because the databases have millions of records covering many decades or a century of the scholarly record.

The search terms used should be as unambiguous and concrete as possible because databases are expanding their coverage into related research areas. The more subject areas covered, the more likely words with multi-meaning will be encountered.

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Synonyms and related terms should be used as appropriate because some databases do not automatically supplement searchs with synonyms or related terms. In addition, the student's vocabulary for a topic may not match the vocabulary used in the literature. Moreover, the vocabulary for a concept can change over time.

The concepts should be as independent from one another as possible.

Students employing 21st century search strategies have results that are focused on their interests. They don't need to do much weeding through the results to find what is of interest to them.

Example 3 from Web of Science:

Results	Search
200	Topic = aspirin AND ("blood clot*" OR coagulat*) AND stroke*
43	Document Type = Review

A 21st century search strategy used two or more key concepts that were as concrete as possible and were as independent from one another as possible. By the end of the semester we had students using a 21st century search strategy. The students were also using more synonyms and truncation and phrases. The search strategies were better. More importantly the students felt the results were better. These students are using a 21st century search strategy because they found results that were useful to them by making the databases work for them.

Our goal with the research strategy worksheet was to have undergraduate students using a 21st century search strategy when looking for information via search engines. However, this goal doesn't translate well for the graduate student, post doc, or faculty member. For this group, they have spent a few years to many years exploring one subject area. As a result they are very aware of the terms to use to get the results that will be helpful to them. Sometimes their subject is so specific that using one term is fine.

Challenges

In our more than forty years of combined experience in academic libraries, the focus when doing library instruction has been almost exclusively on how to use the tools. There has been discussion of trying synonyms and related terms and of examining relevant search results to find useful subject heading to modify the search. Rarely has there been, in our experience, a discussion of what makes for a good key concept.

As we thought about this emphasis on the tool part at the expense of the vocabulary part, we identified several challenges to conveying this to a broader audience.

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First, it is easier to talk about how to use the tool than how to pick good concepts. It is often easier to explain to a large group how to use a tool. As librarians, we make the assumption that instructors will focus on explaining how to pick good search terms. In addition, librarians have had lots of practice searching databases and have learned by trial and error what makes for a good concept. Picking a good search term requires judgment. It has been our experience that is not easily taught to a large group.

Second, when a faculty member asks us to talk to their classes or students they usually expect an emphasis on the tools. Why? The faculty member has spent most of their adult life thinking about different aspects of a topic, their academic specialty, and has a good handle on picking good key concepts for their subject. The political science professor mentioned earlier was a refreshing exception by wanting a discussion of the selection of good search terms in addition to the tools.

In both instances, we make the assumption that students know how to pick good key concepts because we are able to do it and we have forgotten that at one time we didn't know how to do it. Moreover, at the college level, we make the assumption that someone else has taught the students how to pick good key concepts.

Another reason for the difficulty of selecting good key concepts was the student's poorly thought out or articulated problem statement. The problem statement is important since the key concepts come from it. We thought of two reasons for the poor statements. First, generally speaking, the students have no background information for investigating their compound. They have no prior knowledge to make an outline on which to hang new information. We addressed that problem by having an in-class working session for the students to gain the background information about their compound. This helped. But there may be another reason for this difficulty as discussed below.

Higher Order Thinking Skills

Research has found that when attempting to construct a search, many students have difficulty in identifying topics (*11*) and specifically, many have problems in the narrowing down their topic. In fact, in many cases students have to be guided through the narrowing process and require assistance when identifying subcategories (*12*), need help with "...scope and topic choices (*13*)." or have to "...work with the instructor to focus the topic…" (*14*). We also saw that students have difficulty when they have to independently summarize their topic. As mentioned earlier, when the problem statement was provided for them, they had no problem selecting concepts.

When considering the cognitive aspects of the difficulty students experienced when summarizing their research topic, it may be useful to look at educational psychology, and the cognitive domain in the revised version of Bloom's taxonomy (*8*). The taxonomy proposes that different types of learning require different thought processing than others. This pyramidal taxonomy denotes the thinking skills that involve analysis, evaluation and synthesis (creation of new knowledge) are at a higher level than processes that involve simple recall or understanding (learning facts and concepts) (*15*).

It may well be that by asking students to summarize their topic when they write their problem statement, we were asking them to think at a higher level than they were accustomed. Most of the students in CHEM 23201 are sophomores, and it is possible that the level of thinking they have typically engaged in has been at the base, or lower levels of the pyramid (e.g. remembering, understanding). Research question posing is an example of a cognitive activity that is considered "higher order" (*15*). The process of identifying key concepts is a mental activity located higher in the taxonomy, and is aligned with the goal of higher education to enhance students thinking levels (*16*).

Question Posing

The worksheet uncovered student difficulties writing a research question. However, the worksheet may help students with the problem solving process.

Zoller identified the major steps in the problem-solving process in his paper on fostering the question-asking capabilities in students. We observed similarities between the steps Zoller identified and the six steps of research introduced on the research strategy worksheet (Table 1).

Table 1. Comparison between Zoller's Problem-Solving Process and the Research Strategy Worksheet

Major stages of the problem-solving process	*Research strategy worksheet*
Understand / State / Define / Restructure the problem	Summarize your topic
Select appropriate information and concepts	Identify key concepts
Combine the separate pieces of information	Find related terms and synonyms
Select the relevant strategies and processes	Build a search
Decide or select the alternatives for constructing solution(s)	Run your search
Evaluate	Examine results and Refine your research strategy

While there are differences between the two, because of the different approaches, we still see some useful similarities. Zoller's step 1, understanding and stating the problem is much like summarizing a topic. Selecting appropriate information and concepts is like identifying key concepts in the worksheet. Zoller's "Combin[ing] the separate pieces of information" is much like looking for synonym or related concepts. The agreement continues. Selecting relevant

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strategies and processes involves the same thought processes as the steps involved in how we instructed on building a search. The similarities seem to break down in step five. Where we instruct to run a search, Zoller proposes to decide or select the alternatives for construing solutions. While theoretically, running a well-executed search DOES result in a kind of solution, the similarities remain less clear. However, Zoller's final step to evaluate then restructure the problem is essentially the same as our step to examine results and refine the research question. While with these steps Zoller focused on problem solving, he also noted that, "...question-asking is an essential component of problem-solving ability (*17*)."

Orienteering versus Teleporting

The designers of search engines in their attempt at building a perfect search engine assume a searcher has a clear statement of the information prior to the search. This may be another reason for the difficulty the students experienced. In the field of computer science research was done on how people looked for information. The two strategies identified for searching for information are called teleporting and orienteering (*18*). These competing strategies are useful for thinking about the strategies our students might employ when searching the literature.

The teleporting strategy is used when doing a keyword search and arriving directly at an answer. Most search engines are designed to use the teleporting search strategy. Therefore, identifying good search terms is an important aspect of finding information with this strategy. The research strategy worksheet helps students compile a list of search terms.

The orienteering strategy is used when doing a keyword search to get into the vicinity of the answer and then browsing to find the answer. The strategy may be a series of steps before getting the answer. Selecting good search terms is helpful but not critical. Instead, understanding the context of the answer within the information ecosystem and having some prior knowledge on the topic is more helpful.

Either strategy can be used to find information. For example, suppose you are looking for the work phone number of a Notre Dame employee. If you type the name of the employee and the phrases "notre dame" "phone number" into the search engine, then you have used the teleporting strategy to find information. If you search for the Notre Dame website then look for an employee directory or for the department in which employee works or perform a site search for the employee, then you have used the orienteering strategy to find information.

Teevan, et al (*18*) discovered that people searching for information usually employ the orienteering strategy. The authors propose several suggested explanations for their observations. Experience has taught people that teleporting doesn't always work. In addition, orienteering appears to lower the cognitive load of the search process rather than having to accurately describe their research question as people need to do for teleporting. And it gives the answer context and provenance that assists the searcher in understanding their results.

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Cooking Analogy

As we thought about what we had experienced, it dawned on us that using search engines had an analogy to cooking.

In cooking you have tools, such as a sauce pan or a whisk or convection oven, and you have techniques, such as browning meat to get fond (browned bits of meat stuck to the bottom of a pan) or using red wine to unlock the flavor compounds in tomatoes. You need to know how to use those tools and techniques to get good results. But you also have to pay close attention to the ingredients you use; for instance store brand canned greens are different from fresh green beans. In order to prepare a wonderful meal you need to know how to work the tools and techniques and needs to know what ingredients will make for the best taste. Before the dish is served you will season it as needed.

In literature searching, the tools are the search engines and the techniques are Boolean operators, nesting, truncation, etc. You need to know how to use the tools and techniques to get good results. The ingredients are the words that express the key concepts of the search and their synonyms and related terms. And just like cooking, careful attention must be given to the selection of those key concepts to get the best results. Before you are done with the search, you examine the search results and tweak the words used in the search as needed.

For the research strategy worksheet, steps 1-3 (Summarizing the topic; Identifying key concepts; and Finding related terms and synonyms) are the ingredients, step 4-5 (Building a search and Running the search) are the tools and step 6 (Examine results then refine search strategy) is the seasoning as needed. Explaining this analogy to the students might give them some perspective on the research strategy worksheet and help them understand what they are doing while they are using it.

Conclusion

During the first academic year that we more fully integrated the worksheet into the course, we gave a lot of individual attention to each student with steps 1-3 of this worksheet. In subsequent years we made an effort to streamline the course and reduce the time commitment for the librarian. At the same time, we have gotten fewer end-of-the-semester comments mentioning how their research habits have changed. Instead we get more comments that focus more on the tools and techniques, for instance, “I now have so many more tools at my disposal when it comes to gathering information.” We think there is a connection. The research mentioning higher order thinking skills and question posing resonated with us because when something is hard to do students generally will avoid it unless pushed. We conclude that we need to figure out a way go back to more individualized instruction.

A couple of years into the change we began thinking how instructors of courses with more students could scale up the teaching of this worksheet with the emphasis on the improved problem statements and selection of key concepts. We don’t think it does scale up. Every student comes to the class with a unique set of experiences and biases that must be accounted for and dealt with. It has been our observation that typically students are over-confident in their selection of search terms and instead of changing the words in their search strategy they just change their problem statement. Instruction with individuals or small groups over several sessions has been more beneficial for the students than in a larger class setting.

The steps involved in completing the research strategy worksheet, formulating a clear research question, selecting good key concepts, and evaluating the results reminded us of the Research as Inquiry frame in the ACRL Framework for Information Literacy for Higher Education (*19*). Effectively searching for information is iterative and it starts with formulating a research question.

While there is an inherent time commitment in employing a focus on the first three steps of the research strategy worksheet in classes, it has been our experience that this focus has been effective in helping the students understand the basics of what is needed to engage in effective and efficient library research.

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References

1. American Chemical Society *Undergraduate Professional Education in Chemistry*; American Chemical Society: Washington DC, 2008; p 14.
2. McEwen, L. Introduction to the Chemical Literature. In *Chemical Information for Chemists: A Primer*; Currano, J., Roth, D., Eds.; Royal Society of Chemistry: Cambridge, UK, 2013; pp 1−27.
3. Project Information Literacy. *Project Information Literacy poster*; http://projectinfolit.org/images/img/pilresearchiglarge.png (accessed September 10, 2015).
4. Kolowich, S. *What Students Don't Know*; https://www.insidehighered.com/news/2011/08/22/erial_study_of_student_research_habits_at_illinois_university_libraries_reveals_alarmingly_poor_information_literacy_and_skills (accessed November 15, 2015).
5. Newton, A. *MindMaps and literature searching for undergraduates*; http://www.ustlg.org/spring05/angela.ppt (accessed October 15, 2014).
6. Webber, S. *Mapping a path to the empowered searcher*; http://www.slideshare.net/sheilawebber/mapping-a-path-to-the-embpowered-searcher (accessed 12 May, 2015).
7. Prensky, M. Digital Natives, Digital Immigrants. *On the Horizon* **2001**, *9*, 1–6.
8. Overbaugh, R. C.; Schultz, L. *Bloom's Taxonomy*;http://ww2.odu.edu/educ/roverbau/Bloom/blooms_taxonomy.htm (accessed October 16, 2015).
9. Denison, D. R.; Montgomery, D. Annoyance Or Delight? College Students' Perspectives On Looking For Information. *J. Acad. Libr.* **2012**, *38*, 380–390.
10. Johnson, C. M.; Anelli, C. M.; Galbraith, B. J.; Green, K. A. Information Literacy Instruction And Assessment In An Honors College Science Fundamentals Course. *Coll. Res. Libr.* **2011**, *72*, 533–547.
11. Mandernach, M. A.; Shorish, Y.; Reisner, B. A. The Evolution Of Library Instruction Delivery In The Chemistry Curriculum Informed By Mixed Assessment Methods. *Issues Sci. Technol. Libr.* **2014**, *77*.

12. Graham, K. J.; Schaller, C. P.; Jones, T. N. An Exercise To Coach Students On Literature Searching. *J. Chem. Educ.* **2015**, *92*, 124–126.
13. Bruehl, M.; Pan, D.; Ferrer-Vinent, I. J. Demystifying The Chemistry Literature: Building Information Literacy In First-Year Chemistry Students Through Student-Centered Learning And Experiment Design. *J. Chem. Educ.* **2015**, *92*, 52–57.
14. Klein, G. C.; Carney, J. M. Comprehensive Approach To The Development Of Communication And Critical Thinking: Bookend Courses For Third- And Fourth-Year Chemistry Majors. *J. Chem. Educ.* **2014**, *91*, 1649–1654.
15. Zohar, A.; Dori, Y. J. Higher Order Thinking Skills And Low-Achieving Students: Are They Mutually Exclusive? *J. Learn. Sci.* **2003**, *12*, 145–181.
16. Pavelich, M. J. Using General Chemistry To Promote The Higher Level Thinking Abilities. *J. Chem. Educ.* **1982**, *59*, 721–724.
17. Zoller, U. The Fostering Of Question-Asking Capability: A Meaningful Aspect Of Problem-Solving In Chemistry. *J. Chem. Educ.* **1987**, *64*, 510–512.
18. Teevan, J.; Alvarado, C.; Ackerman, M. S.; Karger, D. R. The Perfect Search Engine Is Not Enough: A Study Of Orienteering Behavior In Directed Search. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*l **2004**, 415−422.
19. American Library Association. *Framework for Information Literacy for Higher Education*; http://www.ala.org/acrl/standards/ilframework (accessed June 7, 2016).

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Chapter 10

Learning through Two Lenses: An Analysis of Chemistry Students' Information Literacy Skills

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The development of scientific information literacy skills is a key area of emphasis for science and instructional librarians and academic instructors in the sciences. Information literacy standards are being redefined as the information landscape evolves. The purpose of this study is to investigate the development of chemistry students' information-seeking skills and to evaluate the impact of existing pedagogical methods being utilized in a chemistry seminar course. The information-seeking behavior of 14 junior and senior students was assessed through two questionnaires and two self-narrated screen capture videos at different points during the semester. Information evaluation, synthesis, and communication skills were developed using writing-to-learn techniques, classroom presentations of journal article summaries, and peer evaluations. Students demonstrated a modest improvement in evaluative literature research techniques and persistence during the information-seeking process. The conclusions of this study may assist librarians and instructors in identifying information literacy needs and designing information literacy assessment strategies.

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Introduction

Scholarly research and communication are fundamental skills of the modern chemist. Librarians and chemistry educators alike strive to assist students with the development of information literacy skills throughout the research process, coaching them from early steps such as information seeking, discovery, and analysis through the higher-order outcomes of information synthesis, creation, and sharing. The transition to online scholarly information sources - coupled with a plethora of freely available web-based information ranging from authoritative and scholarly to biased and even misleading - exacerbates the literature research challenges faced by chemistry students. The increasing seamlessness of information discovery and delivery requires information seekers to make additional efforts to understand the nature of the information before them. At Mercer University a 300-level chemistry seminar emphasizes information literacy development and was chosen as the forum to study the information-seeking behavior of chemistry majors while assessing the impact of information literacy training.

Background of the Mercer Chemistry Seminar Course

The chemistry seminar course (CHM 395) is a required course in the curriculum for the University's chemistry majors and chemistry commerce majors. It is a one credit-hour course meeting for 75 minutes each week. The enrollment numbers typically average around 12 students, containing an even mixture of juniors and seniors.

The essential learning outcomes for the course include:

(1) Analysis and communication of experimental information and results from the chemistry literature, as demonstrated in seminar presentations.
(2) Oral communication (including listening) about chemistry concepts, as demonstrated in seminar presentations, asking questions after seminars, and post-seminar discussion periods.
(3) Familiarity with the chemical literature, as demonstrated through the selection of articles and submission of homework.
(4) Effective and accurate written expression involving chemistry concepts, as demonstrated in the weekly homework.

The assessment of the student learning outcomes was carried out from the students' prepared formal presentations (2 per student, 50% of total course grade), weekly discussion and participation (25% of course grade), and weekly homework (25% of course grade), all based upon articles from the primary chemistry literature. In order to achieve success in the course, students needed to rely upon the ability to locate and evaluate chemical information. In the modern library, however, many print resources have moved to online systems, and students often access resources remotely when they are not in the presence of an instructor or librarian. Because the face-to-face aspects of library research are removed, we often do not have a good measure of students' information literacy abilities. Thus, courses (such as this one) that rely upon those abilities may have a mismatch between instructor expectation and student performance.

In order to understand how students were conducting searches and evaluating the results, we needed to find a way of determining students' competencies toward information literacy. In 2013, we provided students with self-assessment questionnaires at the beginning of the semester (week 1) and the end of the semester (week 14) in order for us - as teachers and researchers - to analyze the students' perceptions of their information literacy abilities and how those might change over the course of the semester. To provide an additional layer of analysis, we also issued homework assignments in week 1 and week 8 where students created a screen capture video as they searched for chemical information. By analyzing those videos both quantitatively and qualitatively, we were able to assess students' abilities and areas for growth in information literacy.

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Information Literacy in Context

Much has been written about information literacy over the past several decades, especially when considering its connection to other essential skills such as critical thinking and life-long learning. This literature review is intended to conceptualize how our project fits into the larger information literacy conversation. It does not attempt to summarize any significant portion of the literature available. However, while our specific project is merely one example of how information literacy can be included in chemistry instruction, it is helpful to start with a broad overview of the theories that guide our practice.

Information literacy can be defined as "a set of abilities" focused on the location, evaluation, and use of information (*1*). The American Chemical Society (ACS) and the Special Libraries Association have further delineated the skills needed by undergraduate students, focusing on the role of the library, the purpose of scientific and chemical literature, and the types of information and topics students would find within articles (*2*). While these descriptions focus almost exclusively on skills, the *Framework for Information Literacy for Higher Education*, released in 2015 from the Association of College and Research Libraries (ACRL), offers a new definition of information literacy that highlights the conceptual aspects of information literacy:

> *Information literacy is the set of integrated abilities encompassing the reflective discovery of information, the understanding of how information is produced and valued, and the use of information in creating new knowledge and participating ethically in communities of learning (3).*

This definition of information literacy is both broader and more abstract than earlier definitions. It encompasses the necessary pedagogical shift arising from the digital age: that the challenge is no longer in finding information, but in relating and synthesizing information into the greater whole. As new research tools become available, learners must be able to adapt, drawing upon metacognition to develop a high-level understanding of their own abilities and thinking processes. Such an understanding enhances their ability to adapt to the shifting information landscape.

Metacognition involves "the process by which we understand and alter our own thinking (*4*)." Different examples of pedagogical research in chemistry library instruction rely upon students' self-reported abilities or pre- and post-tests (*5*, *6*). However, research shows that many students over-estimate their abilities, perceiving themselves to be far more competent in a myriad of tasks than they actually are (*4*). These unrealistic self-perceptions are frequently apparent in college classes that require information literacy. Students often believe themselves to possess good information literacy skills when in fact, they display what Ambrose, *et al.* would call "unconscious incompetence (*7*)."

One way of increasing students' self-awareness of their knowledge and skills is to ask them to demonstrate that knowledge. Faculty often use screen capture videos to provide instruction to students, through a pedagogical technique known as the flipped classroom (*8*). Appropriating that same technology by asking students to record their own videos, however, provides an opportunity not only for the faculty member to provide feedback while seeing the students' process, but also for the student to practice metacognition. Beckelhimer reports on an assignment for which students recorded their research process, stating that the assignment "can and does alleviate the problems that the teacher can't usually see and that the student might not even recognize (*9*)." By asking students to screen capture their searches, she found that students were more transparent about the mistakes they were making, and the resulting discussions allowed students to improve.

The aim of the project described herein was to contribute to, as Nilson describes, the cultivation of "intentional, independent, self-directed, lifelong learners who can meet the burgeoning knowledge demands of the future (*10*)." By asking students to demonstrate their current information literacy skills with an aim toward meeting a higher bar, they could focus on metacognition and growth. The questionnaires and screen capture videos made the student research process more tangible. The outcomes of this project can contribute to the larger professional discussion of information literacy in the college curriculum.

Analysis of Chemistry Students' Information Literacy Skills

Methods

At the start of the semester, students were given an overview of the course, and the information literacy research partnership between their instructor and the library faculty was explained. The project had been granted approval from the University's Institutional Review Board (IRB) as research involving human subjects. Students were provided with an informed consent form and given the option to have the data they provided be part of this research study. Only data from students providing consent were included in the research.

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Students provided quantitative data via questionnaires at two points: the opening class session (week 1) and the end of the semester (week 14). They were asked to self-report their overall abilities in information literacy, their aptitudes for locating chemical information, their aptitudes for evaluating chemical information, and their aptitudes for organizing academic information once located. (No important data were discovered regarding the last outcome, so it is not discussed further.) Analysis of the data was quantitative, measured via Likert-scale and multiple choice questions.

The student screen capture videos were assigned at the beginning of the term (assigned in week 1, due in week 2), and at the midterm (approx. week 8). In week 1, students were randomly assigned to one of three tasks: 1.) search for scientific articles on a topic of interest; 2.) download a specific article, given its citation, or 3.) find any article of interest from 2009 in an ACS Journal. The purpose of the three different assignments was to provide the course instructor with a broad overview of students' specific abilities. In week 8, students were asked to create a video as they narrated a search for an article on a chemical or scientific topic of interest, using a resource that they had not used before. The purpose of this specific assignment was to see how the students could transfer their information literacy skills to a new task.

Each video was created using Jing (*11*) (free software which visually records a student's computer screen and audio narration for up to 5 minutes), and students were asked to narrate what they were doing to complete their assignment. This software was chosen in part because it does not allow students to edit either video or audio after recording, and students were instructed to do a single "cold" run, although some students ran into technological issues requiring multiple takes. In analyzing the videos, we utilized the same questions from the student self-reported questionnaires to document evidence of the students' information literacy skills; we also determined our perception of the students' confidence. The content of the students' videos was analyzed via open coding (creating summative categories based on data analyzed) and axial coding (starting with codes and analyzing how data fits within the categories) in order to create a full picture of their information literacy skills. The videos were coded individually by the researchers, followed by a norming session to provide consistency and inter-rater reliability.

Overall Analysis of Student Abilities

The first part of the student questionnaire targeted broad perceptions of confidence in locating general academic information and chemical information. Students were asked questions about their perceived abilities in searching for academic information. Likert-type answer choices included: Frustrated (1), Unprepared (2), Neutral (3), Competent (4), Confident (5).

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Self-Reported Data at Week 1

As seen in Table 1, students reported a mean level of confidence of 3.8 (approaching "Competent") in searching for general academic information, but a lower mean level of confidence of 3.2 (slightly above "Neutral") in searching for chemical information. This suggests that students were much more consistent as a cohort in their perception of confidence in searching for general academic information than chemical information. These results were not unexpected, because students are exposed to general academic research as a cohort early in their university experience, but had only recently been exposed to discipline-specific research. The standard deviation for general academic information was 0.6 while for chemical information it was 1.1. The data showed some variation, but leaned toward the Competent/Confident scale and was not bi-modal in nature. One likely explanation for the standard deviation is that general information literacy is presented in foundational general education coursework, where most students have a similar experience. However, at the start of the semester in question, some participants had undertaken more chemistry laboratory research courses than others, leading to some variance in discipline-specific confidence.

Table 1. Student-Reported Confidence

	Week 1 Mean (std.)	*Week 14 Mean (std.)*
Searching for general academic information	3.8 *(0.6)*	4.4 *(0.8)*
Searching for chemical information	3.2 *(1.1)*	4.1 *(0.7)*

Self-Reported Data at Week 14

With regard to both general and chemistry information searches, students expressed increased confidence by the end of the semester. As seen in Table 1, by week 14, students displayed perceived learning gains and, on average, considered themselves to be at the "Competent" levels. We noted that the means tended towards each other at 4.4 and 4.1 and standard deviations at 0.8 and 0.7 for general academic and chemical information respectively. This is likely an expression of having experienced a period of common chemical research literacy instruction as a cohort. Interestingly, while we noted an anticipated reduction of standard deviation from week 1 to week 14 for finding chemical information, the standard deviation actually increased from 0.6 to 0.8 for general academic information. Perhaps this indicates an increase in awareness of the strengths or weaknesses of prior general academic research strategies in the light of exposure to new information-seeking strategies during classroom instruction.

We also observed that for chemical information, the mean level of student confidence in week 14 is within the standard deviation observed for week 1. This is explained by the large standard deviation of the distribution in week 1, while the week 14 data tended towards a less variant distribution. By week 14, none of the students rated themselves as "Frustrated" or "Unprepared," which was not the case in the week 1 survey.

Analysis of Videos

In addition to the analysis of student responses to the questionnaires, we also assessed student confidence in the screen capture videos that students created at weeks 1 and 8. This provided an additional data point with which to verify students' abilities, as well as a method of attempting to circumvent overconfidence in student-reported data, as noted above (*4*).

The student-created videos demonstrated students searching for chemical information only. We assessed student perception of confidence and our own perception of student confidence, as reported in Table 2. To distinguish between these two subtly different concepts, we assessed student perception of confidence based upon what they said they would do or said they were doing.

Table 2. Researcher Analysis of Videos

	Student perception of confidence		*Researcher perception of student confidence*	
	Week 1 Mean (std.)	*Midterm Mean (std.)*	*Week 1 Mean (std.)*	*Midterm Mean (std.)*
Searching for chemical information	3.8 (1.0)	4.5 (0.7)	3.4 (1.0)	3.3 (0.8)

We established our perception of student confidence by what they actually did or accomplished *in the context of their narrative*. We note that it was a particular challenge to maintain the distinction between students' confidence in what they were doing and their competence in accomplishing it.

Our interpretations of student confidence shows gains from the first video (week 1) to the midterm video (week 8), growing from 3.8 (approaching "Competent") to 4.5 (firmly "Competent"), with diminishing standard deviations in the intervening time. The changes in these measures are somewhat consistent with the student-reported data, as seen in Table 1. We believe that research-focused classroom instruction is the basis for the improved confidence observed.

When we, as researchers, formed our own perceptions of student confidence, we consistently rated the students lower than they rated themselves. We rated the students' videos at both weeks 1 and 8 as closer to the "Neutral" category. We

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did not perceive the students' confidence to be greatly improved on their videos at midterm, which is likely due to the nature of the midterm video assignment, where they were asked to search for information using a tool or database that was new to them. Although we did not perceive the students to have increased confidence by the midterm point, they tended to begin their searches with a well-expressed idea of what they wanted to find and mostly selected appropriate sources. Their intended strategies and subsequent experiences diverged as they encountered greater complexity, and they offset the decrease in confidence with an increased awareness of effective research strategies. In this way, students were able to develop an awareness of what they did not know, an indicator that they were practicing metacognition.

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Aptitudes for Locating Chemical Information

Quantitative Analysis (Student Perceptions and Researcher Perceptions)

The questions that students answered in their questionnaires focused on their typical behavior when conducting literature research. We sought to identify evidence of common traits of a competent researcher: gaining background understanding of a concept, selecting appropriate resources, and refining one's search strategy in a variety of ways to improve the result set obtained. Students were given choices of Never, Almost never, Sometimes, Nearly always, Always, or Not Applicable for each question asked. However, in analyzing the videos, we determined that utilizing a Yes/No/Not applicable scale was more appropriate, as we could only analyze the evidence before us rather than what the student might "almost" or "nearly" do. The students' responses were thus recoded, with Never/Almost never as a "No" and Sometimes/Nearly Always/Always as a "Yes." Table 3 summarizes the student responses to questionnaires and researcher observations based upon analysis of the videos produced by students.

Student Reported Behavior

On all questions but one, the majority of student responses (ranging from 84.6% to 100%) indicated that they exhibited the traits of a competent researcher at least some of the time at the start of the semester. By week 14, 100% of students claimed to exhibit, at least some of the time, those competencies for the same five questions. The only exception to this trend was question 6, on broadening a search beyond local resources, which only 38.5% of students claimed to do in the first week. However, it must be noted that the interpretation of "local resources" quite likely varied by individual student. By week 14 of the semester, this definition was clarified to refer to resources subscribed to or held by Mercer University Libraries, which likely accounts for the doubling of this response, from 38.5% in week 1 to 76.9% by week 14.

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Researcher Observed Behavior

As with the data set from Table 2, we tended to score students much lower through the observations made by watching student videos than students scored themselves. For the videos produced in week 1 of the semester, it was observed that only between 7.7% and 46.2% of students demonstrated the desired research competencies. By week 8 and the second video, an increased percentage of students demonstrated elements of information literacy.

Table 3. Student Aptitudes for Locating Chemical Information

	SRD[1]	*RAV*[1]	*RAV*[1]	*SRD*[1]
Week of the semester data was generated	1	1	8	14
Data analysis: % yes, % no, (% not applicable)[2]				
1. When given an assignment that will require you to search for academic information, how often do you first perform a general search to gain familiarity with the topic?	92.3, 7.7, (0.0)	7.7, 0.0, (92.3)	7.7, 0.0, (92.3)	100.0, 0.0, (0.0)
2. Do you feel that you possess a good understanding of when it is appropriate to use academic/library sources and when general internet searches will suffice?	84.6, 15.4, (0.0)	30.8, 53.8, (15.4)	76.9, 7.7, (15.4)	100.0, 0.0, (0.0)
3. When searching for academic information, do you select and vary search terms specific to the discipline?	100.0, 0.0, (0.0)	38.5, 30.8, (30.8)	69.2, 30.8, (0.0)	100.0, 0.0, (0.0)
4. When searching for chemical information, how often do you vary your searches by author, topic, chemical name, reaction, etc.?	84.6, 15.4, (0.0)	7.7, 61.5, (30.8)	38.5, 61.5, (0.0)	100.0, 0.0, (0.0)
5. When searching for chemical information, how often do you refine or limit your search?	92.3, 7.7, (0.0)	46.2, 23.1, (30.8)	61.5, 38.5, (0.0)	100.0, 0.0, (0.0)
6. When searching for academic information, how often do you broaden your information-seeking process beyond local resources?	38.5, 61.5, (0.0)	n/a[3]	n/a[3]	76.9, 23.1, (0.0)

[1] Notes: SRD = student-reported data, RAV = researcher-analysis of video. [2] For purposes of this analysis, we analyzed the never/almost never categories together as no, and the sometimes/nearly always/always categories together as yes. [3] This question was not applicable to the videos created, so was not analyzed.

The two exceptions are questions 1 and 6. Because of the nature of the assignment instructions, students were sometimes asked to research a topic of interest, which meant that they were probably researching a topic that they already knew something about, thus performing a general search first (question 1) was generally not applicable. As discussed above, the broadening of the search process beyond "local resources" (question 6) was found to be not applicable to the students' search videos as well.

A significant gap remains between student self-perceptions of aptitude for locating chemical information and the students' competence as perceived by chemistry and information literacy practitioners. Many students were focused on completing assignments rather than comprehensively researching a subject as a practicing scientist might. This difference in perspective likely plays a significant role in determining the judgment of confidence and aptitude of students as researchers. That is to say, one is more likely to evaluate oneself as a competent researcher based upon completing discrete assignments, whereas practicing scientists, professors, or academic librarians hold a more comprehensive standard.

Qualitative Analysis (Videos)

Qualitative analysis of the videos suggests that the students became more competent researchers over the eight-week period. This is first apparent in their search strings (that is, the combination of search terms and search operators used), as students moved from using primarily broad and non-subject appropriate terminology to more focused and appropriate terms. Examples from the first week include "ALS treatment" and "veterinary medicine," with nothing more complex than "knoevenagel condensation microwave." By the eighth week, students were using more narrow and specific terms such as "mercury poisoning" and "KaMin," and one student had improved to the point of correctly using truncation with these terms, searching for "Biosurfact* emulsif*" to good effect. The average complexity of the search strings did not improve, but the increased use of refinement and modification techniques led to a moderate increase in the sophistication of search terms.

In the first week, students rarely limited or modified their searches, and the use of both limitations and modifications was heavily impacted by the assigned task, as mentioned earlier. Unsurprisingly, the four students who were required to locate a specific article using a citation simply copied and pasted the citation into Google. Students who were asked to find an article from a specific year either limited or modified their search by publication date, but added no other parameters. Those students searching for an article of interest were most likely to modify their search, adding or changing terms, narrowing to a specific journal, or adding a date range.

In the second set of videos produced at week 8, all of the students were searching only for an article of interest and were more likely to refine or modify their searches. Admittedly, the impact of the type of assignment during the first week suggests that this increase may be due only to task performed. However, students used a wider variety of modifications in week 8 than in week 1, including limiting to a particular journal, adding search terms, author names, and utilizing

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database search features such as subject categories. Students sometimes failed to understand how these modifications would impact their search results, and had to go back to make adjustments. However, they improved overall with implementing the tools to refine and find the information they needed.

By analyzing the student videos, we were able to see the general lack of mastery of information literacy common to undergraduate students. Throughout the videos, the students' misunderstandings were apparent, and we would not have had this data without the submission of the video assignments. Common mistakes included selecting non-scholarly sources when peer-reviewed was required, using "journal" to refer to all articles, and a lack of awareness for accessing full-text articles. A student who claimed to always use Google Scholar, for example, acknowledged the difficulty of finding full-text sources, while simultaneously not noticing the full-text links available for several articles. Additionally, a number of students accessed library subscription resources via Google, missing authentication as Mercer University students, and were therefore unable to access the full text of articles they would otherwise have been able to view. While all of these issues occurred somewhat less frequently in the second set of videos, a number of these problems persisted. These misunderstandings were also displayed by different students in each group of videos, suggesting greater prevalence than may appear from a brief video.

Another significant information literacy skill students seemed to struggle with in the videos was the evaluation of results, although this also improved from the first to the second set of videos. In the initial assignment, many students did not evaluate their search results, although a few gave a cursory glance at the titles. In the second group of videos, all of the students performed some evaluation of their search results, looking at titles, abstracts, and authors' affiliations. The screen capture videos were limited to 5 minutes, so a comprehensive evaluation of the search results was not always appropriate in the time allotted. A more comprehensive evaluation of the articles was performed during the in-class time, as discussed in the next section.

Aptitudes for Evaluating Chemical Information

The videos that the students created captured the search process, but ended with the students finding an article. The best measure for determining the students' evaluation and critical reading of articles - and perhaps the most appropriate methods for determining those skills - came through the weekly homework assignments and the in-class presentation and discussion periods. Students' aptitudes were evaluated in two ways: as a presenter and as a class participant.

Prepared Formal Presentations

Students were expected to choose and present key findings from an article to the class during two different class periods. Students were directed to choose an article that interested them and could be understood by 300-level chemistry students. The selected article could be from any area of chemistry.

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The week before the student was scheduled to present, he or she was to provide to the instructor the article citation (in *Journal of the American Chemical Society* format (*12*)) and a short background essay. The presenter needed to demonstrate a good understanding of the chosen article by describing its content, addressed to the audience of one's classmates. In this way, the students had to evaluate the article for its relevance to their own interests and to determine if its scientific merit was appropriate to the intended audience.

On the students' presentation days, they were expected to prepare a 12- to 15-minute oral presentation on the article, describing its background and relevance, scientific and research methods, findings, conclusions, and references. Students then answered classmates' questions and led the class in a 15-minute discussion on the article. During the discussions, all of the students were expected to speak up in discussing and critiquing the article. This allowed them to focus on two key ACRL-defined skills: "evaluating information and its sources critically," and "incorporat[ing] selected information into one's knowledge base (*1*, *3*)."

During and/or immediately after the students' presentations, their classmates provided peer evaluations on a seminar feedback form. (See Appendix Item 1.) The form allowed for both quantitative and qualitative evaluation of the presenter's abilities to describe the background and science of the article and of his/her overall clarity of the presentation and understanding of the article presented.

Within a week of the presentations, the students scheduled an individual conference with the instructor to discuss the outcomes of the presentation. Each student received the feedback from his/her classmates in aggregate, along with comments and constructive advice for improving on the next presentation. These individual meetings were important for helping each student to realize how his/her knowledge of chemistry was conveyed, and look for areas of growth in locating and evaluating appropriate chemical information.

Weekly Discussions, Participation, and Homework

Through the formal presentation process, each student had two chances to assume a leadership role in the course, and all students were exposed to approximately twenty-four articles on diverse topics from the chemical literature. In order to guide the students' ability to read and comprehend technical information from the chemical literature, their weekly homework included required annotation of the two articles chosen by their presenting classmates. In annotating an article, students were taught how to read actively, by circling, underlining, highlighting, and writing in the margins. They were asked to write questions, find ways that the article connected with other topics they were learning about or had learned about in other chemistry courses, and to look for themes or possible weak points in the research design.

Two "writing-to-learn" (WTL) (*13*) activities were also regularly used as homework assignments. The WTL movement is designed to help equip students with the tools of critical reading and critical analysis, especially important when reading difficult texts and/or technical information. During the first half of the semester, students prepared a double-entry journal as they read their articles. (See

Appendix Item 2.) A double-entry journal is directly related to metacognition, as students write points of interest from their reading on a left column of a notebook, and then write their thoughts on the corresponding right column. When reading the students' double-entry journals, it was apparent that they were exhibiting evolving information literacy skills. The students would frequently connect the information to what they were learning about in other courses, or pose questions or provide critiques of how the authors used data to arrive at their conclusions.

In order to allow students to experience different WTL tools, the use of double-entry journals was dropped and another WTL activity added at the midpoint of the semester. During the second half of the semester, students' homework entailed providing a 4-sentence summary of the article, with one sentence each representing the background, methods, results, and discussion. (See Appendix Item 3.) The assignment was challenging, in that students had to read very carefully and use their words wisely in order to represent the article in a concise way.

Applying qualitative research analysis to the students' homework is beyond the scope of this chapter, but it was apparent that the assignments of reading, annotation, and writing-to-learn were beneficial in moving students beyond a superficial treatment of the articles. They were able to engage the texts in more meaningful and higher-level ways, and these advanced learning outcomes are much desired in modern information literacy (*1–3*). We would recommend these types of activities to anyone seeking to improve their students' abilities to evaluate information from disciplinary literature.

Conclusions

Our investigation demonstrates that self-confidence and competence in finding relevant scholarly chemical information are by no means synonymous. Students tended to be initially over-confident in their abilities while demonstrating rather limited aptitude for locating quality and relevant scholarship. Similarly, their self-reported confidence did not correlate to our perception of their confidence, which we assessed as they went about their research process. Student-reported confidence is a product of their past research experiences and general online searching habits as well as limited theoretical research knowledge. Our analysis of their confidence was based upon a specific observed research assignment. A potential follow-up study might assess student-reported confidence both directly before and after a research assignment to provide a more complete picture of their self-awareness. Students tended not to initially endeavor to locate the most relevant or highest quality information through an evolving search process, but rather settled early on for something that they perceived to be "good enough" with a superficial evaluation. However, by involving students in information literacy building activities that included evaluative exercises during the semester, we observed an increase in competence demonstrated by improved complexity and refinement of search strategies.

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Perhaps the best pedagogy for teaching information literacy is *doing* information literacy rather than merely listening to potentially abstract concepts about information literacy. We also recognize that students need to feel a vested interest in the activity in which they are engaging for them to make an appropriate investment of effort. Requiring students to summarize, present, and discuss scholarly articles increased their level of engagement and understanding. We consider information literacy to be the ability to apply a suite of particular skills during any form of research, and the interactive and participatory chemistry seminar provides a strong foundation upon which to build further chemical information literacy. The initial information literacy analysis and observed progress of students in this chemistry seminar suggest, however, that the acquisition of critical chemistry information literacy skills must be facilitated beyond a single academic course with an ongoing, strategic process. Thus demonstrating a well-honed repertoire of research and information processing skills, the information literate chemistry graduate will be confident when undertaking research because that confidence will be a product of the competence that is developed, tested, and refined in a well-structured academic program.

List of Items in Appendix

Item 1: Seminar feedback form
Item 2: Instructions for double-entry journal
Item 3: Instructions for 4-sentence summaries

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Appendix Item 1

Student Feedback Form for Chm 395

Date: ________ Speaker: ______________ Evaluator: __________________

For each category below, please provide a numerical score as well as commentary that will be helpful to the speaker. (Your numbers and comments will remain anonymous to your classmates.)

The numerical scale is meant to correspond to: a "3" for an essentially perfect performance (with only few minor problems); a "2" for several minor problems or just one major problem; a "1" for major problems throughout; and a "0" for making no effort in that area.

I. **BACKGROUND**: Speaker adequately described the purpose of the experiments and the scientific principles involved; made references to the literature where appropriate.
Score:
Comments:

II. **SCIENCE**: Speaker adequately described the chemical system under investigation and the experimental techniques employed; made logical interpretation of results.
Score:
Comments:

III. **CLARITY**: Speaker demonstrated organization and style in the presentation that maximized its clarity; made effective use of visual aids.
Score:
Comments:

IV. **UNDERSTANDING**: Speaker demonstrated mastery of the subject matter; effectively handled questions from audience.

Score:
Comments:

Total Score: _______ out of 12

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Appendix Item 2

Weekly Homework: The Double-Entry Journal

Unlike a customary journal or notebook, dialectical/double entry is named for the divided sides of the page and divided functions. In the left-hand column of the page, you will take notes from the article that you are reading. The right-hand column is for you to respond to those notes by asking questions, writing down ideas that you would like to discuss with your classmates, providing insights, and clarifying what you do and do not know.

Basic Example (from an actual student's work):

Text Notes	Comment
Studies report a heat-induced increase in ATP metabolites	Does this mean that cellular processes are still going, or this occurs as a result of degradation?
The present study aims to elucidate the chemical and sensory fate of IMP	This is the focus of the article
Measured sensory attributes	Their measurements seem subjective. Not sure I can trust the data.

Such a journal is frequently used to help students understand the course content, particularly when the material is difficult.

You will be submitting a Double Entry Journal frequently in this course as part of your Weekly Homework Assignment. (The assignments will be posted on Blackboard every week.) This journal is intended to help you focus while you are reading each week's required literature by compelling you to organize your understanding of the article and what questions you might have.

Your Double Entry Journal Assignments:

- To be done in your course notebook. Tear out the copy pages along the perforation and staple.
- Include your name, the date you wrote your journal, and the citation for the article according to *The ACS Style Guide*.
- For each article, make at least 10 double entries. Two of these should include questions/terms that you looked up.
- These Journals are not formal writing (proper sentence structure, punctuation, etc.), but they must be legible.

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Appendix Item 3

Weekly Homework: 4-sentence summaries

When you have completed your careful reading and annotation, write a four-sentence summary of each scientific article, followed by two questions.

- Your first four sentences make up a four-sentence summary of the scientific article – one sentence for each section of the article. Recall that the *Introduction* states the question addressed in the study and explains why the question is important; *Methods* tells how the question was answered; *Results* shows the outcome of the experiment; and *Discussion* analyzes the results and suggests the impact of the new knowledge.
- Your second set of sentences are two questions raised in your mind by the article.

These may be typed or neatly hand-written.

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References

1. Association of College and Research Libraries. *Information Literacy Competency Standards for Higher Education*; http://www.ala.org/acrl/standards/informationliteracycompetency (accessed Nov. 2, 2015).
2. Special Libraries Association, Chemistry Division/American Chemical Society, Division of Chemical Information. *Chemical Information Literacy*; http://chemistry.sla.org/il/ (accessed Nov. 2, 2015).
3. Association of College and Research Libraries. *Framework for Information Literacy for Higher Education*; http://www.ala.org/acrl/standards/ilframework (accessed Nov. 2, 2015).
4. Krueger, C. E.; Rosen, H. J.; Taylor, H. G.; Espy, K. A.; Schatz, J.; Rey-Casserly, C.; Kramer, J. H. *Clin. Neuropsychol.* **2011**, *25*, 741–756.
5. Locknar, A.; Mitchell, R.; Rankin, J.; Sadoway, D. R. *J. Chem. Educ.* **2012**, *89*, 487–491.
6. Mandernach, M. A.; Shorish, Y.; Reisner, B. A. *Issues Sci. Technol. Libr.* **2014**, *77*.
7. Ambrose, S. A.; Bridges, M. W.; DiPietro, M.; Lovett, M. C.; Norman, M. K. *How Learning Works: Seven Research-Based Principles for Smart Teaching*; Jossey-Bass: San Francisco, CA, 2010.
8. *Flipped Learning Network. Definition of Flipped Learning*; http://www.flippedlearning.org/definition (accessed Nov. 2, 2015).

9. Beckelhimer, L. Harnessing Technology to Help Students Reveal an Authentic Research Process: Pictorial and Video Research Steps. In *Implementation and Critical Assessment of the Flipped Classroom Experience*; Scheg, A. G., Ed.; Information Science Reference: Hershey, PA, 2015; pp 246–273.
10. Nilson, L. *Creating Self-Regulated Learners: Strategies to Strengthen Students' Self-Awareness and Learning Skills*; Stylus Publishing: Sterling, VA, 2013.
11. *Jing*. http://www.techsmith.com/jing.html (accessed Nov. 2, 2015).
12. *The ACS Style Guide*, 3rd ed.; Coghill, A. M., Garson, L. R., Eds.; Oxford University Press: Washington, DC, 2006.
13. Bean, J. C. *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*, 2nd ed.; Jossey-Bass Higher and Adult Education Series; Jossey-Bass: San Francisco, 2011.

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Chapter 11

Chemistry and Information Literacy for Informed Citizens: Creating and Implementing a Chemistry Research Assignment Using News Media

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In an undergraduate chemistry research assignment, students used popular media to explore science in the news and connected the science media reports to the original scientific literature. A librarian and chemistry instructor collaborated on information literacy instruction to teach students the research skills required to successfully complete the assignment. Students participated in three scaffolded library lab activities: a pre-reflection exercise in which students were asked to articulate what they knew about scientific information and how they would conduct a search for scientific literature; a Google search activity on finding credible science news reports; and an exercise linking science found in popular news reports to the original scientific literature located in academic databases. Learning outcomes assessment is provided in qualitative summaries detailing student interactions with the library lab activities and class discussions.

Introduction

Popular media can be used as a hook to introduce undergraduate chemistry students to scientific literature. In the course *UCOR 1810 Chemistry for the Informed Citizen,* offered at Seattle University (*1*) and designed by Emily Borda (*2*), students explored science research topics in the media and connected the science media reports to the original scientific literature. Students participated in a library instruction session where they learned the information literacy skills necessary to complete the research assignment.

The Association of College and Research Libraries (ACRL) defines information literacy (IL) as an individual's ability to "recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information (*3*)." Commonly, IL is integrated into undergraduate science curricula with the aim to help students strengthen critical thinking in science and become lifelong learners. ACRL's *Information Literacy Standards for Science and Engineering/Technology* is used as the prominent guideline for library instruction in the sciences and addresses the issue of teaching critical thinking and lifelong learning (*4*).

The benefits of integrating IL instruction into science curricula are described in the literature. Holden reported science students show an increase in positive attitudes toward the relationship of science literacy and lifelong learning after having IL instruction incorporated into science courses (*5*). When science instructors and librarians collaborate to teach science literacy in conjunction with information literacy, they work toward a shared goal of teaching students how to be lifelong learners (*6*). Brown and Krumholz described how critical thinking and lifelong learning are typically taught by helping students search for, select, and evaluate scientific literature (*7*). Exposing undergraduate science and nonscience majors to scientific literature has been explored through methods including connecting scientific literature to experimental lab design (*8*) and helping students examine scientific literature in order to effectively communicate scientific concepts and data (*9*).

While evaluating and understanding scientific literature remains a target literacy competency for undergraduate chemistry students, requiring students to focus solely on scientific literature presents a challenge for those students who are unable to relate directly to the literature or who have not yet been taught how to read and process dense scientific information. Scientific knowledge and chemistry literacy can be strengthened by exploring additional forms of science information. Gaining science literacy through evaluating science in the news and popular media can help build reading literacy, strengthen critical thinking, and play a role in students becoming lifelong learners. Majetic and Pellegrino described how lifelong science literacy includes the ability to understand how science research is presented in the media, a skill that many undergraduates lack (*10*). Additionally, Murcia found that undergraduate students lacked the ability to critically engage with science media reports and had little knowledge of how science is connected to a broader social community (*11*). Despite students' low competencies in engaging with science media reports, using popular science news

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to teach science literacy greatly contributed to students' overall understanding of scholarly scientific literature (*10*, *11*).

A study of science faculty and librarians in Ireland noted that faculty across science disciplines *believe* students' ability to develop information literacy comes from the students' personal interest and motivation regardless of the pedagogical structure (*12*). The study further states, students' failure to develop information literacy is largely due to their personal decision to not practice the necessary skills (*12*). However, this chapter describes an alternative approach in which the instructors have assumed the responsibility to inspire and encourage student literacy. Exploring popular media can engage students' interest, helping them to remain focused and to participate. Majetic and Pellegrino reported on teaching science to non-science majors using popular media science reports, arguing, "Our approach appears to create a "low-pressure" environment in the classroom, which seems to render the science presented in news articles less intimidating and results in students who are more willing to engage in examining scientific papers (*10*)." Similarly, studying science reports in popular media helps students develop their personal interests in science, which is different from telling students what they are required to know about science (*13*). From this perspective, directing instruction to meet students' personal interests can increase the likelihood of lifelong learning in the sciences.

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The Research Assignment: *Analyzing Media Reports of Scientific Research*

The final research assignment for UCOR 1810, titled *Analyzing Media Reports of Scientific Research,* is designed to give students a sense of the wonders and complexity of chemistry in the environment. The assignment is a group project that includes a final presentation on chemicals in the environment. Students are put into teams and assigned a news topic and a set of chemicals. In addition to the group portion, students are individually required to write their own research paper that covers a science topic and an associated chemical that ties into the shared group topic. Examples of current news topics and their corresponding chemicals include:

- Climate change in connection with black carbon or nitrous oxide
- Mental health and anti-depressants: flouxentine, duloxetine
- Recreational drugs and stimulants: nicotine, methamphetamine
- Life in space and organic molecules: adenine, guanine, uracil

Working individually, students must first search the free Web to find news reports about their assigned chemical and then search for original scholarly research to support claims read in the popular media. In their research papers, students address the issues presented in the media report in connection to their chemical and the scientific literature. Then, as a team, students work to identify and understand a scientific model of a chemical property. The group compiles an annotated bibliography and delivers a presentation which includes a presentation abstract. In summary, individual and group assignment requirements are as follows:

1. Write a research paper using popular news media and scholarly articles that discuss chemicals in the environment (Individual)
2. Find and explain a scientific model of a chemical property (Group)
3. Compile annotated bibliography of media reports and scientific literature (Group)
4. Research Microsoft PowerPoint presentation, includes presentation abstract (Group)

Table 1 illustrates the information literacy learning outcomes for this assignment and the assessments used to evaluate student comprehension.

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Table 1. Information Literacy Learning Outcomes and Student Assessment

Information Literacy Learning Outcomes	
Students learn to: Search for, discover and select resources for researching basic chemical information and popular media reports. Evaluate information based on authority, purpose and reliability. Identify the characteristics between quality popular media reports and poor popular media reports. Find primary sources referenced in secondary sources. Cite others' work and construct bibliographic citations.	**Students understand:** Authority is constructed and contextual. Research is inquiry and searching is strategic exploration. The value of academic databases for finding primary, peer reviewed scientific literature.
Student Assessment	
Student competencies of IL learning outcomes are assessed by: Observing students interact with open Web and academic database searching. Engaging students in discussion on evaluating information types. Reviewing student written work and presentations.	

Collaborating to Integrate IL into Chemistry Assignments

The librarian and chemistry instructor worked together to develop and teach the research components of *Analyzing Media Reports of Scientific Research*. Collaboration began at the start of the term, allowing ample time to write IL segments for the assignment, design a lesson plan and create student worksheets and handouts.

Co-writing the Chemistry Research Assignment

The portion of the assignment written by the librarian outlined questions students can use to evaluate media reports (or any information found on the free Web). In addition to locating and selecting information, a key component of IL includes critical evaluation of all types of information, scientific and popular. Current practice in IL instruction attempts to comply with ACRL's *Framework for Information Literacy for Higher Education,* which outlines six frames or aspects of IL. The six frames speak directly to students' ability to interact with and understand information in terms of authority, creation process, value, inquiry, scholarship conversation, and exploration (*14*). Using the framework as a guide, questions were designed to help students think critically about chemical information. Ideally, students would become adept at judging works based on these characteristics: authority, content, purpose, voice, and reliability. Table 2 outlines questions students were asked to consider when evaluating popular media.

Table 2. Surface Analysis of Media Reports Using Information Literacy Based Evaluation

Authority	• Is the author a scientist or a journalist? How can you tell if the author is considered an expert? • Who published the news? • Does the author mention other experts and reputable institutions that contributed to the information in the article?
Content	• Are the results of scientific research discussed? Are the original sources of the scientific research mentioned in a way that you can find the original research? Is the original research peer-reviewed? • If illustrations are used, how do they help explain the science or correlate with the written content?
Purpose and Voice	• Is the written language familiar or formal? • Is the information subjective or objective (or a combination of the two)? Is the article written with opinion or bias?
Reliability	• Based on the observations made about the news piece, the author, and publishing organization, is the science information discussed in the article reliable and credible? Explain your reasoning.

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In addition to the questions written by the librarian, the chemistry instructor added prompts that question the nature of science (NOS) tenets, seen in Table 3. These questions were distributed to students and discussed during chemistry class lectures. Daniel Domin explains why integrating NOS tenets into science courses is essential (*15*):

> *Researchers in the field have concluded that through an implicit approach, it is unlikely that students will learn what teachers do not intentionally teach by simply engaging in science activities or by exposure to historical episodes ... Rather students' NOS views are best developed in content-based courses ... using an explicit-reflective approach ... where the NOS instruction has been built into the course curriculum.*

Combining an analysis of NOS with an information literacy based-analysis gives students a well-rounded, in-depth critical thinking experience that strengthens competency in chemistry education and information literacy.

Table 3. Analysis of Media Reports in Relation to NOS

Scientific Knowledge	• What scientific hypothesis, theories or laws are mentioned in the article (either explicitly or implicitly)? Is the difference between law and theory made clear? • What new scientific knowledge is presented?
Scientific Method	• What information is given about the scientific methods used in the investigation? Who or what were the subjects? How long did the research take? Is there evidence of different scientific methods used for the same investigation?
Scientists and Society	• How does the scientific investigation show evidence of creativity or imagination? • What does the research offer to science and society? Does the article discuss benefits or limitations/risks of the research?

Co-teaching Chemistry Education and IL

Chemistry for Informed Citizens included one 2-hour lab session per week. One of those lab sessions was devoted to IL instruction where students met in a library computer lab instead of the chemistry lab room. Library computers were available for every student.

All instruction during library lab, including database demonstrations and facilitating student discussion, was conducted by the librarian. The chemistry instructor answered questions related to chemistry and the NOS tenets, as well as questions regarding the assignment requirements. The librarian and chemistry instructor worked as a team, exemplifying the collaborative nature of the librarian

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and instructor relationship. The participation of the chemistry instructor during library instruction helped students perceive that library instruction is part of chemistry education. This approach contributes to developing a holistic learning experience where information literacy is integrated into chemistry education.

The Library Lab

The library lab session lasted two hours and was divided into three activities. These activities led students through a scaffolded learning process that increased in complexity. Students began with a self-reflection exercise designed to help them examine their understanding of scientific literature. Next, students engaged in a Google search activity to find science news reports in popular media. In the third activity, students learned how to connect the science in news reports to the original science discussed in scholarly articles.

ACTIVITY ONE: Focusing Exercise

To prepare students to think about searching and using information resources, reflection exercises were used to draw students into the learning experience. Students were assured that the exercise was not a test and that they did not have to tell their answers to anyone, but could share with the group if they felt comfortable. The point of the exercise was for students to quietly focus on their individual experiences. Reflection questions included: "When you hear the term, *scientific literature*, what comes to mind?" and "If an instructor asks you to find an article from the scientific literature but does not give you any direction on how to do so, what would you do?"

After giving students a few moments to consider their thoughts, students were asked to share with the class. Responses to these questions varied. In response to what students think *scientific literature* is, answers included "peer-reviewed articles" and "articles found in journals". Students shared that journals are different from magazines, though differentiating between the two is sometimes difficult.

In response to how students would locate scientific literature, some students shared they might begin their search in Google but admitted the number of results would be overwhelming and they would have to guess at what resources are acceptable to use. Other students indicated they would search Google Scholar but would feel stuck if Google Scholar did not provide the full article. One student shared that even though Google Scholar may have scholarly articles, the results are confusing and hard to read. Students also shared that they would consider using the library's academic databases but were not sure which databases to use or how to find them on the library website.

To conclude the reflection exercise, students were encouraged to keep their ideas in mind while completing the library activities.

ACTIVITY TWO: Effective Google Searching

The second activity was a hands-on Google search designed to train students to critically think about their search queries, intelligently read Google results, effectively refine searches, and choose appropriate sources.

Studies indicate that free Web searching, specifically the use of Google, is the preferred search method for undergraduate students. Fast and Campbell reported students generally preferred searching the free Web over using the university's OPAC (online public access catalog) even though they knew of the issues related with questionable search results on the free Web (*16*). In a study on first year applied science students' use and views on finding information, Wilkes and Gurney concluded that nearly 70% of surveyed students prefer using the Internet to find background and scientific information (*17*). Google and Google Scholar were the top two choices for preferred Internet use (*17*). In a 2014 study of undergraduates use of Google and federated search tools, Georgas reported students generally believe they are skilled researchers and users of Google even though student search behaviors do not support that belief (*18*). Students did not examine Google results before selecting suitable sources. Likewise, students did not investigate metadata to improve searching (*18*). Instead students relied on information that surfaced on the first results page such as commercial sites and content farms like About.com (*18*). Georgas reported "Students in this study seemed to have little conceptual understanding of how information is structured and how searches work in either Google or the federated search tool (*18*)." Georgas' findings help build a case that teaching students to intelligently search for and select quality sources on the free Web and in proprietary academic databases continues to be a necessary component of library instruction for undergraduates.

Students in the library lab were asked to perform a series of Google searches, as illustrated in Table 4. The tasks were designed to help students observe aspects of Google search results and the types of information retrieved from basic searches. Students were encouraged to test various search terms with the goal of being able to understand the differences between natural language and keyword or phrase search queries. During this process, students evaluated individual sources by answering questions about authority, content, purpose, voice, and reliability, as shown in Table 2.

While students completed the activity, the librarian and chemistry instructor observed the class execute searches, answered questions related to Google results, and offered suggestions for identifying quality news sources. The librarian observed that students tended to select a source from the first page of results and rarely looked beyond the first page to find sources that could be more suitable to their needs. It was observed that when students did not see a useful source on the first page of Google results, they tended to execute a new search. When students were asked how they could learn more about the purpose and credibility of a Website, the librarian observed that students had difficulties locating a Website's "About" section. However, students easily identified URL domains and commented that they understood the commercial nature of .com sites as being distinct from .gov or .edu sites. Students commented they did not know how to find the credentials of news article authors. In response, instructors suggested searching for authors in Google to find the author's history in journalism or scientific research. After students completed the Google search activities, the librarian *briefly* demonstrated the search exercises to point out how to identify the "About" pages. Additional tips for refining search results such as adding dates and using synonyms were covered during the demonstration.

Table 4. Google Search Exercise Tasks 1−3

<table>
<tr><th colspan="3">Google Search Exercise</th></tr>
<tr><th>Task 1</th><th>Task 2</th><th>Task 3</th></tr>
<tr>
<td rowspan="3">In the Google search box type: aspirin

A. Examine the results list and consider:

What does the Website and domain of the first result tell you about the source?

What other types of results are on the first page? Look at the titles, URLs and descriptions for information.</td>
<td>In the Google search box type: how aspirin works

A. Look at the aspree result.

Who is the author? When was this site published? Can you tell what aspree is?</td>
<td rowspan="3">In the Google search box type: aspirin. Under the search box select the news link.

A. View the results list and notice source type.

Which sources are newspapers, blogs, commercial sites, etc.?

In your opinion, are these quality sources?

Are any of these results quality science media sources?</td>
</tr>
<tr><td>B. Look at the HowStuffWorks result.

What is this site selling? Can you find an author's name or publication date? What information is on the "About Us" link? Does the article have references at the end?</td></tr>
<tr><td>C. Look at the Wikipedia article on Aspirin

Can you find a section on how aspirin works? When was this article last updated? Do the illustrations have descriptions? How much of this article is written with facts? Can you detect bias? How can you tell if the references are credible?</td></tr>
</table>

Class discussion time was used to explore the unique characteristics and differences between personal blog posts, Websites used for commercial, political, educational, scientific or entertainment purposes (to name just a few purposes), video sources, and the pros and cons of using Wikipedia. Students voiced

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concerns about Wikipedia's credibility and did not understand when Wikipedia might be used as an acceptable starting point for basic information. Students wanted to know, for example, how to determine if the model of the aspirin molecule shown in Wikipedia was correct. In response, classmates suggested comparing the model with a more reputable source but were not sure where to look on the free Web for such a source. The librarian offered options such as the National Library of Medicine site PubChem or the reputable ChemSpider as alternative free Web resources that can be used to learn more about molecular information. This discussion led to students understanding the importance of evaluating authority and why comparing claims and ideas with multiple sources is essential in helping identify the differences between poor and high quality sources.

Incorporating a discussion component into the library session helps build a community of learners who discuss their discoveries, leading to higher competencies and knowledge creation. When students engage in conversation they shift from passive to transformative learning (*19*). Pankl and Coleman stress that dialog is a critical and necessary component to bridging information seeking with knowledge creation (*19*). The authors state that the research process must present itself within a rhetorical context where discovery and dialog are present: "'Static' information seeking only leads to flat and perfunctory research and contributes very little to the growth of the researcher's intellectual identity. Thus, the mutability of purpose is perhaps the most significant concern within the context of IL; without it, dialog and discovery are unlikely to occur (*19*)." This process contributes to a chemistry student's growth in becoming a lifelong learner and contributor to science discovery and creation. By sharing with their peers what they discovered during the Google searching activities, including what they found surprising or inspiring and what remained challenging or confusing, students made real life connections between their personal experience and a larger social structure.

ACTIVITY THREE: Bridging to Academic Databases

One of the more challenging and time consuming tasks students encountered in this assignment was finding quality news articles that referenced original research. When students were asked to share with the class how to pull citation information from reputable news sources, some students mistook hyperlinked text in news reports and blog posts to be links to cited references. News reports including bulleted lists of links on where to "find more information" were also mistaken for links leading to original research. To correct this error, students were taught to look for citation clues, such as author names, dates, or scholarly article titles that can be used to track down original research. Once students located a reputable media report and identified citation information, they were ready to transition to the final activity on searching academic databases.

Students were given two options for proceeding in this third activity. In option one, students could explore interdisciplinary databases such as Academic Search Complete and subject specific databases including ACS Publications to find information related to their topic or to the researchers referenced in the science news reports.

In option two, students who found a science news report that referenced an academic journal title could use the library's federated search tool to execute an e-journal search. Since locating e-journals by title is a valuable skill all students should know, the librarian briefly demonstrated to the class how to search for e-journal titles and read item records in the federated search tool. Figure 1 shows a portion of the instructions students were given on how to navigate from the federated search item record to locating an article. Students had access to Ulrichs Serials Directory and were taught how to locate the peer-reviewed status of journal titles. Students were also directed to Interlibrary Loan services for requesting titles to which the library did not have direct access.

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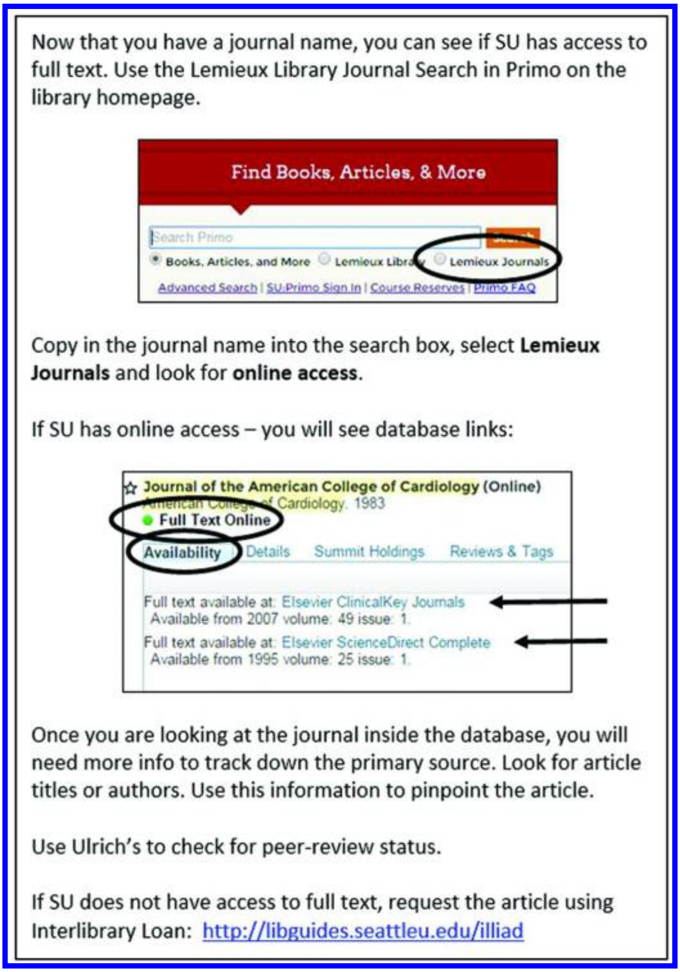
Now that you have a journal name, you can see if SU has access to full text. Use the Lemieux Library Journal Search in Primo on the library homepage.

Copy in the journal name into the search box, select **Lemieux Journals** and look for **online access**.

If SU has online access – you will see database links:

Once you are looking at the journal inside the database, you will need more info to track down the primary source. Look for article titles or authors. Use this information to pinpoint the article.

Use Ulrich's to check for peer-review status.

If SU does not have access to full text, request the article using Interlibrary Loan: http://libguides.seattleu.edu/illiad

Figure 1. Screenshot from student handout showing instructions on how to locate journal titles owned by Seattle University. (Reprinted with permission from reference (20). Copyright 2015.)

After the e-journal search demonstration, students used the remainder of the library session to proceed with option one or two. Students were set free to search and locate potentially useful information for their assignment. The librarian and chemistry instructor continued to circulate the room, observing student progress, offering suggestions and answering questions. Building on the Google searching experience, students learned to adapt to a new way of finding information in academic databases. For example, student searches demonstrated how a known title or author search in an academic database can lead them to the scholarly article referenced in the news media report. Likewise students discovered a subject search in an academic database delivered an organized list of relevant results, whereas Google results were ordered based on different criteria. Students were able to conceptually understand that search results in Google and proprietary databases are structured differently and that the proprietary databases offer accessible refining options based on specific record fields.

While the third activity was given a generous time limit, students with especially challenging research topics needed more time than the library session allowed to locate potentially useful scholarly articles. However, all students left the library lab equipped with the skills necessary to continue their search. When asked how they would proceed with their research after the library lab, students commented that they felt more confident in their abilities to use the academic databases explored in the library lab for future literature searches.

Outcomes

Student competencies of IL learning outcomes were assessed by observing students interact with the library lab activities, engaging students in class discussion, and reviewing student work, as described in Table 1. Table 5 displays a qualitative summary of the student competencies observed during library lab activities two (Google search for popular science news reports) and three (locating original scientific literature in proprietary databases). The competency levels in Table 5 are divided into two categories: 1) low to medium and 2) medium to high. The low to medium category suggests students showed little knowledge of the IL skills addressed and required more instruction. The medium to high competency category suggests students showed a higher command and understanding of the IL skills and concepts addressed in the library lab. The indicators should be understood as falling within a spectrum where low competency means the majority of student achievement was weaker and inconsistent, and high competency means the majority of student achievement was stronger and more consistent. The conclusions of the library lab's reflection exercise from activity one are omitted from Table 5 because of the activity's introspective nature.

Considering the outcomes of the library lab, students would benefit from more instruction on identifying citation information in popular science news reports and locating original published scholarly articles in proprietary databases. However, students enjoyed the process of discovering popular science news reports on the Web and commented that they were interested to learn how chemistry is discussed in popular media. Students also liked the process of linking

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popular science news reports to the original scientific research, even though the task was challenging. By the end of the library lab session, students indicated they understood the importance of reviewing multiple sources to compare scientific claims and ideas. Students also finished the library lab with a strategic plan to continue their research and complete the assignment.

Table 5. Student Competencies of IL Learning Outcomes Observed through Student Interaction with Class Activities and Class Discussion

	Students indicated low to medium competency throughout the activity.	***Students indicated medium to high competency throughout the activity.***
Activity Two: Google searching and locating popular science news reports	Student weaknesses during the library activities: Locate a Website's "About" section to learn more about a site's purpose. Locate background information about popular science news authors. Identify citation information for the original research referenced in popular science news reports. Evaluate Web sources based on authority, purpose, and reliability.	Student strengths during the library activities: Identify URL domain type and purpose: .com, .edu, .org, etc. Read Google results and identify domain types within results list. Understand general characteristics of information types found on the Web: blogs, news reports, political sites, educational sites, etc.
Activity Three: Locating original scientific research in academic databases	Student weaknesses during the library activities: Use citation information to search for primary scientific literature in proprietary databases. Understand that research is inquiry and searching is strategic exploration.	Student strengths during the library activities: Understand Google and proprietary databases are uniquely structured. Understand the value of proprietary databases for finding primary scientific literature.

Final average grades for the assignment, *Analyzing Media Reports of Scientific Research* were in the B+ range. Prior to this assignment and library instruction redesign, final average grades from the previous academic term were in the B range. The increase in average grade cannot be solely attributed to the library session or to the fact that the assignment instructions were more directed. Other variables contributing to student final grades and competencies for this assignment

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included the chemistry instructor spending more time in class discussing NOS tenets, providing students a sample paper as a guide for their final, and distributing detailed grading rubrics for the assignment.

Formal assessments of similar projects are needed to evaluate: (1) students' actual or perceived competencies in their understanding of chemistry in science media and their everyday lives; (2) students' actual or perceived gains in skillset using Google, federated search tools and proprietary databases; and (3) students' actual or perceived gains in ability to evaluate and interpret chemistry information. Formal assessment outcomes can be used to strengthen chemistry and information literacy among undergraduates, as well as spotlight the benefits of librarian and chemistry faculty collaborative efforts.

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Conclusion

This project suggests that using popular media as a tool for helping undergraduate science and non-science majors develop chemistry and information literacy is effective. A key component to this success is the librarian and chemistry faculty collaboration. The literature describes how popular science news reports can help students make a personal connection to scientific concepts, which can strengthen science literacy. The activities used in the library lab build on this knowledge and provide a means for undergraduate students to learn how original scientific research is displayed in popular science news media.

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The author would like to thank Seattle University chemistry instructor, Andrea Verdan, for her collaboration on integrating information literacy instruction into *Chemistry for the Informed Citizen* and for crafting the assignment *Analyzing Media Reports of Scientific Research*. The information literacy instruction discussed in this chapter was completed during Myra Waddell's employment at Seattle University. Waddell is currently an instruction and research support librarian and liaison librarian to the School of Ocean and Earth Science and Technology, and the College of Engineering at the University of Hawai'i at Mānoa.

References

1. Seattle University. *University Core Curriculum*; https://www.seattleu.edu/core/the-curriculum/ (accessed June 6, 2016).
2. Borda, E. *Chemistry for the Informed Citizen: A Constructivist Curriculum for Non-Majors' Chemistry*; Presented at the Meeting of NSF-CCLI/TUES Principal Investigators, Washington, D.C., Jan 2013.
3. ACRL. *Information Literacy Competency Standards for Higher Education*; http://www.ala.org/acrl/standards/informationliteracycompetency (accessed Mar 17, 2016).

4. ACRL. *Information Literacy Standards for Science and Engineering/Technology*; *http://www.ala.org/acrl/standards/infolitscitech* (accessed Mar 10, 2016).
5. Holden, I. I. Science Literacy and Lifelong Learning in the Classroom: A Measure of Attitudes among University Students. *J. Libr. Adm.* **2010**, *50*, 265–282.
6. Oh, J.; Starkey, A.; Kissick, B. Fostering Students to be Lifelong Learners with Science Literacy, Information Fluency, and Communication Skills. Proceedings of the ASEE 2007 Annual Conference and Exposition, Honolulu, HI, June 24−27, 2007.
7. Brown, C.; Krumholz, L. R. Integrating Information Literacy into the Science Curriculum. *Coll. Res. Libr.* **2002**, *63*, 111–123.
8. Bruehl, M.; Pan, D.; Ferrer-Vinent, I. J. Demystifying the Chemistry Literature: Building Information Literacy in First-Year Chemistry Students through Student-Centered Learning and Experiment Design. *J. Chem. Educ.* **2015**, *92*, 52–57.
9. Gross, E. M. Green Chemistry and Sustainability: An Undergraduate Course for Science and Nonscience Majors. *J. Chem. Educ.* **2013**, *90*, 429–431.
10. Majetic, C.; Pellegrino, C. When Science and Information Literacy Meet: An Approach to Exploring the Sources of Science News with Non-Science Majors. *Coll. Teach.* **2014**, *62*, 107–112.
11. Murcia, K. Science in the News: An Evaluation of Students' Scientific Literacy. *Teach. Sci.: J. Aust. Sci. Teach. Assoc.* **2009**, *55*, 40–45.
12. McGuinness, C. What Faculty Think-Exploring the Barriers to Information Literacy Development in Undergraduate Education. *J. Acad. Libr.* **2006**, *32*, 573–582.
13. Cakmakci, G.; Yalaki, Y. Popular Media as a Tool for Teaching Science and Its Nature. In *Promoting Student Teachers' Ideas about Nature of Science through Popular Media*; S-TEAM/NTNU: Trondheim, Norway, 2012; pp 1−14.
14. ACRL. *Framework for Information Literacy for Higher Education*; 2015; http://www.ala.org/acrl/sites/ala.org.acrl/files/content/issues/infolit/Framework_ILHE.pdf (accessed Nov 17, 2015).
15. Domin, D. S. Integrating the Nature of Science into Content-based Science Courses. In *Chemical Education*; Ladage, S., Samant, S. D., Eds; Proceedings of the First International Conference on Education in Chemistry, Mumbai, India, Nov 12−14, 2010; Narosa Publishing House: New Delhi, India, 2012; pp 17−25.
16. Fast, K. V.; Campbell, D. G. "I Still Like Google": University Student Perceptions of Searching OPACs and the Web. *Proc. Am. Soc. Inf. Sci. Technol.* **2004**, *41*, 138–146.
17. Wilkes, J.; Gurney, L. J. Perceptions and Applications of Information Literacy by First Year Applied Scientific Students. *Aust. Acad. Res. Libr.* **2009**, *40*, 159–171.
18. Georgas, H. Google vs. the Library (Part II): Student Search Patterns and Behaviors when Using Google and a Federated Search Tool. *Portal: Libr. Acad.* **2014**, *14*, 503–532.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch011

19. Pankl, E.; Coleman, J. “There’s Nothing on My Topic!” Using the Theories of Oscar Wilde and Henry Giroux to Develop Pedagogy for Library Instruction. In *Critical Library Instruction: Theories and Methods*; Accardi, M., Drabinski, E., Kumbier, A., Eds.; Library Juice Press: Duluth, MN, 2010; pp 3−12.
20. Waddell, M. *Excerpt from class handout*; Seattle University: Seattle, WA, 2015.

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Chapter 12

Teaching Climate Change Concepts and the Nature of Science: A Library Activity To Identify Sources of Climate Change Misconceptions

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A library activity was developed in which students found information about climate science misconceptions from popular and scientific literatures. As part of the activity, students developed a rubric to evaluate the credibility and type of literature sources they found. The activity prepared students to produce an annotated bibliography of articles, which they then used to create a training document about a climate science misconception for staff at a local science center. Evaluation of annotated bibliographies showed that students were able to distinguish between popular and scholarly literature but struggled to identify primary and secondary sources within the scholarly literature. In the training documents produced four weeks later, students retained information literacy skills and demonstrated aspects of scientific literacy, using language that addressed common barriers to scientific literacy such as the idea of scientific consensus. In self-assessments, students felt that they could identify and evaluate information resources related to climate science.

Introduction

In May 2013, a news article titled, "Dinosaurs 'gassed' themselves to extinction, British scientists say," appeared in social media posts (*1*). The news article, from a prominent American media organization, suggested that plant-eating dinosaurs might have caused their own demise by producing clouds of methane, a greenhouse gas, which increased the global temperature and led to catastrophic climate change (*2*). The news article referenced a journal article from *Current Biology*, so the authors of this chapter, a librarian and a chemist, accessed the original article to learn more (*3*). The journal article that attracted national coverage was two pages in length, contained only estimates of calculations, and was written by two biologists with little experience in climate science. The news article did not summarize a peer-reviewed research article, but distorted information from a letter published in the "Correspondence" section of a scientific journal. The author of the news article either misinterpreted the information presented by the scientists, or approached the reporting with deliberate bias. Either way, it is unlikely that casual readers, even those critical of the news story, would have located the original source to evaluate it and discover its context and content.

This news article about dinosaurs, and the work required to interpret the information behind it, inspired the authors of this chapter to design a new project for students in a course on the chemistry of climate change. Working together on the project led the instructors to explore the idea of improving scientific literacy and information literacy simultaneously by helping students overcome common barriers to these two inter-related types of literacy.

Scientific and Information Literacy

Scientists and the general public alike are bombarded with scientific information from a variety of sources. Interpreting this information requires some degree of scientific literacy. As such, improving scientific literacy is widely recognized as an important goal for K-12, post-secondary, and informal education in the United States (*4–7*). An important aspect of scientific literacy is the ability to understand the nature of science: what science is, and how it is conducted and communicated (*5*, *8–10*). In order to understand the nature of science, one must apply the core skills of information literacy – discovering and evaluating information and analyzing the context and processes in which the information was created (*11*, *12*). Because information literacy and scientific literacy require some similar skills and cognitive abilities, integrating these literacies in class activities may be both efficient and meaningful.

Barriers To Accessing and Understanding Science Information

When readers approach scientific writing, they require skills in information literacy and scientific literacy. At a basic level, people need to understand the difference between popular and scientific literatures, but they also need to differentiate between primary and secondary sources in the scientific literature, determine the skill and training of authors who wrote the information, and identify whether data and/or opinions are expressed in an article. Even with these skills, it may be difficult for readers to access science articles due to their publication in academic journals with a high subscription cost. Finally, even readers with easy access to science articles and the necessary information literacy skills to evaluate them may still encounter barriers to understanding the scientific knowledge under discussion, including how scientists process that knowledge.

Sinatra, Kienhues, and Hofer describe three main challenges to public understanding of science: difficulty in understanding the process of scientific reasoning, misconceptions about the science, and unconscious biases (*9*). Difficulties in understanding the process of scientific reasoning arise when non-scientists are unprepared to handle knowledge conflicts (epistemic knowledge) and/or they are more likely to be persuaded by arguments that appeal to self (personal pleas) rather than logic. In the context of climate change, the current scientific consensus is that climate change is caused by human-induced increases in atmospheric carbon dioxide, but cognitive conflict may arise when readers find alternate explanations. Arrhenius first proposed the link between global temperature and atmospheric carbon dioxide in the 1700s, but since then, other scientists argued that the earth's tilt, solar radiation, and volcanic dust have a greater effect on atmospheric temperatures than carbon dioxide (*13*). Even today, a few leading scientists disagree with the consensus that carbon dioxide is the primary cause of climate change (*14*). Most scientists understand the way that scientific consensus changes over time, and recognize the various knowledge conflicts in this process, but non-scientists may find it difficult to reconcile these competing arguments, especially when they appear in scientific journals. As such, the Yale Program on Climate Communication considers public misunderstanding of scientific consensus to be a "gateway belief" that may prevent people from accepting scientific arguments for climate change (*15*).

The second barrier to public understanding of science relates to misconceptions about the science. Non-scientists reading about climate change may hold misconceptions about the science, which leads to confusion or misunderstanding. For example, many Americans erroneously believe that the ozone hole contributes to global warming (74% of American adults surveyed in 2010, according to one study) (*7*). This misconception, which conflates two separate concepts that both relate to gases in the Earth's atmosphere, may lead to the idea that Earth's temperature is increasing because the ozone hole allows more heat from the sun into the planet's atmosphere (*16*). The ozone hole misconception could also lead people to believe that increasing atmospheric gasses may 'plug' the hole in the atmosphere and prevent further warming (*17*). Misconceptions about important science concepts, such as these, may prevent students from interpreting information correctly or using appropriate search terms to find credible resources on complex scientific issues such as climate change.

Learning about science topics can also be hindered by the third challenge to public understanding of science, unconscious bias towards previous ideas/knowledge. Scientists and non-scientists alike may be motivated to find

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information that fits their world view. This type of bias, conscious or unconscious, is defined as motivated reasoning. For example, a person who believes that vaccinations cause autism may find information that disproves their belief, but they may be more likely to select and read articles that reinforce their beliefs. This bias in information selection may exist even if the science in the article with which they agree is not as strong as the science in the article that disproves their belief. Multiple studies have linked motivated reasoning and rejection of climate science, illustrating how individuals' experiences and world views can influence what they believe about scientific information, or what information they choose to seek out and consume (*18–21*).

Educators use many approaches to overcome these barriers that students face when trying to understanding science, including focusing on information literacy. Carefully constructed information literacy assignments can lead to improved scientific literacy in both those information literacy assignments and in later assignments (*22–28*). Educational psychologists have shown that directing students to review the structure and source of a scientific text can improve understanding of scientific information (*29*). In a non-major science class, students who were taught how to evaluate the reliability of sources of scientific information about Mt. St. Helens improved their ability to use online resources to find credible scientific information about other topics, including controversial topics (*22*). Students who were instructed to find retracted publications also developed deeper understanding about the ethics associated with science (*26*). When dealing with controversial topics like climate change, students may experience great difficulty in overcoming the barriers to understanding science. Therefore, it has been suggested that students should read articles explaining multiple sides of an argument so that they encounter the misconception and scientifically correct concept simultaneously (*27*, *30–32*). In summary, multiple studies show that assignments can succeed in helping students overcome barriers to learning science by asking students to develop conceptual models of the source and type of scientific information and then providing opportunity to use those models to investigate other scientific topics.

This chapter builds on prior work by describing how information literacy and scientific literacy skills were developed in a chemistry class that focused on climate change. The assignment that the authors designed for the class utilized best practices for developing scientific and information literacy. Students developed a rubric (mental model) to differentiate between different article types, which they then used to identify specific articles for an annotated bibliography. Students then worked in groups to produce a training document about a climate science misconception for staff at a local science center. Assignments were carefully structured to address barriers to understanding science by asking students to determine the source and type of information, acknowledge biases that may have been present in the information, and discuss how the misconception may have come from misunderstandings of the scientific literature. The project described in this chapter focuses on the chemistry of climate change, as it was the focus of this particular course. However, the general principles discussed here can be extended to other topics.

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Course Description

Climate Change: Chemistry and Controversy was a five-credit course (quarter system) developed for non-science majors at a private comprehensive university. This 10-week-long course, described previously (*33*), served 16 first-year (freshman) students. The goal of the course was to help students evaluate and communicate climate change misconceptions through development of foundational content knowledge in climate science concepts, development of critical thinking skills, understanding of the nature of science, and application of their skills to a service project. Throughout the course, students learned the chemistry behind climate science and were provided opportunities to learn how climate science data were produced and published. The course utilized outcome-based design, which meant that each outcome was paired with course activities and assessments (*34*, *35*). The course had several learning outcomes but two outcomes were specifically related to information literacy. The relevant outcomes were:

Upon successful completion of this course, students will be able to:

(1) evaluate the reliability and interpretation of data from various sources to analyze the impact of climate change on society.
(2) locate scientific information from a range of paper-based and online sources.

In order to meet these goals, students participated in two course activities: a session with the science librarian culminating in the submission of an annotated bibliography and a group project to produce a training document that discussed a climate change myth for staff at a local science center. The final training document had to include a variety of references, including a source exemplifying the climate change myth. Students worked on the project for 6 weeks. Two two-hour class periods were dedicated to the project; one for the library activity and one for peer review of the project. Prompts for the annotated bibliography and final project are provided in Table 1. The rubrics used to evaluate the annotated bibliography and training document are included at the end of this chapter.

Library Activity

The library activity took place four weeks into the academic term, a little less than halfway into the academic quarter, prior to the first exam. The placement of the activity was such that students had a basic understanding of climate and chemical concepts before starting their literature research. The library activity consisted of three parts: (1) creating a rubric to distinguish between types of literatures, (2) using the rubric to assess and categorize articles, and (3) creating an annotated bibliography of articles for the final project. Before the library session, the professor had provided a list of climate change misconceptions derived from a list at SkepticalScience.org (*36*). Students had been assigned to form groups, select a climate change misconception, and prepare to find information related to the misconception.

The guided inquiry session, designed by the librarian and the professor, had the following goals:

At the end of the library session, students will be able to:

- Distinguish between articles from the scientific literature and those from the popular literature.
- Articulate the main difference between subscription databases and other search tools for the open web.
- Find the subscription databases on the library web site.
- Search for and locate articles in a subscription database.

Table 1. Example Prompts for the Annotated Bibliography and Final Paper

Annotated Bibliography	Your objective is to identify at least one source of your assigned misconception (newspaper, TV show, government document, senate hearing, internet meme, journal article, etc.) and then explore the scholarly literature on the topic. When possible, identify the earliest source of the misconception and if you can, explain why it was made (incorrect interpretation of data, blatant misstating of data, something that was later disproved due to better instruments). You also need to find 3 peer-reviewed articles with data that disprove the misconception.
Final Project	Each group will prepare a document for staff at the science center. You will be evaluated based on your ability to: • identify climate change misconceptions • identify and use peer-reviewed data to disprove misconceptions • explain information that portrays the science correctly without oversimplifying or using overly complex language. • portray certainty/uncertainty in data. • propose ways of overcoming the misconception without being preachy. • write clearly and succinctly. The final draft should have 5-10 scholarly sources.

Library Activity Part 1: Students Create a Rubric To Distinguish between Literatures

As a preparatory activity prior to the library session, the librarian and professor asked the students to examine, compare, and contrast three articles and determine distinguishing characteristics of each. The three articles were:

- “Dinosaurs ‘gassed’ themselves into extinction, British scientists say (*1*)”
- “Could methane produced by sauropod dinosaurs have helped drive Mesozoic climate warmth (*3*)?”
- “Enhanced chemistry-climate feedbacks in past greenhouse worlds (*37*)”

At the start of the 2-hour session, students were divided into groups and given the task of collaboratively examining the articles, building on the analysis they had done as homework. Without receiving prior instruction about evaluating information or distinguishing between popular and scholarly literatures, groups of students were asked to look for differences and similarities in the articles. They were told that one or more of the articles were "popular" and one or more were "scholarly" or "scientific," and instructed to work in small groups to develop a draft list of characteristics of scholarly and popular literatures based on the differences in the articles they observed.

Following the group work, the full class discussed the differences observed in the articles, shared their draft lists of characteristics, and compiled them in a shared document visible on a large screen. Class discussion, facilitated by both the faculty member and the librarian, led to a collaboratively-created list of characteristics of scientific/scholarly and popular literatures, such as: audience (is the language aimed at the general public or scientists/experts?), authors (what are the credentials/positions of authors?), design (is the article colorful or text-heavy?), references (does the article have a long list of references, or few, or none?), and more. This discussion led to brief coverage of broader concepts relevant to scholarly communication, such as the peer-review process. The librarian and professor also guided the discussion so that students could learn to distinguish the difference between primary sources within the scientific literature (e.g. research papers) and secondary sources within the scientific literature (e.g. commentaries and review articles). The students were then able to refer to these lists of characteristics, which they developed together (rather than receiving from the instructors), when they were seeking and evaluating articles for their project. The first part of this activity took 35 minutes of the class.

Library Activity Parts 2 and 3: Students Locate and Evaluate Information Resources on Climate Change

The first product required for the course's final project was an annotated bibliography of resources about their selected climate change misconception. Following the group activity, the librarian provided a brief overview of starting points for discovering resources for their annotated bibliography. These starting points included tools on the open web, such as a site for searching television news transcripts (TV News Archive: https://archive.org/details/tv), as well as library resources, such as a subscription database that includes science articles, news articles, and more. Rather than demonstrating all of the database's features, she explained that they could construct their own understanding of the database by exploring it themselves, in small groups, and with help from the instructor as needed. Students working on similar misconceptions could work together to find appropriate resources but had to cite different resources.

For the remainder of the session (about 1.5 hours), students were given time to search for articles for their annotated bibliography, with the professor available to answer questions. Before leaving the session, students were required to find sources from the popular literature exemplifying their selected climate change misconception, as well as sources from the scientific literature providing

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evidence related to their misconception. As part of the activity, students were instructed to evaluate the credibility of all the literature sources they found, by determining if sources were written by expert scientists, contained real scientific data, and were written for a scientific audience. These criteria linked to the characteristics/qualities of scientific and popular literatures that the class had developed together at the start of the session. The activity prepared each group to produce an annotated bibliography of articles, which they then used to create a training document educating science center staff on the science behind a common climate change misconception.

Results: Student Work and Evaluations

We evaluated student attainment of the course's information literacy goals by looking at three types of evidence: student responses to the annotated bibliography assignment, resources used in the final project, and student self-assessment of learning. The results from each of these are described below. Evaluations described below are independent of the rubrics provided in the appendix. The data presented below are anonymized so that students can not be identified. This work was granted exemption from the university's Institutional Review Board (IRB).

Evaluation of Annotated Bibliographies

Students submitted their annotated bibliographies electronically one week after the library session. After grading the assignment, the instructor then anonymized the bibliographies and shared them with the librarian for evaluation. The librarian evaluated the bibliographies to determine whether students could correctly identify sources from the popular literature and scientific literature, as well as primary sources within the scientific/scholarly literature. The results listed below are from the librarian evaluation. The instructor grade was not known to the librarian and did not influence the evaluation described below.

The purpose of the annotated bibliography was to determine if the students could find and identify the types of information resources needed to complete their final project. In order to complete the assignment successfully, students needed to apply the skills they learned in the library activity. Each person was asked to find a minimum of three articles related to their climate change misconception: at least one article exemplifying the misconception in the popular media, and at least two research papers, or primary sources from the scholarly literature, that provided evidence related to the misconception. Students were asked to provide a brief description of the source that addressed the following questions.

- How do you know this is a credible source?
- How is the content of this article relevant to your topic?
- How do you expect to utilize the information in this article?
- Describe anything else that you think is interesting.

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Results from the librarian's evaluation of annotated bibliographies are shown in Figure 1. In the annotated bibliographies, 100% of students (16) identified sources from the popular literature correctly. Over 80% of students (13) could identify sources from scholarly/peer-reviewed literature. Students struggled to identify primary sources within the scholarly literature, with only 69% of students identifying one primary source and 38% of students identifying two primary sources correctly.

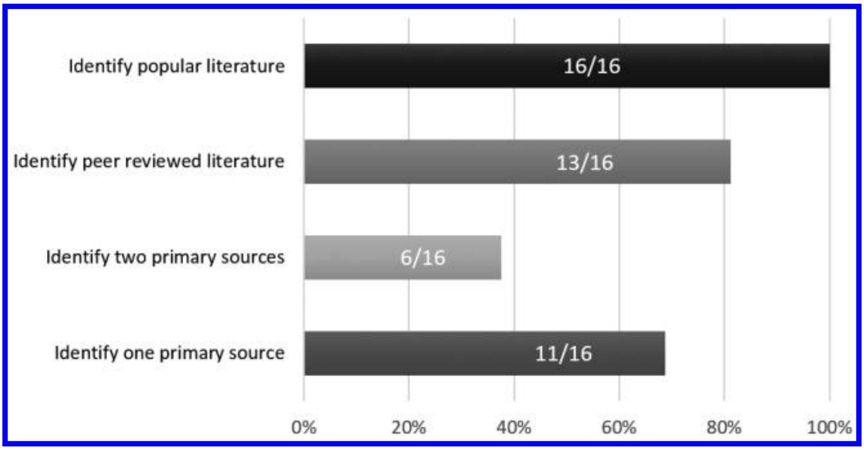

Figure 1. Percent of students able to correctly identify sources from the popular literature and the scholarly literature, directly after the library activity.

Students examined a variety of evidence to analyze their articles, but most of their evidence focused on three main points: whether the journal was peer-reviewed, the expertise of the people who performed the research described in the article, and whether the expertise of the author matched the content of the article. Here is an example from a student describing the identification of a peer-reviewed article.

> "This article is trustworthy because it is from the peer reviewed scientific publisher Journal of Climate, part of the American Meteorological Society. The authors are affiliated with climate and environmental physics, astrophysics, earth and ocean sciences, and research focusing on climate change. These qualifications would enable them to be well-versed in the area of climate change, temperature increase, and the causes and effects of these and the ramifications they imply for the future."

This response suggests that the student understood two issues covered in the library session: the concept of peer review and the critical evaluation of author expertise/authority with respect to the content of the source.

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The students who were unable to correctly identify sources from the scholarly literature made two types of errors. One confused an editorial in a peer-reviewed journal with a peer-reviewed article; the other believed an article from a trade magazine was a peer-reviewed article from the scientific literature.

The first student provided reasoning that demonstrated awareness of peer review but failed to distinguish between editorials and research articles:

> "This article is credible because it comes from the academic journal, Pediatrics, which has been peer reviewed. Pediatrics is published by the American Academy of Pediatrics, and the article has listed its contributors."

In contrast to the first student quoted, this student neglected to check that the credentials of the author matched the context of the article. Additionally, the student did not analyze the structure or genre of the article. In this case, the journal is considered part of the scholarly literature because its research articles are written by scientists and are peer reviewed, but the editorial/commentary was not peer-reviewed, so it is not considered a scholarly source, which the student did not understand. The library session had covered the presence of non-peer-reviewed articles (such as editorials) in scholarly journals, but this student was not able to recognize such an article. This oversight indicates a lack of understanding of the concept that "authority is constructed and contextual," as described in the *Framework for Information Literacy in Higher Education* (*38*). Even though the article is written by an expert in the field and is in a peer-reviewed journal, most scientists (including this course's instructor) would judge this article less authoritative than a research article, based on its context as an editorial. The student's error is similar to the error made by the journalist who wrote the news article claiming that methane-producing dinosaurs could have caused global warming.

Another student who incorrectly identified a scholarly article assumed that a trade journal, *Hydrocarbon Processing*, was part of the scholarly, peer-reviewed literature:

> "I believe that this article is credible on the grounds that it was published relatively recent, 2009. It was peer reviewed twice by Chemical Engineering Progress. Some background research on the Chemical Engineering Progress shows that it is the world's leading organization for chemical engineering professionals in over 90 countries and has a credible monthly magazine published."

The student states that the article was peer reviewed by *Chemical Engineering Progress*. However, *Chemical Engineering Progress* is a trade magazine, which typically does not publish peer-reviewed research articles. Additionally, the student does not correctly identify the source of the article, *Hydrocarbon Processing*, which is a trade magazine for the petrochemical industry, similar to *Chemical and Engineering News* for chemists (*39*). To a non-scientist, a trade magazine may appear similar to a scientific journal because both contain

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technical information and significant amounts of jargon. However, it is likely that this student did not look at the magazine or take the time to read the full article, as they did not provide a date of the publication and they recorded an incorrect name of the article. The library session had not covered trade magazines and how they differ from scientific journals or popular magazines. This student's error suggested a point of improvement for future library session lesson plans.

Overall, the annotated bibliography assignment showed that students could identify and apply the criteria necessary to distinguish between scientific and popular literature. However, some students still struggled to apply all criteria with articles placed in an unexpected context, as exemplified by the choice of an editorial in a science journal or a jargon-filled article in a trade magazine.

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Evaluation of Science and Information Literacy in the Final Project

After the library session and annotated bibliography, students worked in groups of four to create an informative paper of two to three pages aimed at helping a science interpreter at the Pacific Science Center in Seattle respond to a frequently encountered misconception about global warming. Information literacy goals were explicitly part of the final assignment: students needed to identify at least 4-5 sources for their paper, including peer-reviewed articles with data directly related to the misconception. Before evaluation by the professor, the document was reviewed by students in the class and by staff at the science center.

For the quarter described in this chapter, students investigated four climate science misconceptions:

- Global warming is caused by the hole in the ozone layer.
- Carbon dioxide is not the most potent greenhouse gas, so there is no need to regulate it.
- Venus is also warming, so our planet is warming due to increased solar output.
- Human contribution to carbon dioxide is tiny, thus we cannot be the cause of increased levels of this gas.

Because students worked in groups of four, it is not possible to describe specific student performance. However, it is possible to determine if groups demonstrated an understanding of information and/or scientific literacy.

In their final projects, students provided narratives that directly discussed the three barriers to understanding science information discussed by Sinatra, et al.: scientific reasoning, misconceptions, and motivated reasoning (*9*). All projects discussed the idea of scientific consensus, but two groups specifically discussed ways in which uncertainty in scientific information can be misreported in the media. One such example is from the group researching human contributions to carbon dioxide:

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> "Misunderstandings in the general public regarding human contributions to carbon dioxide (CO_2) in the atmosphere have often resulted from scientific arguments. One such example was an article appearing in Forbes which claimed that human carbon emissions only accounted for ".9 of 1 percent" of the greenhouse effect (Hendrickson). Some scientists, particularly those whose primary focus of study is not on climatology or a related field, focus on data that they have heard before instead of the findings of more recent studies. For instance, many scientists refute the claim that mankind's burning of fossil fuels is impacting the climate by arguing that there have been temperature fluctuations long before humans were emitting CO_2 into the atmosphere. Articles appearing in scientific publications have made additional claims that the "average temperature has remained roughly level globally" while also acknowledging that human carbon emissions have increased in the last century (Paterson). While articles such as these [Forbes article] reference multiple scientific articles, they fail to address the science behind current trends. The media will often then misinterpret arguments such as this and accept them as truth, failing to provide data to support their claims."

One group provided a nuanced explanation of how misconceptions and motivated reasoning influence scientific understanding. In particular, this group discussed how skeptics can select specific studies in ways that contradict the general scientific consensus:

> "When encountering this misconception, it is important to note that much of the confusion is rooted in scientific errors that are often difficult to understand. Take the following graph from The Washington Times for example. In their article Global-warming fanatics take note; sunspots do impact climate, the misconception of the sun effecting climate change is supported by what seems like a well put together graph. However, if we look deeply into the sources of this data, we find that the entire study is called into question, as all the data reported came from locations about the poles of the earth. Basic scientific errors or biases are not taken into account, and it creates data that does not represent an overall trend.... there have been many studies taken using nearly the same techniques and the same instruments, but with unbiased methods that take the entirety of the earth's climate into consideration, show a very unrelated trend."

Other groups did not use specific language that demonstrated scientific or information literacy. However, in reflection papers assigned outside of the course, most students described ways in which they recognized unconscious bias, corrected their own misconceptions, or understood the process of scientific reasoning (*33*). Additionally, student groups used language in their final documents that described the iterative process of scientific reasoning (such as the CO_2 example above) and ways in which unconscious biases and motivated reasoning lead to articles that contradict scientific consensus (such as the sunspots example above). Finally, in their projects, students provided a wide number of resources, both popular and scientific, showing that as a group, they could find and evaluate different types of information resources about climate science topics.

Student Self-Evaluation of Information Literacy Outcomes

At the end of the course, students self-reported how well they met the information literacy outcomes of the course. The data are reported in Figure 2. Overwhelmingly, students felt that they met the two learning outcomes: the ability to locate scientific information from a variety of sources and the ability to evaluate reliability of data related to climate change. Only one student felt that they had not met the outcome, stating, *"For locating scientific information, we only focused on that for a very short period of time and I only used one source when actually looking."* As the survey was anonymous, we can only speculate that this student was unable to locate a wide range of sources and thus scored low on the annotated bibliography.

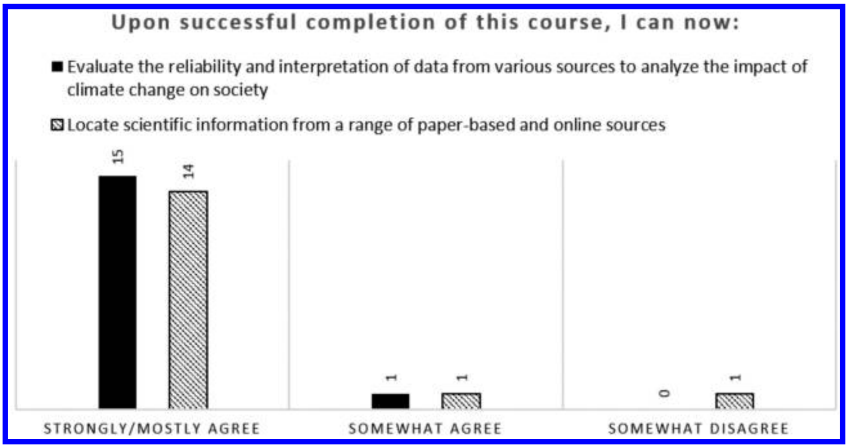

Figure 2. Student evaluations of information literacy outcomes. (Survey data was collected on the last day of class using a 6-point Likert scale. The survey was issued one week after the final project due date, before students had received scores on their final project. The numbers above each column indicate the number of students who selected the option.)

Discussion: Integrating Science and Information Literacy

The data presented in this chapter suggest that science assignments incorporating information literacy learning outcomes can help students overcome a key barrier to scientific literacy — the difficulty in understanding scientific reasoning and the related assumption that scientific knowledge is certain.

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Assignments that ask students to consider the evolving nature and limitations of scientific truth (*40*) and help them overcome other common barriers to understanding science (*9*, *41–43*) are necessary if students are to learn how to interpret scientific information.

The assignment described in this chapter approaches these barriers to understanding science in several ways. First, the assignment and library activity utilize a learning cycle approach, which reflects the nature of science and scientific reasoning with an emphasis on process, exploration, and discovery. This learning cycle approach, which has been shown to work effectively in many academic settings (*44*, *45*), includes phases of exploration, concept development, and application. Approaching teaching and learning in this way also reflects the information literacy threshold concept of "research as inquiry," especially the idea that the research process may include "points of disagreement where debate and dialogue work to deepen the conversations around knowledge (*38*)."

By working with the chemist author on this chapter, the librarian leading the information literacy sessions incorporated this learning cycle approach, which engaged the students in exploration at the start of the activity. This approach contrasted with some of the previous information literacy sessions led by the same librarian, in which the instructional approach was more traditional, with students receiving a short lecture on scholarly and popular literatures before applying that information in an activity. With this focus on "research as inquiry" and an emphasis on the nature of science, the librarian and chemist designed the library activity to allow the students to construct and refine their own understanding of evaluating sources, and then provided opportunities to practice applying these concepts in multiple assignments, iteratively building up to the final project (*46*). This learning cycle approach seemed successful, as all students seemed engaged during the activity in class and the majority of students were able to correctly identify the types of information required for the annotated bibliography assignment. Students also retained these skills in the final project four weeks later.

Assignments like the one described in this chapter can also help address misconceptions about science content, another barrier to understanding science. Educational researchers have suggested that the process of correcting misconceptions can be more difficult than learning concepts for the first time because students must break connections with old concepts before learning new concepts (*27*, *47*, *48*).

In an attempt to help students work through the difficult process of un-learning misconceptions, this activity asked students to identify and analyze contradictory sources, which has been shown to lead to conceptual change (*33*). Some of these sources upheld the climate change misconception, and others refuted it. In the final documents, all groups were able to provide both a popular source that described the misconception and a scientific source which related to the misconception. In addition, the majority of students also reported an ability to evaluate the reliability and interpretation of data from climate sources (Figure 2), suggesting that students believed that they were able to use these information literacy skills to critically approach misconceptions present in the sources they consulted. One student discussed misconceptions in her reflection, stating,

> "This class really opened my eyes to everything about global warming and how important it is to our future to correct misconceptions on global warming and learn the true facts before its [sic] too late."

By working with these contradictory sources, students focused on the misconception as well as the credible scientific information, rather than just ignoring the misconception. Confronting these sources also helped students learn about the complexities of research as an iterative process that may include contradictory findings. During class, the instructor often pointed out the uncertainty in climate change data and the process of scientific consensus building over time. The final documents that students produced suggested that they understood some of this process, and two groups explicitly discussed the role of scientific consensus in understanding these misconceptions.

Reflection and Authentic Audience as Motivators for Conceptual Change

According to Sinatra and Danielson, "strong emotional reactions may be produced when prior knowledge, beliefs, and identity conflict with new information (*49*)." They also argue that emotions may be heightened when discussing global challenges such as climate change, stating that "even students who understand and accept... climate change may find these ideas disheartening (*49*)." Thus when encouraging students to seek out sources of information that conflict with each other and perhaps even conflict with the students' assumptions about science or worldviews, instructors should consider ways to help students acknowledge and explore their own biases in a low-stakes way. Reflection papers and journaling can be effective in helping students deal with biases that are emotionally charged (*50*).

In this course, students were asked to provide four short reflections (each 2 to 3 paragraphs long) through an informal blog to other students in the class (*33*). In these reflections, students provided evidence that they were encountering their biases and beliefs during the course. This was particularly evident in one reflection from a student:

> "I distinctly remember during a presentation in my government class last year ... [where a government official] stated that her party did not even believe that global warming was happening, let alone that it was an issue that needed to be dealt with. Although I found that to be shocking, I disregarded the statement …[Now]… I can no longer dismiss this statement. Because climate change is a global issue, the government must intervene in order for change to happen (*33*)."

This student mentioned a specific instance where her prior experience (high school class) was contradicted by her college experience. By noting the discrepancy between these experiences, she recognized how information provided in the prior experiences may have been biased.

Motivated reasoning, or bias (whether conscious or unconscious), has been described as another major challenge to learning science (*18–20*). Teachers can avoid potentially singling out one "biased student" by designing assignments that require all students to identify articles that contradict the scientific consensus. This assignment required students to search for and evaluate multiple types of information, including articles whose arguments or data directly contradict each other, as discussed above. Engaging in this type of searching may teach students about the bias inherent in the search for information. In a reflection post one student provided an excellent description of bias in selecting sources:

> "As we have seen in class, scientists use different types of graphs and data to show the public what they "want" them to see and find ways to hide the ones that could be hurtful to their research/hypothesis. It is extremely important when doing scientific research to look at many different articles and at how valid/official they are before forming a final conclusion (*33*)."

Reflections such as this one, with its mention of "valid/official" with respect to articles, suggest that students not only learned about bias in searching, but they were able to connect the idea of bias and scientific authority. This comment about validity of sources connects to the information literacy threshold concept that "authority is constructed and contextual (*38*)."

To help motivate the students to do the intellectual work required to overcome common barriers to learning new science, the instructor decided to provide an authentic audience for the students' final projects. All of the student groups' final documents were provided to staff at the Pacific Science Center. The projects were to be used to train staff in further educating patrons about climate change misconceptions. Student comments on course evaluations suggested that the authentic audience was indeed a motivating factor. One student said, "Feeling I had a real impact on people's perceptions just motivated me to address this topic to a greater extent (*33*)." Staff at the science center found the documents interesting, but ultimately decided not to use the documents for training, because they were too dense with information. In future iterations of this course, we propose that students focus more on communicating this information effectively to an identified audience beyond the instructor or the classmates.

Conclusion

A general goal of information literacy instruction is to equip students with "the critical skills necessary to become independent lifelong learners (*12*)." Non-scientists reading scientific information or popular source summaries of scientific information, such as the dinosaur article that launched this project, may be able to better encounter and understand such information throughout their lives if they possess basic skills in information literacy, including the ability to evaluate information and to understand the context in which the information was created. Projects like the one described in this chapter can help achieve both scientific and information literacy goals in ways that are meaningful to non-science majors. Additionally, teaching the “nature of science - that is, what science is, how it is conducted, and what practices are or are not scientific,” including science communication practices and information literacy, may help educators “improve public understanding and acceptance of science” in important areas such as climate change (*49*). By strategically combining information literacy and scientific literacy exercises, it is possible to successfully equip students with real-world application of these related forms of literacy.

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Appendix – Rubrics

Rubric 1 - Rubric used by instructor to evaluate annotated bibliographies.

Rubric 2 - Rubric used by students to evaluate the work of other students.

Note: Rubrics are provided for pedagogical purposes. These rubrics were not used in the librarian-led evaluation of annotated bibliographies described in this chapter.

Rubric 1 - Rubric used by instructor to evaluate annotated bibliographies

Identify articles from popular sources and Academic Search Complete		
10 9 8	7 6 5 4	3 2 1 0
Meets assignment specs of finding at least one article from popular sources and one article from Academic Search Complete.	Generally meets assignment specs for using popular sources and Academic Search Complete.	Generally fails to meet assignment specs or show ability to use Academic Search complete.
Identify five articles/sources		
10 9 8	7 6 5 4	3 2 1 0
Meets assignments specs of finding at least five articles; one of them from the popular literature, two primary sources, two others.	Generally meets assignments of finding at least 5 articles but many miss one or more of the following; one from popular literature, two primary sources, two others; or incorrectly identifies articles.	Generally fails to meet assignment specs, explain search process, or show ability to use Academic Search complete.
Correct APA format		
10 9 8	7 6 5 4	3 2 1 0
Cites articles correctly using APA style for "Reference" list.	Generally follows APA style but with missing elements or some mistakes in ordering or punctuation of data.	Doesn't follow APA style or provides no references.
Summary of Articles		
20 19 18 17 16	15 14 13 12 11 10	9 8 7 6 5 0
Complete, clear, useful summaries of articles; puts source's argument into writer's own words with minimal quotation; effective analysis of article's usefulness for writer's purpose.	Summaries are satisfactory, but less complete, clear, accurate, balanced, or idea-centered; may be less effective than a 16+ in analyzing each article rhetorically or analyzing its usefulness.	Summaries are too short, vague, or unclear to be useful. Reader can't benefit from writer's research; may be overly thin or not address required components of rhetorical analysis and evaluation of usefulness.

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Rubric 2- Student Peer Review

Misconception #
Names of people reviewing this misconception:

Statement of Misconception

Text.

Professional	Insufficient	Unprofessional
Text is complete and concise. Misconception clearly explained.	Text is wordy or incomplete in some sections. Misconception not explained.	Text is missing. Contains no description of misconception.

Briefly describe the misconception:

Comments/suggestions for improvement.

Are references to sources of the misconception provided?

Professional	Insufficient	Unprofessional
Includes more than one non-technical source of the misconception. Link between misconception and initial source is clear.	Includes at least one non-technical source of the misconception. Or link between misconception and initial source is unclear.	Does not include non-technical sources of the misconception.

Briefly list the non-technical references used:

Comments/ Suggestions for Improvement:

Discussion of Scientific Information

Is Basic Terminology Explained?

Professional	Insufficient	Unprofessional
Text is complete and concise. Technical jargon is used sparingly and is well-defined/ explained.	Text is wordy or incomplete in some sections. Technical jargon is used often but some explanation is provided.	Text is missing or entirely technical. Contains no description of jargon.

Briefly list the technical jargon that is used and the definition of this jargon:

Comments/ Suggestions for Improvement:

Are the data/figures presented in a logical, organized, professionally formatted fashion.

Professional	Insufficient	Unprofessional
Presentation choice (table, graph, or figure) enhances understanding. Clear legends/captions are included.	Presentation confuses understanding of information. Legends/captions are vague or difficult to follow.	Presentation choice makes understanding the data impossible. Legends/captions are missing.

Briefly describe the format of tables and graphs. Do captions match the graphics?

Comments/ Suggestions for Improvement:

Does the data choice, data processing, figures support or contradict the misconception?

Professional	Insufficient	Unprofessional
Contain ample data that support or contradict the arguments made in the discussion. Contain no irrelevant or redundant data. Data are interpreted correctly.	Missing some critical data or contain some irrelevant or redundant data. Data are interpreted incorrectly in some places.	Missing most critical data or contain a large amount of irrelevant or redundant data. Data are interpreted incorrectly in most places.

Briefly describe the data that is contained in the discussion: Does the data support/contradict the misconception?

Comments/ Suggestions for Improvement:

Are the pictures described in the text?

Professional	Insufficient	Unprofessional
Ratio of pictures to text description is balanced. Pictures support the text and text supports the description.	High ratio of pictures to description. Description of figures is present but not adequate.	The ratio of pictures to description is high. Very little description of the figures is provided.

Briefly describe the text that is used to explain the figures. Does the text support the figures (and do the figures support the text?)

Comments/ Suggestions for Improvement:

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Is discussion engaging?		
Professional	Insufficient	Unprofessional
Discussion is presented in an engaging manner. Reader is encouraged to think about material as they read it.	Discussion is partially engaging. Reader is encouraged to read the material but it is possible to read without thinking about the material.	Discussion is not engaging. Reader is confused or bored by material.
Comments/ Suggestions for Improvement:		

Is discussion persuasive?		
Professional	Insufficient	Unprofessional
Effectively uses data to address misconception. Key data are interpreted correctly. Argument structure and quality logically leads to conclusions.	Relationship between data and misconception are sometimes muddled. Key data are not always interpreted correctly. Uses some unimportant data. Argument is sometimes weak or poorly structured.	Does not effectively use data to address the scientific aim. Key data are interpreted incorrectly. Fails to use the KEY data. Argument is generally weak or lacks structure.
Read through the discussion in its entirety, then summarize the key points of the discussion here.		
Comments/ Suggestions for Improvement:		

<u>How to refute the misconception (FAQs)</u>

Before reading this section, write down any questions you have about the misconception.

Now read the section. Were there any unanswered questions? Put a star next to the unanswered questions.

Are the sections on outreach consistent with scientific principles?		
Professional	Insufficient	Unprofessional
Yes, sections on outreach are supported by data.	Mostly, sections on outreach are mostly supported by data.	No, sections are not supported by data.
Comments/ Suggestions for Improvement:		

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Is the Text sufficient?

Professional	Insufficient	Unprofessional
Text is complete and concise.	Text is wordy or incomplete in some sections.	Text is missing.

Comments/ Suggestions for Improvement:

References

Are references appropriate?

Professional	Insufficient	Unprofessional
Reference sources are appropriate. Number and variety of references indicate that authors have a high level of understanding of the subject.	Some reference sources are not appropriate for a scientific paper. Number and variety of references indicate that author has a moderate understanding of the subject.	Reference sources are inappropriate for a scientific paper. Small number of references indicate that author has little understanding of the subject.

Briefly list the references used for the scientific part of this paper:

Comments/ Suggestions for Improvement:

Are references formatted properly? (APA format)

Professional	Insufficient	Unprofessional
References properly cited in text and formatted correctly.	References not properly cited in text or formatted correctly.	References are improperly cited in text and formatted incorrectly.

Comments/ Suggestions for Improvement:

Overall Writing Style

Is the writing style appropriate for your audience?

Professional	Insufficient	Unprofessional
Sounds like a professional writer—clear, concise, persuasive. Language is clear without being too technical.	Sounds like a good student—somewhat clear, concise, and persuasive. Language is sometimes too technical.	Sounds like a student new to writing—not clear, concise, or persuasive. Language is technical without explanations.

Comments/ Suggestions for Improvement:

Writing Mechanics		
Professional	Insufficient	Unprofessional
Grammar, punctuation, usage, and spelling enhance paper quality.	A few mechanical errors, but does not distract reader too greatly.	Many mechanical errors severely detract from meaning of paper.
Comments/ Suggestions for Improvement:		

Writing Submission		
Professional	Insufficient	Unprofessional
Document looks professional. Font, style, and formatting approach are not distracting.	Document is well-formatted but does not look professional. Formatting enhances text but distracts.	Document looks unprofessional. Font and figures are distracting to the reader. Formatting does not enhance the text.
Comments/ Suggestions for Improvement:		

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References

1. *NewsCore. Dinosaurs "gassed" themselves into extinction, British scientists say*. http://www.foxnews.com/scitech/2012/05/07/dinosaurs-farted-their-way-to-extinction-british-scientists-say/ (accessed May 30, 2016).
2. In short, the news article claimed that dinosaur "farts" caused climate change. Considering the amount of "hot air" spent discussing dinosaurs and farts, it was important to explore the "source" of this news.
3. Wilkinson, D. M.; Nisbet, E. G.; Ruxton, G. D. Could methane produced by sauropod dinosaurs have helped drive Mesozoic climate warmth? *Curr. Biol.* **2012**, *22*, R292–R293.
4. Kober, L. *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and Engineering*; National Academies Press: Washington, DC, 2015.
5. American Association for the Advancement of Science. *Science for All Americans: Education for a changing future*; Oxford University Press: New York, 1990.
6. Bell, P.; Lewenstein, B.; Shouse, A. W.; Feder, M. A. *Learning Science in Informal Environments: People, Places, and Pursuits*; National Academies Press: Washington, DC, 2009.
7. Leiserowitz, A.; Smith, N.; Marlon, J. R. Americans' Knowledge of Climate Change. *Yale Proj. Clim. Chang. Commun.* **2010**, 1–60.
8. Sadler, T. D. Situated learning in science education: socioscientific issues as contexts for practice. *Stud. Sci. Educ.* **2009**, *45*, 1–42.

9. Sinatra, G. M.; Kienhues, D.; Hofer, B. K. Addressing Challenges to Public Understanding of Science: Epistemic Cognition, Motivated Reasoning, and Conceptual Change. *Educ. Psychol.* **2014**, *49*, 123–138.
10. Sinatra, G. M.; Heddy, B. C.; Lombardi, D. The Challenges of Defining and Measuring Student Engagement in Science. *Educ. Psychol.* **2015**, *50*, 1–13.
11. *Information Literacy Compentency Standards for Higher Education*; http://www.ala.org/acrl/standards/informationliteracycompetency (accessed Jun 13, 2016).
12. *Introduction to Information Literacy*; http://www.ala.org/acrl/issues/infolit/intro (accessed Nov 27, 2015).
13. Weart, S. R. *The Discovery of Global Warming*, revised; Havard University Press: Cambridge, MA, 2008.
14. *Video - Ivar Giaever (2015): Global Warming Revisited*; http://www.mediatheque.lindau-nobel.org/videos/34729/ivar-giaever-global-warming-revisited/laureate-giaever (accessed Nov 27, 2015).
15. van der Linden, S. L.; Leiserowitz, A. A.; Feinberg, G. D.; Maibach, E. W. The Scientific Consensus on Climate Change as a Gateway Belief: Experimental Evidence. *PLoS One* **2015**, *10*, 1–8.
16. Seethaler, S. Five Things Chemists (and Other Science Faculty) Should Know about the Education Research Literature. *J. Chem. Educ.* **2016**, *93*, 9–12.
17. This misconception is not documented in the literature but the chemistry instructor heard students discuss this idea during class.
18. Howe, P. D.; Leiserowitz, A. Who remembers a hot summer or a cold winter? The asymmetric effect of beliefs about global warming on perceptions of local climate conditions in the U.S. *Glob. Environ. Change* **2013**, *23*, 1488–1500.
19. Myers, T. A.; Maibach, E. W.; Roser-Renouf, C.; Akerlof, K.; Leiserowitz, A. A. The relationship between personal experience and belief in the reality of global warming. *Nat. Clim. Change* **2012**, *3*, 343–347.
20. Hart, P. S.; Nisbet, E. C. Boomerang Effects in Science Communication: How Motivated Reasoning and Identity Cues Amplify Opinion Polarization About Climate Mitigation Policies. *Commun. Res.* **2011**, *39*, 701–723.
21. Mason, L.; Pluchino, P.; Ariasi, N. Reading information about a scientific phenomenon on webpages varying for reliability: an eye-movement analysis. *Educ. Technol. Res. Dev.* **2014**, *62*, 663–685.
22. Wiley, J.; Goldman, S. R.; Graesser, A. C.; Sanchez, C. A.; Ash, I. K.; Hemmerich, J. A. Source Evaluation, Comprehension, and Learning in Internet Science Inquiry Tasks. *Am. Educ. Res. J.* **2009**, *46*, 1060–1106.
23. Soules, A.; Nielsen, S.; LeDuc, D.; Inouye, C.; Singley, J.; Wildy, E.; Seitz, J. Embedding Multiple Literacies into STEM Curricula. *Coll. Teach.* **2014**, *62*, 121–128.
24. Griffin, K. L.; Ramachandran, H. Science Education and Information Literacy: A Grass-Roots Effort to Support Science Literacy in Schools. *Sci. Technol. Libr.* **2010**, *29*, 325–349.

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25. Majetic, C.; Pellegrino, C. When Science and Information Literacy Meet: An Approach to Exploring the Sources of Science News with Non-Science Majors. *Coll. Teach.* **2014**, *62*, 107–112.
26. Burnett, S.; Singiser, R. H.; Clower, C. Teaching About Ethics and the Process of Science Using Retracted Publications. *J. Coll. Sci. Teach.* **2014**, *43*, 24–29.
27. Sinatra, G. M.; Broughton, S. H. Bridging Reading Comprehension and Conceptual Change in Science Education: The Promise of Refutation Text. *Read. Res. Q.* **2011**, *46*, 374–393.
28. Ferrer-Vinent, I. J.; Bruehl, M.; Pan, D.; Jones, G. L. Introducing Scientific Literature to Honors General Chemistry Students: Teaching Information Literacy and the Nature of Research to First-Year Chemistry Students. *J. Chem. Educ.* **2015**, 617–624.
29. Britt, M. A.; Richter, T.; Rouet, J.-F. Scientific Literacy: The Role of Goal-Directed Reading and Evaluation in Understanding Scientific Information. *Educ. Psychol.* **2014**, *49*, 104–122.
30. Lombardi, D.; Seyranian, V.; Sinatra, G. M. Source Effects and Plausibility Judgments When Reading About Climate Change. *Discourse Process.* **2014**, *51*, 75–92.
31. Lombardi, D.; Sinatra, G. M. College Students' Perceptions About the Plausibility of Human-Induced Climate Change. *Res. Sci. Educ.* **2012**, *42*, 201–217.
32. Sadler, T. D. Informal reasoning regarding socioscientific issues: A critical review of research. *J. Res. Sci. Teach.* **2004**, *41*, 513–536.
33. Flener-Lovitt, C. Using the Socioscientific Context of Climate Change To Teach Chemical Content and the Nature of Science. *J. Chem. Educ.* **2014**, *91*, 1587–1593.
34. Wiggins, G. P.; McTighe, J. *Understanding by design*, 2nd ed.; Association for Supervision & Curriculum Development: Alexandria, VA, 2005.
35. Fink, L. D. *Creating Significant Learning Experiences: An Integrated Approach to Designing College Course*, 2nd ed.; Jossey-Bass: San Francisco, CA, 2013.
36. *Global Warming and Climate Change skepticism examined*; http://www.skepticalscience.com/ (accessed Sep 28, 2013).
37. Beerling, D.; Fox, A. Enhanced chemistry-climate feedbacks in past greenhouse worlds. *Proc. Natl. Acad. Sci. U.S.A.* **2011**, *108*, 9770–9775.
38. Association of College & Research Libraries (ACRL). *Framework for Information Literacy for Higher Education*; http://www.ala.org/acrl/standards/ilframework (accessed Jul 27, 2016).
39. *About Hydrocarbon Processing*; http://www.hydrocarbonprocessing.com/AboutUs.html (accessed Mar 25, 2016).
40. Moore, J. W. Are We Really Teaching Science? *J. Chem. Educ.* **2009**, *86*, 411.
41. Bråten, I.; Britt, M. A.; Strømsø, H. I.; Rouet, J.-F. The Role of Epistemic Beliefs in the Comprehension of Multiple Expository Texts: Toward an Integrated Model. *Educ. Psychol.* **2011**, *46*, 48–70.

42. Barzilai, S.; Zohar, A. Epistemic Thinking in Action: Evaluating and Integrating Online Sources. *Cognit. Instr.* **2012**, *30*, 39–85.
43. Ivar Strømsø, H.; Bråten, I.; Anne Britt, M. Do Students' Beliefs About Knowledge and Knowing Predict Their Judgement of Texts Trustworthiness? *Educ. Psychol.* **2011**, *31*, 177–206.
44. Bailey, C. P.; Minderhout, V.; Loertscher, J. Learning transferable skills in large lecture halls: Implementing a POGIL approach in biochemistry. *Biochem. Mol. Biol. Educ.* **2012**, *40*, 1–7.
45. Jin, G.; Bierma, T. STEM for non-STEM Majors: Enhancing Science Literacy in Large Classes. *J. Coll. Sci. Teach.* **2013**, *42*, 20–26.
46. Information literacy standards for science and technology: A draft. *Coll. Res. Libr. News* **2005**, 381–388.
47. Shtulman, A.; Valcarcel, J. Scientific knowledge suppresses but does not supplant earlier intuitions. *Cognition* **2012**, *124*, 209–215.
48. Lewandowsky, S.; Ecker, U. K. H.; Seifert, C. M.; Schwarz, N.; Cook, J. Misinformation and Its Correction: Continued Influence and Successful Debiasing. *Psychol. Sci. Public Interest* **2012**, *13*, 106–131.
49. Sinatra, G. M.; Danielson, R. W. Adapting to a Warmer Climate of Scientific Communication. *Bioscience* **2014**, *64*, 275–276.
50. Ash, S. L.; Clayton, P. H. Documenting Learning: The Power of Critical Reflection in Applied Learning. *J. Appl. Learn. High. Educ.* **2009**, *1*, 25–48.

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Chapter 13

Improving Information Literacy through Wikipedia Editing in the Chemistry Classroom: Lessons Learned

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Assignments in which students edit Wikipedia may help students learn about the complexities of information creation and production, while engaging them in researching and writing about topics related to class content. This chapter presents two case studies that illustrate how Wikipedia-based activities can be designed to achieve both chemistry and information literacy learning outcomes. In both examples, faculty partnered with a librarian to implement the Wikipedia editing assignments. Through these experiences, those involved learned about Wikipedia and its community, and identified promising practices for project requirements based on formal and informal assessment and observations. Reflections are offered on the value of using Wikipedia editing assignments and concrete suggestions for creating effective projects are offered.

Introduction

Wikipedia, the online encyclopedia, is the seventh most visited website in the world as of June 2016 (*1*) and one of the leading sources of information for internet users (*2*). University students are often told by faculty not to use or cite Wikipedia articles in assignments, often because of faculty concerns about the credibility of Wikipedia articles, which are written by multiple, anonymous volunteers and do not undergo traditional peer review (*3–5*). However, even if students do not cite Wikipedia in an assignment's bibliography, many are consulting it for academic purposes (*5–8*). Rather than discouraging students from using Wikipedia in their research, librarians and teachers can guide them to use it wisely. This chapter addresses how chemistry educators can engage students in the effective use of Wikipedia, focusing on improving their understanding of how its information is created, by designing assignments in which students edit and write Wikipedia articles.

By engaging students in writing for Wikipedia's worldwide audience, instructors and librarians can provide an opportunity to learn both subject content (in this case, chemistry) and information literacy (IL) skills simultaneously. As emphasized in the latest Framework for Information Literacy for Higher Education by the Association of College and Research Libraries (ACRL) (*9*), engaging students in the process of creating information with the purpose of developing their IL competencies will help them succeed in the emergent information ecosystem and higher education environment. Wikipedia editing assignments are relevant to the six threshold concepts in the ACRL Framework, especially the second one, "Information Creation as a Process" and the fourth one, "Research as Inquiry," since the assignments require students to perform thoughtful searches for a variety of information resources, evaluate them, digest them, and then create new information appropriate for the general public to consume.

As research on the use of Wikipedia progresses, many scholars argue that educators should embrace Wikipedia — provide guidelines for using it in coursework, and consider creating Wikipedia editing assignments for further engagement — rather than discouraging or banning its use by students (*2*, *4*, *6*, *10*, *11*). Multiple studies have documented the use of Wikipedia in college classes, including contributing to it, for teaching information literacy (*2*, *12*, *13*). Since 2008, several chemistry classes have explored the concept of using Wikipedia editing as course assignments (*14–19*). This chapter adds to this body of knowledge by providing two case studies describing in detail how librarians and chemistry professors from two universities engaged students in writing Wikipedia articles on chemistry topics. The designs of the projects are compared to reveal the flexibility and effectiveness of Wikipedia projects in delivering information literacy skills. These two case studies offer the educators' reflections on what students can learn from completing Wikipedia-based assignments designed to emphasize both chemistry and information literacy learning outcomes. The chapter also includes some lessons learned about designing Wikipedia assignments, including notes on what did not work well in early iterations of the assignments, and tips for writing effective Wikipedia assignments. The case

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studies also provide an example of integrating librarian involvement into a course, beyond a one-time instruction session, from assignment design to assessment.

Case Studies

The instructors for the classes described in these case studies assigned Wikipedia editing for a variety of reasons. In the first case study, the goal was to develop activities that would engage non-science majors in science writing for authentic audiences (*20*). This goal supported a new university core curriculum, with required science courses for non-science majors. In the second case study, the objective was to enable students to digest advanced science concepts and communicate those to a general audience. Another goal of the second case study was to have students contribute to the public good while learning (*4*, *16*). In both case studies, an intention was to devise assignments and activities that would help students gain subject knowledge in chemistry while simultaneously improving their information literacy and communication skills. Both cases focused on improving the English-language edition of Wikipedia since they both occurred in U.S. classrooms.

Case Study 1: Wikipedia Editing for Non-Science Majors

The first case study provides an example of a Wikipedia editing activity for students not majoring in the subject matter being taught in the class. In this case, the discipline was chemistry and the course was composed of freshmen and sophomores who were not majoring in science. The activity was designed by a librarian and a chemistry professor at a private comprehensive master's university in the Pacific Northwest of the U.S. The class for which the Wikipedia editing activity was designed was "Chemistry for Informed Citizens," a new class offered as part of the university's new core curriculum (*21*). The Wikipedia activity was repeated three times, in three consecutive ten-week-long academic quarters, in 2012. The class size during those quarters ranged from 16 to 32 students. Class met twice a week for two hours in a lecture space and once a week for a three-hour laboratory. For the library session, the class met for one of the three-hour lab sessions in the library's instruction room, with laptops for hands-on work and tables set in clusters for group work.

In advance of the Wikipedia editing assignment, the professor created a list of Wikipedia articles from which the students could choose for their assignment. The professor started by exploring a Wikipedia-based list of chemistry articles needing expert attention (*22*). She evaluated a wide range of Wikipedia articles to find several that met three criteria: relevant to chemistry topics taught in class, in need of editing or expanding, and not too technical for first- and second-year students. Articles selected included, for example, "Humectant (*23*)" and "Food additive (*24*)." The class self-selected into groups of 2 or 3 students, and each group chose a Wikipedia article (or a section of an article) from the list the professor provided.

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The project was six weeks long, from introduction to due date. To help students build the skills needed, the professor and librarian designed several interim steps and scaffolding tasks. Table 1 describes these steps.

Table 1. Interim Assignment Steps in Case Study 1

Students completed the following tasks during the six-week-long Wikipedia editing project:

- Receive an introduction to Wikipedia and editing articles.
- Establish a Wikipedia editor account and associated sandbox page. (A sandbox page is a special type of web page on Wikipedia where people can practice editing Wikipedia; it is public but will not get confused with a formal Wikipedia entry (*25*).)
- Participate in a library session.
- Create an annotated bibliography of sources to use and cite in the article.
- Write an initial draft of revised articles on sandbox pages.
- Work with a classmate to create a new version of the article.
- Review other groups' draft articles.
- Receive peer reviews from classmates and further edit the article.
- Publish to Wikipedia and monitor edits by later editors.

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Early in the project, the instructor introduced students to the process of editing Wikipedia and the basics of participating in the Wikipedia community. The librarian then led an in-class information literacy session that focused on providing students with the skills needed to find the reliable information that would help them write the Wikipedia article. The session included multiple modes of interaction and instruction, including structured small-group activities, short videos on relevant topics such as peer review, brief lecture and demonstration segments, and time to work alone or in pairs on searching for and evaluating resources. The librarian and instructor provided feedback and answered questions, especially during the portion of the class when the students were searching on their own or in pairs.

In the first iteration of this class, the library session focused on searching for primary sources in the scientific literature and secondary sources in the scientific or popular literature. For this class, "primary sources" were defined as documents such as scientific journal articles that provide data collected via scientific research performed by the authors. "Secondary sources" were defined as documents such as magazine articles (popular literature) or review articles (scientific literature) that summarize or interpret primary sources. However, as assessment and reflective work on the first iteration of the course progressed, it was noted that students needed to rely more heavily on tertiary sources (documents such as textbooks, science encyclopedias, and chemistry dictionaries, which summarize information from primary and secondary sources) and secondary sources for this project. It took a higher level of science expertise than these students possessed to understand, summarize, and synthesize information from primary sources into encyclopedic articles appropriate for Wikipedia, a tertiary source. In addition, with experience, the librarian and instructor gained a clearer understanding of the Wikipedia editing community, including the guideline, "Wikipedia articles should be based on reliable, published secondary sources and, to a lesser extent, on tertiary sources and primary sources (*26*)." Thus, in the second and third iteration of the course, the librarian designed activities to teach students about finding, evaluating, and using secondary and tertiary sources from popular or scientific literature (rather than primary sources from the scientific literature) relevant to their topics and appropriate for citing in Wikipedia.

The librarian contributed to the class in several ways beyond the single in-class session. By knowing the professor's list of acceptable Wikipedia articles for the class project, the librarian was able to add several relevant chemistry books (secondary sources) to the library's collection, so that students would have easier access to them. These books covered such specific topics that they would not have been acquired had the librarian not known the content of the assignment. For example, the librarian selected "The Chemistry of Food Additives and Preservatives," a 2012 e-book, to support the work on Wikipedia articles about food additives. In addition to acquiring relevant books and leading an in-person session, the librarian created an online guide providing links to useful resources including those used in the library session. A link to the librarian's guide was placed in the course's web site. The librarian was also available to students who wanted one-on-one help with research for the Wikipedia assignment, via appointments, online chat, e-mail, or drop-in visits to the library. Finally, the librarian reviewed the final annotated bibliographies to assess the students' work and to inform future lesson plans for the library sessions.

After the library session, students submitted annotated bibliographies of the resources they planned to use in writing their article. The professor reviewed the bibliographies and provided formative feedback. Students then worked in groups on writing or editing their chosen Wikipedia article and submitted drafts for peer review within the class. Later, they published their work to a Wikipedia sandbox page, a special type of page that allows users to practice the process of editing Wikipedia (*25*). In the first iteration of the course, students were graded on their sandbox submission and did not add their work to Wikipedia itself. In the second and third iterations of the course, the instructor had more experience with Wikipedia and felt more confident in the students' potential contributions to it, so the students were directed to move beyond the sandbox and publish their work to Wikipedia. This provided an authentic audience for their work.

Student learning was assessed formally and informally. In terms of chemistry knowledge, anecdotal evidence suggests that the students, who were not science or chemistry majors, understood more about their selected chemical topic, but this suggestion was not tested directly. One of the ways this was noted was through poster presentations, in which students were required to teach classmates about their topic. In all three iterations of the course, every student in the course could correctly define the chemistry terms associated with their Wikipedia article to other students in the course. This evidence is significant because these students researched rather obscure topics like humectants and surfactants.

With respect to information literacy outcomes, the librarian reviewed the annotated bibliography assignments turned in after the library session in the first iteration of the course. Careful reading of each bibliography revealed that after the library session, 76% of students were able to correctly identify 3 sources from the scientific literature (such as a peer-reviewed journal or a scientific book). Additionally, 48% could accurately determine if the 3 sources were primary, secondary, or tertiary sources. These two skills are fundamental to a basic level of information literacy, especially with respect to science information.

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Case Study 2: Wikipedia Editing for Chemistry Graduate Students

The second case study covers two graduate-level chemistry courses at a large, doctoral Research I university in the Midwest of the U.S. In 2008, one of the authors, a chemistry professor, introduced a collaborative Wikipedia editing project to a class focused on physical organic chemistry. The project was designed to enhance students' understanding of advanced chemistry concepts and improve their ability to communicate science to the general public. From 2008 to 2014, the Wikipedia project was used almost continuously in this course, as well as in a different course on the synthesis of macromolecules. Both classes met three times per week for a one-hour lecture. Class sizes ranged between 11 and 45 students, with graduate students from multiple departments and some senior undergraduate chemistry majors enrolled. The librarian liaison to the chemistry department supported these Wikipedia assignments starting in 2011. Because the two classes in this case study targeted similar student populations and both covered advanced chemistry topics, the strategies in designing the Wikipedia editing project and interventions to help students were similar. Thus, the two classes are discussed as one case study, in contrast to the first case study, which discussed one class.

Table 2 lists sample learning outcomes expected from completing the Wikipedia editing assignment.

The details of this Wikipedia assignment have been published previously (*16*) and are summarized in Table 3 below. The length of the project ranged from 5 to 8 weeks, depending on the academic term in which it was assigned. A sample timeline and students' work from a recent implementation are publicly available on the Wikipedia course page (*27*).

Unlike the students in the first case study, the students in these graduate classes were not given a list of Wikipedia articles from which to choose. Instead, they were required to propose topics that were related to the chemistry course material and that were not adequately covered in Wikipedia, for example, those articles classified as "stubs" in Wikipedia (*28*). A brief description of an editing plan was also required for each proposed topic. To write such a plan, students needed to critically evaluate the current Wikipedia article and then identify the gaps in the content coverage by using their previous knowledge of the discipline as well as newly acquired concepts from the class. To provide direction, the instructor and the librarian suggested that students review a list of topics from the WikiProject Chemistry (*29*) group, which provides a list of "open tasks" identifying articles needing improvement. Examples of "before" and "after" articles modeling what was expected were also provided to students as a handout posted on the course web site. The instructors then selected topics from the list of student-proposed topics, based on the relevance of the topic to the class as well as how reasonable their editing plans were within the class timeframe. Topics selected included "Biodegradable polymer (*30*)" and "Physical organic chemistry (*31*)." More topics edited by students in these classes are linked on two course pages on Wikipedia (*32*, *33*). Allowing students to propose Wikipedia articles for editing assignments works better with students majoring in science because of the higher level of science knowledge required at the start of the project.

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Table 2. Sample Learning Outcomes of the Wikipedia Editing Assignment in Case Study 2

Learning Outcomes
• Evaluate the quality of the existing Wikipedia article
• Identify and evaluate relevant sources to cite
• Find appropriate media to use or reuse
• Handle copyright /ethics issues properly and avoid plagiarism
• Understand subject knowledge relevant to the selected topic
• Write about scientific matters with the general public as the audience
• Recognize bias in Wikipedia and in one's own writing
• Provide peer reviews and respond to reviews from classmates and the broader Wikipedia community
• Format articles with Wikipedia markdown syntax
• Consume Wikipedia content with a critical eye in the future

In the implementations after 2012, students received an overview of Wikipedia community dynamics and were introduced to editing basics during a library workshop given by the science librarian. Other topics covered in the library workshop included finding and evaluating sources, copyright issues, and other IL topics. Table 4 outlines the content covered in the workshop.

Similar to the previous case study, students published drafts to their Wikipedia sandboxes for peer review from their classmates, the instructor, and the librarian. They then published their work on Wikipedia. Thus, their work receives ongoing "peer review" from the Wikipedia community.

Table 3. Summary of Wikipedia Assignment in Case Study 2

Tasks and requirements completed by students:
Task: • Create or substantially improve a Wikipedia article on a chemistry-related topic, invoking concepts learned in class. • Work in groups of 2 or 3.
Requirements: • Sandbox draft (20 points) and final post with response to reviewers (60 points). ○ Add a minimum of 3 sections, including an introductory paragraph, to the Wikipedia article. ○ Add a minimum of 3 original figures and/or schemes. ○ Add a minimum of 8 appropriate references to diverse sources. ○ Consider the general public as the audience. • Review each others' work before the article is posted to the main space of Wikipedia articles (20 points).

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Table 4. Outline of Library Workshop on Wikipedia Editing in Case Study 2

• Discuss what makes a good Wikipedia article ○ community "peer review" ○ encyclopedia writing style ○ searching for and evaluating sources ○ citing sources ○ copyright issues
• Learn editing basics ○ creating usernames and sandboxes ○ basic formatting ○ how to add references ○ how to add images ○ moving content from sandbox to article
• Special editing tips for chemistry-related content
• Where to find help

The extent of interactions between the students in this case study and the Wikipedia community varied depending on the topics. For example, among the 14 articles students edited for the Winter 2014 implementation (*32*), only two articles ("Polybenzimidazole fiber" and "Star-shaped polymer") received comments from the broader Wikipedia community between 2014 and 2016; while six articles from the Fall 2013 implementation received comments in that same time frame (*32*). Some feedback has been very positive and encouraging, such as this comment from a Wikipedia user:

> "I have this page on my watchlist so I have just seen the recent changes to the article. What an outstanding improvement. I can't make out who has done what, but anyway it has worked out well and has been very successful. In the past there have sometimes been rather unhappy examples of Wikipedia editing being used for educational purposes. In this case it looks to me the article has become both informed and accessible (*34*)."

Most Wikipedia edits contributed by students in this case study remained intact. However, since the feedback from other "Wikipedians" (volunteers who edit Wikipedia) was mostly posted after the classes ended, most students did not address the comments. In fact, this is one of the most popular criticisms in the Wikipedia community regarding students editing Wikipedia as course assignments, as illustrated in the following comment from the "Talk" page of one of the articles edited by students in this case study:

> "History shows us that students who are tasked with creating such essays are unlikely to ever edit again. What we have is a snapshot of the mostly primary literature that looks very good today, but what about its relevance in 5 years time? Who is going to tend this article? I guess one could say that an obsolete review is better than none. I would argue that it is possible to write content that is less time-senstive [sic] (*35*)."

In contrast, the "Polyfluorene" article from the 2011 implementation received an extensive review from the community and the students responded to some of the questions and comments professionally (*36*). Overall, the interactions between the Wikipedia community and students are often unpredictable, but can be productive when both parties are engaged.

Assessment of student learning in this case study focused on chemistry content knowledge, communication skills, and student reflections on the experience of editing Wikipedia. Student feedback submitted via optional, anonymous end-of-term course evaluations across five implementations of the class between 2008 and 2014 (56 responses in total) was analyzed. Course evaluation data was collected anonymously without direct interaction with the students. The university's Institutional Review Board (IRB) does not consider this work human subjects research and determined that IRB review was not required for it. Analyzing this feedback showed that on average, 73% of students considered editing Wikipedia for the course as a positive experience, while 7% considered it a negative experience and 20% considered it a good experience overall but had some reservations. Students reported that they: (1) gained a greater understanding of their chemistry topics, (2) learned how to communicate science concepts to the public, and (3) were able to connect to classmates and learn together. A few students reported that they improved their literature search and analysis skills. The students recognized their growth and the benefit of doing public good. A few representative statements are listed here.

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> "The wikipedia project and the proposal project were my favorite parts of the course. It was challenging, (relatively) comprehensive independent research on topics I found interesting."
> "The wikipedia project is certainly a great thing to have in the upper-level chem classes!! I wish that all the departments would do this to help Wikipedia become more useful for educated levels. I will say that I did not enjoy doing it, mainly because I have no computer skills whatsoever and the demo in class was very limited."

Two common complaints from those students who had negative responses were that the project was too time-consuming and that working in teams can be challenging. The students did not have an opportunity to choose their partners. Assigning teams was a pedagogical decision made by the instructor to ensure the diversity of groups. Some students recognized that teamwork is necessary due to the complexity of the project. For example, a few students reported that:

> "The wikipedia project is neat because there is a tangible product at the end, but it is a disproportionate amount of effort compared to the actual material learned, especially as the pool of course-related topics shrinks after every year."
> "The Wikipedia project was a lot of fun and I enjoyed getting to make an impact on something so global. Working in pairs/groups could have been frustrating or difficult for some students, but it would probably be a very difficult project to do alone, so I think keeping it in pairs or groups is a good idea."

It was also observed that fewer students reported lacking guidance on editing and the research process in later implementations, which can be attributed to improved guidelines, sample finished products, the in-class library workshop and other learning materials. The concerns about "the pool of course-related topics shrinks after every year" also appeared less often in the more recent implementations.

In one of the earlier implementations of the project, the revised Wikipedia articles appeared to be much more engaging for general readers than the original articles, according to independent analysis of the final Wikipedia articles by a faculty member affiliated with the Department of English Language and Literature, the School of Education, and the Writing Center (*16*).

Students in these classes were able to make substantial contributions to Wikipedia. Some of their articles were accepted as "Did You Know (*37*)?" articles, which were featured on the Wikipedia home page and received more than a thousand visits within one day. For example, the article, "Physical organic chemistry," was visited 1381 times on the day it was featured as a "Did You Know?" article (*38*). The success of the project in these classes inspired other university instructors to adapt the Wikipedia editing assignment for other courses in science, social science, humanities, and engineering departments. The librarian supported many of these classes and more examples of the courses are linked on the librarian's Wikipedia user page (*39*).

Reflections and Discussion

Writing for an encyclopedia like Wikipedia has some qualities in common with the process of writing for academic audiences, as opposed to writing a traditional assignment, whose audience is often one professor assigning a grade. First, students publishing articles to Wikipedia will engage with the community of active contributors to Wikipedia, who possess a range of perspectives and agendas, and who can share their feedback with the students. In this way, the process of writing for Wikipedia is somewhat similar to presenting at academic conferences, where authors share academic writing with a community of practice and receive feedback from multiple people in that community. This worldwide audience for students' writing may also increase student motivation when writing for Wikipedia for a class (*4*, *16*). Second, by participating in the process of writing for Wikipedia, students are able to contribute to a scholarly conversation that may be otherwise inaccessible to them. This aspect of writing for Wikipedia reflects the "Scholarship as a Conversation" threshold concept of the ACRL information literacy framework (*9*). Finally, writing for Wikipedia requires citations, clarity, and accuracy, which is similar to academic writing requirements. However, Wikipedia articles do not require an argument, which is usually part of academic writing. Instead, students write an overview of a topic after digesting the concept, with the general public as the audience. Focusing on this type of writing may serve as an effective scaffold, by allowing students to master some of the fundamental skills of academic writing without having to construct arguments, a higher-level skill (*14*).

By writing for Wikipedia, students may learn more about the nature of science. Wikipedia content changes over time, in a way that is somewhat similar to the process of scientific knowledge creation. The Wikipedia community adds knowledge to the encyclopedia as it is discovered, and debates knowledge as it comes into question. Like science, Wikipedia may appear to be static, but in reality both scientific knowledge and Wikipedia content continuously change.

Students writing for Wikipedia may learn about the process of creating information resources, including Wikipedia itself, a source they probably use regularly. This relates to the "Information Creation as Process" threshold concept in the ACRL information literacy framework (*9*). Students writing or editing articles can actively gain an in-depth understanding of Wikipedia's distributed authorship model, instead of just being told by an instructor that anyone can edit Wikipedia. Students in both case studies in this chapter experienced first-hand the process of writing for Wikipedia, including both positive and negative moments. For example, some of the students' contributions to Wikipedia were criticized or overwritten by established "Wikipedians." Ultimately, this process is similar to science, with new knowledge changing our understanding over time, and somewhat similar to the academic world, in which peers comment publicly on each others' work.

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Lessons Learned

By repeating Wikipedia activities over time, the educators in these two case studies were able to learn about designing effective Wikipedia-related assignments based on their assessment of student learning as well as their informal observations of the activities and interactions with the students. Applying an iterative design approach, they updated the Wikipedia assignments over time, based on their new knowledge. For other educators considering incorporating Wikipedia editing assignments in their courses, some of the lessons learned from these two case studies may be helpful.

The first lesson learned is that Wikipedia truly is a community. Instructors and students editing Wikipedia must understand that even though Wikipedia can, in theory, be edited by anyone, it is not just anyone participating independently and blindly. Rather, Wikipedia consists of a community of about 76,000 active "Wikipedians" for all language editions of Wikipedia (30,000 of which are active "Wikipedians" for the English-language version of Wikipedia) (*40*). Like any community of people, Wikipedia's community includes personalities, politics, and bureaucracy. The people who are active in the community care deeply about their work, and they might be critical of changes made to their articles, or of new editors' interactions with the established community. For instructors creating Wikipedia assignments, some tips related to this point include:

- In selecting articles to edit, instructors should look at the "Talk" pages for articles under consideration (*41*). Evaluate how recently edits have been made and which users made them. Instruct the students to mention on the "Talk" page that they will be working on the article for a class project.
- Use Course pages provided by the Wiki Education Foundation (*42*) (previously Wikipedia Education Program (*43*)) to organize students' work and act as a portal for the class to communicate with the community.
- For graduate students or advanced undergraduates majoring in the discipline taught, consider having them analyze Wikipedia articles and select several to propose editing. For first- or second-year students, or non-majors, supply them with a list of articles appropriate for the assignment.

The second lesson learned is that, like any community, Wikipedia has a culture to understand and norms to follow. Just as scholars learn about an intellectual community before engaging with it by publishing or presenting, students should not expect to enter this community without learning about the expectations for doing so. In both case studies described here, it took more than one implementation for the activity to run smoothly. Before designing these Wikipedia editing activities, the authors of this chapter were not active editors in the Wikipedia community. However, the Wikipedia projects improved over time as the authors gained experience as editors, learned more about the culture of Wikipedia, and edited the assignments accordingly. Tips related to this point include:

- Instructors should have a good understanding of the Wikipedia community. Participating in editing or partnering with an experienced editor before bringing students into the Wikipedia community is ideal. A good starting point is to go through the Training for Instructors provided by WikiEdu (*44*). At least one instructor in the instruction team should have actually edited some Wikipedia articles and interacted with the community by the time the class starts.
- Instructors should teach students to follow Wikipedia style guidelines (*16*). Use, for example, the WikiEdu Training for Students (*45*), Wikipedia Manual of Style (*46*), Wikipedia Manual of Style for Chemistry (*47*), and most importantly, the Five Pillars of Wikipedia (*48*).
- Students need to be reminded of the established norm requiring writing for a general audience, using language easily understood, and taking a neutral point of view (*48*).
- Choose articles with topics that seem to have a low potential for controversy. In an early iteration of the activity in the first case study, the "Preservative" article was too controversial, and got too much attention from the Wikipedia community. Also, it may be more difficult for students to provide a neutral and balanced perspective on controversial topics (*14*).
- Teach students to add one paragraph at a time, not multiple paragraphs. Also, recommend that they add an "edit summary," which shows up in the revision history of an article, explaining to the community why they are adding the new paragraph.

The final lesson learned is about sources. As described in the first case study, the information cited in Wikipedia articles should come from a range of sources, not only primary sources published in the scientific literature (*16*). In fact, secondary sources (books, review articles, magazine articles) often represent the best option to cite when writing for Wikipedia. Because Wikipedia is an online encyclopedia, a tertiary source, citing only primary literature could make an article's content too current and therefore quickly outdated. Citing more sources tested by time reduces the risk of sharing incorrect information in Wikipedia. In addition, Wikipedia's guidelines specify that its content should not contain original research, including new "analysis or synthesis of published material that serves to reach or imply a conclusion not clearly stated by the sources themselves (*26*)." When only primary sources (original research) are cited in a Wikipedia article, the article itself may come too close to original research, which is not appropriate for this tertiary source. For instructors creating Wikipedia assignments, some tips related to sources include:

- Teach students how to find and use reference sources for citing in Wikipedia. Reference sources are also useful for comparison, considering students are writing a reference source when writing for Wikipedia. Also, help students understand the verifiability and reliability of a source in the Wikipedia context (*49*, *50*).

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- Break the big task of writing/editing an article into smaller pieces to allow time for formative assessment on tasks such as source selection from the librarian and/or instructor on the early stages of the project (*14*).

How To Incorporate Wikipedia Editing into a Class

This chapter describes two approaches to designing an assignment leading students through the process of editing chemistry-related Wikipedia articles. Instructors who want to do similar full-fledged, multi-week class projects may find these examples, and tips above, useful. However, instructors and librarians may also want to design shorter, more focused assignments/activities that encourage students to engage critically with Wikipedia, without actually publishing a full Wikipedia article. Examples of such smaller-scale activities, which could also serve as scaffolding activities to help students develop the skills needed to write an article, include:

- Analyze Wikipedia articles for strengths and weaknesses. The assignment format could be a short proposal explaining why an article needs improvement and what the approach would be for improving it.
- Research information sources to add citations of reliable sources to existing Wikipedia articles. The assignment format could be an annotated bibliography. If appropriate, the students could actually add the citations to Wikipedia.
- Write a draft of a Wikipedia article and submit to class for peer review feedback without publishing to Wikipedia. This eliminates the need to teach students about setting up an editor account and sandbox page, using the Wikipedia markup language, or following best practices for adding content to Wikipedia such as adding one paragraph at a time.
- Provide structured peer review feedback to fellow students on draft Wikipedia articles.

Instructors and librarians interested in creating activities related to editing Wikipedia should consider connecting with the Wiki Education Foundation (*42*), which provides support and resources for educators. The program also includes example lesson plans and ways to integrate the instructor and the course into the Wikipedia community.

Conclusions

This chapter offers reflections on the pedagogical possibilities of having students write for Wikipedia, an online reference source read by millions of people. The case studies illustrate how a variety of assignments engaging students in editing Wikipedia can be used to achieve both chemistry and information literacy learning outcomes for a variety of students. Working together, chemistry faculty and librarians can design creative, engaging Wikipedia-based assignments that help students understand the complexities of information creation and

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production, as well as the nature of science, while engaging them in researching and writing about chemistry topics.

References

1. Wikipedia contributors. *List of most popular websites*; https://en.wikipedia.org/w/index.php?title=List_of_most_popular_websites &oldid=723172377 (accessed June 22, 2016).
2. Okoli, C.; Mehdi, M.; Mesgari, M.; Nielsen, F. Å.; Lanamäki, A. Wikipedia in the eyes of its beholders: A systematic review of scholarly research on Wikipedia readers and readership. *J. Assoc. Inf. Sci. Technol.* **2014**, *65*, 2381–2403.
3. Chen, H. l. The perspectives of higher education faculty on Wikipedia. *Electron. Libr.* **2010**, *28*, 361–373.
4. Konieczny, P. Teaching with Wikipedia in a 21st-century classroom: Perceptions of Wikipedia and its educational benefits. *J. Assoc. Inf. Sci. Technol.* **2016**, *67*, 1523–1534.
5. Purcell, K.; Rainie, L.; Heaps, A.; Buchanan, J.; Friedrich, L.; Jacklin, A.; Chen, C.; Zickuhr, K. *How Teens Do Research in the Digital World*; PewResearchCenter: Washington, DC, 2012. http://www.pewinternet.org/Reports/2012/Student-Research.
6. Lim, S. How and why do college students use Wikipedia? *J. Am. Soc. Inf. Sci. Technol.* **2009**, *60*, 2189–2202.
7. Head, A. J.; Eisenberg, M. B. How today's college students use Wikipedia for course-related research *First Monday* [Online], 2010. http://firstmonday.org/ojs/index.php/fm/article/view/2830/2476 (accessed June 22, 2016).
8. Garrison, J. C. Getting a "quick fix": First-year college students' use of Wikipedia *First Monday* [Online], 2015. http://firstmonday.org/ojs/index.php/fm/article/view/5401/5003 (accessed June 22, 2016).
9. Association of College and Research Library, *A. L. A. Framework for Information Literacy for Higher Education 2015*. http://www.ala.org/acrl/standards/ilframework (accessed November 4, 2015).
10. Carver, B. W.; Davis, R.; Kelley, R. T.; Obar, J. A.; Davis, L. L. Assigning Students to Edit Wikipedia: Four Case Studies. *E-Learning Digital Media* **2012**, *9*, 273–283.
11. Walker, M. A.; Li, Y. Improving Information Literacy Skills through Learning To Use and Edit Wikipedia: A Chemistry Perspective. *J. Chem. Educ.* **2016**, *93*, 509–515.
12. Jennings, E. Using Wikipedia to Teach Information Literacy. *Coll. Undergrad. Libr.* **2008**, *15*, 432–437.
13. Oliver, J. T. One-shot Wikipedia: an edit-sprint toward information literacy. *Ref. Serv. Rev.* **2015**, *43*, 81–97.
14. Scharf, D. College Students as Wikipedia Editors: New Pathways to Information Literacy. In *Successful Strategies for Teaching Undergraduate Research*; Deyrup, M., Bloom, B., Eds.; Scarecrow Press: Lanham, MD, 2013.

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch013

15. Roth, A.; Davis, R.; Carver, B. Assigning Wikipedia Editing: Triangulation Toward Understanding University Student Engagement *First Monday* [Online], 2013. http://journals.uic.edu/ojs/index.php/fm/article/view/4340 (accessed June 22, 2016).
16. Moy, C. L.; Locke, J. R.; Coppola, B. P.; McNeil, A. J. Improving Science Education and Understanding through Editing Wikipedia. *J. Chem. Educ.* **2010**, *87*, 1159–1162.
17. Martineau, E.; Boisvert, L. Using Wikipedia To Develop Students' Critical Analysis Skills in the Undergraduate Chemistry Curriculum. *J. Chem. Educ.* **2011**, *88*, 769–771.
18. Sormunen, E.; Eriksson, H.; Kurkipaa, T. Wikipedia and Wikis as Forums of Information Literacy Instruction in Schools. In *Road to Information Literacy: Librarians as Facilitators of Learning*; Gwyer, R., Stubbings, R., Walton, G., Eds.; IFLA: Berlin, 2012; Vol. 157, pp 311−327.
19. Sormunen, E.; Tanni, M.; Alamettala, T.; Heinstrom, J. Students' Group Work Strategies in Source-Based Writing Assignments. *J. Assoc. Inf. Sci. Technol.* **2014**, *65*, 1217–1231.
20. Bean, J. C. *Engaging ideas: the professor's guide to integrating writing, critical thinking, and active learning in the classroom*; Jossey-Bass: San Francisco, 2011.
21. Seattle University. *University Core Curriculum*; https://www.seattleu.edu/core/ (accessed December 22, 2015).
22. Wikipedia contributors. *Category:Chemistry articles needing expert attention*; https://en.wikipedia.org/w/index.php?title=Category:Chemistry_articles_needing_expert_attention&oldid=262878782 (accessed December 22, 2015).
23. Wikipedia contributors. *Humectant*; https://en.wikipedia.org/w/index.php?title=Humectant&oldid=702938414 (accessed March 25, 2016).
24. Wikipedia contributors. *Food additive*; https://en.wikipedia.org/w/index.php?title=Food_additive&oldid=707899817 (accessed March 25, 2016).
25. Wikipedia contributors. *Wikipedia: About the Sandbox*; https://en.wikipedia.org/w/index.php?title=Wikipedia:About_the_Sandbox&oldid=683968591 (accessed March 18, 2016).
26. Wikipedia contributors. *Wikipedia:No original research*; https://en.wikipedia.org/w/index.php?title=Wikipedia:No_original_research&oldid=693348006 (accessed November 17, 2015).
27. Wikipedia contributors. *Education Program:University of Michigan/CHEM 540 (Fall 2013)*; https://en.wikipedia.org/wiki/Education_Program:University_of_Michigan/CHEM_540_(Fall_2013) (accessed November 17, 2015).
28. Wikipedia contributors. *Wikipedia: Stub*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Stub&oldid=709802055 (accessed March 18, 2016).

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch013

29. Wikipedia contributors. *Wikipedia:WikiProject Chemistry*; http://en.wikipedia.org/w/index.php?title=Wikipedia:WikiProject_Chemistry&oldid=665024998 (accessed June 30, 2015).
30. Wikipedia contributors. *Biodegradable polymer*; https://en.wikipedia.org/w/index.php?title=Biodegradable_polymer&oldid=599592404 (accessed June 22, 2016).
31. Wikipedia contributors. *Physical organic chemistry*; https://en.wikipedia.org/w/index.php?title=Physical_organic_chemistry&oldid=581195278 (accessed June 22, 2016).
32. Wikipedia contributors. *Education Program:University of Michigan/CHEM 540 (Fall 2013)*; https://en.wikipedia.org/w/index.php?title=Education_Program:University_of_Michigan/CHEM_540_(Fall_2013)&revid=1117 (accessed June 22, 2016).
33. Wikipedia contributors. *Education Program:University of Michigan/Chem538 Organic Chemistry of Macromolecules (Winter 2014)*; https://en.wikipedia.org/w/index.php?title=Education_Program:University_of_Michigan/Chem538_Organic_Chemistry_of_Macromolecules_(Winter_2014)&revid=1403 (accessed June 22, 2016).
34. Wikipedia contributors. *Talk:Water-gas shift reaction/Outside comment*; https://en.wikipedia.org/w/index.php?title=Talk:Water-gas_shift_reaction&oldid=717892249 - Outside_comment (accessed June 22, 2016).
35. Wikipedia contributors. *Talk:Borylation / Writing for Wikipedia is difficult*; https://en.wikipedia.org/w/index.php?title=Talk:Borylation&oldid=590500902 - Writing_for_Wikipedia_is_difficult (accessed June 22, 2016).
36. Wikipedia contributors. *Talk:Polyfluorene / GA Review*; https://en.wikipedia.org/w/index.php?title=Talk:Polyfluorene&oldid=599270738 - GA_Review (accessed June 22, 2016).
37. Wikipedia contributors. *Wikipedia: Did you know*; https://en.wikipedia.org/wiki/Wikipedia:Did_you_know (accessed March 18, 2016).
38. *Wikipedia article traffic statistics (physical organic chemistry)*; http://stats.grok.se/en/201401/physical_organic_chemistry (accessed March 18, 2016).
39. Wikipedia contributors. *User:ChemLibrarian*; http://en.wikipedia.org/w/index.php?title=User:ChemLibrarian&oldid=644416351 (accessed June 30, 2015).
40. The Wikimedia Foundation. *Wikimedia Report Card*; http://reportcard.wmflabs.org/ (accessed May 25, 2016).
41. Wikipedia contributors. *Wikipedia:Talk page guidelines*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Talk_page_guidelines&oldid=694172817 (accessed November 17, 2015).

42. Wiki Education Foundation. *Wiki Ed: About Us*; http://wikiedu.org/about-us/ (accessed June 30, 2015).
43. Wikipedia contributors. *Wikipedia:Education program*; http://en.wikipedia.org/w/index.php?title=Wikipedia:Education_program&oldid=633427068 (accessed June 30, 2015).
44. Wiki Education Foundation. *Instructor Orientation Modules*; https://dashboard.wikiedu.org/training/instructors (accessed June 22, 2016).
45. Wiki Education Foundation Student. *Training Modules*; https://dashboard.wikiedu.org/training/students (accessed June 22, 2016).
46. Wikipedia contributors *Wikipedia:Manual of Style*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Manual_of_Style&oldid=725477518 (accessed June 22, 2016).
47. Wikipedia contributors. *Wikipedia:Manual of Style/Chemistry*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Manual_of_Style/Chemistry&oldid=721829852 (accessed June 22, 2016).
48. Wikipedia contributors. *Wikipedia:Five pillars*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Five_pillars&oldid=719366310 (accessed June 22, 2016).
49. Wikipedia contributors. *Wikipedia:Verifiability*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Verifiability&oldid=726420713 (accessed June 22, 2016).
50. Wikipedia contributors. *Wikipedia:Identifying reliable sources*; https://en.wikipedia.org/w/index.php?title=Wikipedia:Identifying_reliable_sources&oldid=725234829 (accessed June 22, 2016).

Chapter 14

Debunking Pseudoscience: A Video Project To Promote Critical Thinking About Scientific Information in a General Chemistry Course

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In the General Chemistry sequence at the University of Wisconsin–Sheboygan, assignments and video projects related to the debunking of pseudoscience have been incorporated. The goal of these assignments was to foster critical thinking and information literacy in science majors. This chapter describes the project, topics covered, rubric, and related assignments. Two surveys, Student Assessment of Learning Gains and Student Surveys of Instruction, were used to evaluate student response to the project. Survey results suggest that students were able to critically appraise information, including pseudoscientific information, in the context of a chemistry course. Students also developed and enhanced information literacy skills through participation in the video project and related assignments.

Introduction

After looking at Facebook for five minutes, it is possible to find "cures" for cancer, HIV, diabetes, obesity, back pain and gastrointestinal distress. Most of these "cures" have no basis in scientific research, but instead rely on anecdotes, false science and outright lies (*1*). With the development and expansion of the Internet, a platform for anyone to publish anything, the general public has been encountering pseudoscience increasingly over time (*2*, *3*). It is important that students develop the ability to detect and critically analyze pseudoscience in contrast to peer-reviewed science. To meet this goal, a video project and connecting assignments were added to the General Chemistry I/II sequence at University of Wisconsin-Sheboygan. This video project provides an example of an engaging, media-based method for college students in the sciences to develop necessary critical thinking and information literacy skills.

Pseudoscience and Scientific Knowledge

Students often struggle to differentiate between science and pseudoscience. Recent studies have shown that significant parts of the population in the United States cannot adequately separate astrology from astronomy, still believe astrology is scientific, and support other forms of pseudoscience like ESP and UFOs (*4–7*). Advertising agencies and individuals can easily confuse consumers by using chemical-sounding names. For example, some toothpastes use the term "iso-active" (*8*). The dental products that invoke the term "iso-active" never make it clear what the term means. The term sounds somewhat scientific, but has no real scientific meaning. In addition, most laypeople have limited understanding of the nature of matter, chemical structure and reactivity, or how scientific research is performed, making pseudoscientific terms like iso-active very confusing.

Critical evaluation of pseudoscientific claims and products is especially important with health topics (*9*). With health topics, the influx of new technology, including electronic devices, medicines, supplements, and other consumable materials, makes it far more difficult for the typical citizen to discern what is scientifically supported information and what is not (*10*, *11*). Many people making important health decisions are not familiar with the peer-review process, or worse, have a general distrust of anything relating to the government or academics (*12*).

Scientific Information in Popular and Scientific Sources

Peer-reviewed, scientific journals provide members of academic and business communities with credible information on a variety of sciences and disciplines, but they are outnumbered by news sites, blogs, and other websites that provide a wealth of poor information that has little or no basis in scientific fact. Websites such as Natural News (*13*) and Food Babe (*14*) proclaim to have information that is supported by scientific research, but the research is questionable at best. The popularity of sites like these is cause for significant concern. It must be noted that such websites often sell products, books, and other related material that also cause their motives to come under question.

Articles presenting scientific information to general audiences may not be based on scientific logic. As a journalist is attempting to tell a story, sometimes one side is given emphasis and the other side not much attention at all. There may be inherent bias on the part of the journalist, or the information presented could be twisted into a form that does not allow the reader to make a judgment on the quality of the information. Several recent news articles highlighted examples of journalism that did not provide balanced analysis on important topics such as the autism and vaccine "connection," fibromyalgia, and organic foods, among others (*15–17*).

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A common feature of pseudoscientific articles is that the scientific information is often relegated to the end of the article or is completely absent. Even when the scientific information is present, the author of the article uses language that puts false or pseudoscientific information in a much more prominent light. As DeGregori states, "Until we have a public that is more literate in science, ideological certainty and clever phraseology will most often trump the probability statements of scientists (*17*)."

The Internet, and more specifically Facebook and YouTube, is filled with instances of pseudoscience, most often from individuals who do not have any scientific training and often rely on incorrect assumptions, anecdotes, and narrowly selected scientific data (*1*, *18*). Students, because they are typically very experienced with social media and online media in general, see these instances of pseudoscience (*19*) on a regular basis, though they do not always look at such situations with a critical eye. Recent polling suggests that smartphones and related devices are becoming "external brains" for the Millennial Generation (*19*), and that much information is observed but not retained adequately because of the perception that it can be accessed so easily on the Internet. How then do instructors encourage students to stop and think about the information that is so easily gathered? Encouraging students to use their devices thoughtfully is one way to improve their critical analysis skills.

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Motivation for Developing the Video Project

It should be a goal of every academic institution to train students in critical thinking, not just in science, but in all disciplines (*20–22*). There are many aspects to pseudoscientific concepts that should be explored, including media analysis, psychology, and economics. Discussions of this nature typically occur in upper-level courses, but not many of these discussions occur in general education and core courses for majors. Thus, it becomes vital for instructors in these core courses to highlight instances of pseudoscience and to help train students to be able to find appropriate scientific information.

Performing an Internet search that provides reliable information requires some practice and skill, and students should be given practice and guidance in searching. It can be difficult to acquire information because students often lack full technological access, which is common at UW-Sheboygan due to the economic status of many of the students. In addition, some students may not have any kind of training (formal or informal) on properly accessing websites, articles, databases, or even doing useful Google searches (*23*). It is for all of these reasons that an emphasis on pseudoscience in the form of a video project, in-class worksheets, and information literacy skills activities were incorporated into the General Chemistry I/II curriculum at UW-Sheboygan.

Core chemistry courses such as General Chemistry and Organic Chemistry are already filled with content deemed essential (largely for majors and those planning on taking exams like the MCAT and PCAT), so that adding any alternative material can be difficult or impossible. Despite the difficulty, it is important to add projects and other assignments that provide students substance that goes beyond the conceptual material. General Chemistry students at UW-Sheboygan complete a video project in which they use information literacy and critical thinking skills to investigate current pseudoscience topics. As part of the project, students produce a video and a summary of references about their selected topics. This video project gives the students a chance to study and deconstruct a topic by reviewing the source and quality of information about the topic and determining how media was used to inform the public about the topic. The students must be able to search the primary literature to support or debunk the information related to their topic. In this way, they should develop a skepticism for information and the media, while providing a foundation of critical thinking skills.

The choice of video as the medium for the project came from a desire to mirror one of the most common media used to sell products supported by pseudoscience. Video also taps into students' interest and creativity while allowing them to explore different ways of presenting the information gathered during the course of the project.

Course Description

UW-Sheboygan is one of the thirteen UW Colleges, the two-year transfer schools within the University of Wisconsin System. The UW Colleges are the institutions of access, serving many first-generation students, students from low-income families, or those who may not have the ACT scores to get into a four-year comprehensive institution. The total enrollment for the UW Colleges is around 9000 students, with around 750 at UW-Sheboygan.

Each semester of General Chemistry in the UW Colleges comprises a total of five credits: three credits of Lecture, one credit of Lab, and one credit of Discussion. Discussion sections meet once per week for 50 minutes, and the instructors of the Discussions have the choice to use the time as they wish. The instructor can incorporate practice of concepts, preparation for exams, working through of lab calculations, and discussion of current events related to science. At UW-Sheboygan, Discussions were used to connect chemical concepts taught in lecture to investigations of pseudoscience and information literacy. In order to investigate pseudoscience scientifically, students had to learn critical concepts related to information literacy, including the peer-review process, ways to perform Google searches including the use of keywords, and an introduction to certain databases and journal websites, specifically the ACS journals website (*24*).

The UW-Sheboygan library offers a variety of information retrieval resources, including online databases, printed journals, and books. Until recently, the campus had a librarian whose focus was information literacy, and she often gave presentations or provided activities that helped students understand the resources available to get necessary information. After that position was eliminated, the instructors became responsible for teaching information literacy to the students.

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Assignment Description

To teach information literacy in the context of chemical concepts, the instructor asked students to participate in a video project about a pseudoscience topic related to general chemistry. The video project was supported with other assignments, which were:

- Introduction to pseudoscience and the video project (Weeks 1-2)
- Worksheets during Discussion introducing information literacy, information retrieval, and analysis of pseudoscience (Weeks 2-3)
- Topic approval by instructor (Weeks 4-5)
- Written script submitted (Weeks 9-10)
- Video project and written summary submitted (Weeks 14 or 15, depending on semester)

The students were required to find a topic related to pseudoscience and chemistry, have it approved, develop a script, and create a video. Often groups chose nutritional supplements or other marketed items, though topics were not limited to consumer products. All videos were presented in class at the end of the semester on the due date in the syllabus. Accompanying the project was a three- to five-page summary, including references, that focused on the information presented in the video. As of Spring 2016, this video project was completed in three semesters: in Fall 2013, Fall 2014, and Spring 2016.

The PseudoBS Meter

In the class, students were introduced to an instructor-created tool called the PseudoBS Meter (Figure 1). The purpose of this tool was to help students become intelligent skeptics, and was introduced in order to begin a conversation about the quality of scientific information from a variety of media sources. This meter provided a qualitative metric for looking at different sources of scientific information and also suggested questions to be asked when evaluating these sources. The PsuedoBS meter helped students evaluate the scientific content and nature (i.e. “voice” or informational context) of their chosen topic. For example, many articles and websites that are pseudoscientific in nature contain inflammatory language against scientists and peer-reviewed scientific information. A quick perusal of a representative website, vaccinetruth.com (*25*), does not show credible scientific evidence but instead shows anecdotes, references to discredited doctors, and suggestions for alternative treatments for anything from the common cold to cancer. Students were encouraged to reference the PseudoBS Meter during their video project.

Pseudoscience Assignments and Project Preparation

The project started during Discussion in the first two weeks of the semester when students were provided with a worksheet assignment on information literacy. The worksheet provided directions on performing Google searches, using library databases, and going to the American Chemical Society website to look at peer-reviewed scientific journals. While completing the worksheet, students were encouraged to refer to the PseudoBS Meter. The students used smartphones, tablets, and personal computers for this assignment. (Campus computers were not necessary for this assignment because enough group members had their own internet-capable devices to complete the worksheet in the Discussion classroom.)

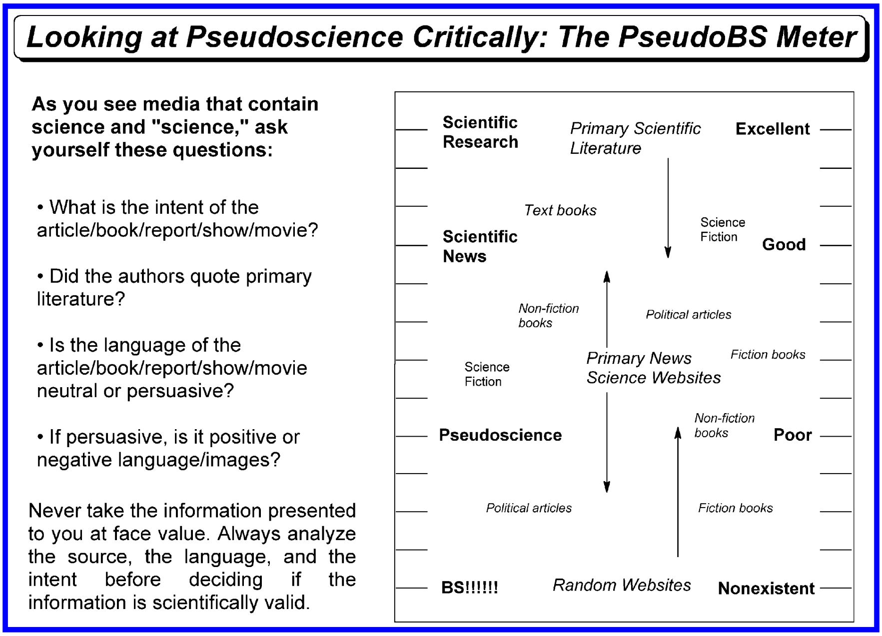

Figure 1. – The PseudoBS Meter: a qualitative metric for analysis of pseudoscience.

The worksheet included a set of questions that placed information literacy in the context of a real-life situation. For example, one question stated: "A member of your immediate family is looking at purchasing a supplement online that contains açai berry. You have not heard of it before, and you are concerned about what it might do. Where would you look for accurate, scientific information?"

After this introductory information literacy assignment, the students were encouraged to continue to look for pseudoscientific-sounding articles on social media on a daily basis so that informal discussions of pseudoscience could continue in class as often as possible. Most articles found by students included a product that was supported by pseudoscientific information, but others covered broader topics such as Genetically Modified Organisms (GMOs) presented in a pseudoscientific context. It was not difficult for students, especially those who

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were involved in social media, to identify topics for discussion. Students were encouraged to bring any relevant articles they found to class to be discussed. The frequency of such discussions varied year to year based on the engagement of the students in the class. During some years, there were conversations of this type once a week, either in Discussion or at the beginning of Lecture, while in other years the conversations took place only 1-2 times during the semester. Most discussions lasted for at least ten minutes, but some took more time.

Pseudoscience Video Project

For the video project, students were organized into groups of three to five students. Group formation was done in the second or third week of the semester in Discussion. The students were allowed to choose their own groups. The students' work involved the production of a video that began with the identification of a pseudoscientific topic. If the topic chosen was a non-ingestible consumer product, the group researched the product, the company that produced it, the cost, and how it was marketed to the public. The group was then required to investigate the actual science behind the product. If the product was a supplement or other ingestible material, they were required to investigate the science of the effect the product was supposed to have, and whether or not the product showed the desired effect.

Most products had marketing associated with them therefore, advertisements could be analyzed. Students were often asked by the instructor, "How is the product marketed?," "Is an ingredients list available?," or "Can you find a real review for the product and not one created by the company itself?" Students were usually surprised at how much misinformation was created to confuse or distract the consumer from the falsified information presented in the advertisements. Some products had company-created websites that supported the products, which popped up during simple Google searches, but which did not provide any useful analytical information about that product.

The project was worth 10% of the final grade for the course, which encouraged the students to take the project seriously. The video was required to be between four and seven minutes in length, and all students in the group needed to be on camera. (Early iterations of this project had groups with one or more students that were unwilling to be on camera and instead took the position of "editor," but that made assessing their contribution to the video project very difficult.) A properly referenced summary paper (3-5 pages) was required along with the video. Students needed to include at least three proper references in the paper, including at least one reference that had been peer reviewed.

The video project was evaluated by assessing:

- Scientific Content (40%)
- Video Length (10%)
- Presence of all Group Members on Screen (10%)
- Grammar/Structure/Etc. (10%)
- Analysis of the Media Sources (10%)
- Summary Paper with Proper References (20%)

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Since many of the ingestible products researched for this project are potentially dangerous, the students were not required to test the product themselves. Many supplements were on the market and could be purchased for study, but since there was an inherent danger in taking the supplements, students were instructed not to use the supplements themselves. The students were never required to spend any money on products for the project, so if they wished to test a non-ingestible product via chemical analysis, it was purchased by the Chemistry department.

The class was shown example videos from previous years to get some sense of the style of video that was expected, along with the level of scientific and pseudoscientific information expected in the project. Topics recently studied include:

- "Flex Seal" (a spray sealant)
- L-arginine
- "Sensa" (a diet/food additive system)
- "Do microwaves destroy food?"
- garcinia cambogia (a supplement ingredient)
- recombinant bovine somatotropin (rBST)
- "Hydroxycut" (a diet supplement)
- argentum nitricum (a supplement)
- titanium/copper jewelry

Most students used smartphones or tablets to record the videos, either in one take or in several takes. The quality of videos was excellent with these devices. Most of the groups had at least one member with video editing experience or a friend who could teach them, but if not, the instructor assisted using iMovie. Video recording equipment was also available from the campus library or from the instructor, but few groups used that equipment since the video quality of their phones was adequate for the project. The instructor was also available to film the videos if the students requested it.

When the videos were completed, the students provided the videos to the instructor either via flash drive or by uploading the video to a website and sharing the link. The videos were shown during Lecture, typically in the last two weeks of the semester. Showing the videos in the classroom allowed the whole class to learn the information that each group presented. All students had to provide reviews of their group members, as some group members did not contribute fully, and the reviews of the group members were taken into account for the final project grades. Sometimes, with student permission, the videos were shared on the campus Facebook page.

The quality of the final projects varied, both in the ability of the students to provide scientific information to debunk the product or contradict the claims as well as to stay within the allotted time frame and speak clearly and effectively. However, most groups were able to adequately identify the pseudoscientific aspects of their chosen topic and refute them.

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Assessment of Student Learning

Student responses to the project were measured using two surveys: Student Assessment of Learning Gains (SALG) (*26*) and Student Surveys of Instruction (SSI) (*27*). The collection of student data via the SALG surveys was given IRB exemption before the study began. All data shown below were collected anonymously during the Fall 2014 semester.

The first SALG assessment tool, a Pre-Survey, was given at the beginning of the semester. The second SALG assessment tool, a Post-Survey, was given at the end of the semester. These two tools were used to gauge the development of understanding about the project goals by the students. Both surveys had questions that asked how well students developed basic scientific understanding (e.g. "As a result of your work in this class, what gains did you make in the following? Confidence that you understand that material") as well as specific questions about the development of the understanding and analysis of pseudoscience (See Table 1). Other questions specifically referred to the pseudoscience-based assignments and video project. The SALG website allowed the students to share observations and comments along with the rest of the questions. The surveys were designed as a five-level Likert scale, along with a "not applicable" option.

The SSIs were typical student evaluations of course and instructor, completed by the students during a lecture period in one of the last two weeks of the semester before the final exam. The surveys were provided in a paper format, and the results were given to the instructor after the final grades for the course were completed.

Student Survey Results

The results of the Pre-Survey provided an overview of the abilities of the incoming students to deal with pseudoscience. Of the respondents (n = 25), 81% had either "just a little" or "somewhat" understanding of pseudoscience at the beginning of General Chemistry I (survey given in September). An underdeveloped understanding of pseudoscience is not surprising considering the lack of focus on such material in other science courses, even at the secondary level. Within the same survey group, 69% believed that they could critically read articles presented in this class. The question did not specify chemistry articles so it is possible that students felt comfortable thinking critically about general articles but not necessarily chemistry-specific articles.

Students were given the Post-Survey at the end of the semester after the in-class pseudoscience conversations, Discussion assignments, and video project had all been completed. The Post-Survey did not focus on whether students improved their understanding of pseudoscience, but rather on what activities they felt helped them learn. Nearly 80% of the respondents (Line 6.3.1 in Table 1) felt that the video project positively contributed a moderate to significant amount to their learning in the class. When asked about specific assignments or article discussions that helped them with general learning in the class, a majority (69% and 75%, respectively) felt that these activities helped learning a moderate to significant amount.

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Table 1. – Sample Section of SALG Post-Survey Including Results

Class Activities (N=16)						
6.	*1: No Help*	*2. A Little Help*	*3. Moderate Help*	*4: Much Help*	*5: Great Help*	*9: Not Applicable*
6.1	0%	6%	6%	19%	69%	0%
6.2	0%	12%	25%	25%	38%	0%
6.3	*1: No Help*	*2. A Little Help*	*3. Moderate Help*	*4: Much Help*	*5: Great Help*	*9: Not Applicable*
6.3.1	0%	12%	31%	38%	19%	0%
6.3.2	0%	31%	6%	38%	25%	0%
6.3.3	6%	19%	12%	38%	25%	0%

Table Legend
6. How Much Did Each Of The Following Aspects Help Your Learning?
6.1 Attending Lectures
6.2 Participating In Discussions During Class
6.3 Specific Class Activities
6.3.1 Debunking Pseudoscience Video Project
6.3.2 Debunking Pseudoscience Discussion Activities
6.3.3 Various Pseudoscience Articles Presented In Class

Students were also given the ability to write comments about specific questions. One student said, “The class activities allow me to look at articles on various sources in a different way, while assess[ing] whether the points made are valid.” Another stated that, “The video project was a great help for me in understanding how to critically think about information presented to me.”

As compared to the SALG surveys (*26*), which asked direct questions about the pseudoscience assignments and activities, the SSIs provided more general feedback about students’ impressions of the course as a whole. Although there were no specific questions about the video project on the SSIs, many students added written comments about their impressions of the project. Overall, these unsolicited comments were positive in regards to the video project. Many students seemed to enjoy the project, saying, “I like working well with other students through labs and other group activities” and “The research/video project allowed for exploration of the subject matters that interest us.” However, several students wrote that they did not enjoy the video project (e.g., “no video project” was written multiple times in the section for suggested changes to the course).

Connection to Information Literacy Goals

The survey results about the project can be discussed in the context of the American Library Association’s “Framework for Information Literacy for Higher Education (*28*).” The ALA Framework concepts “Authority is Constructed and Contextual” and “Information Creation as a Process” were a focus of this project.

Based on the data obtained from SALG surveys and SSIs, the pseudoscience activities provided development of (and reinforcement of) information literacy skills.

Looking specifically at the "Authority is Constructed and Contextual" frame, when students analyzed sources for their project, they sought authoritative voices and valid information, and they were encouraged to develop an "attitude of informed skepticism (*28*)." This video project required students to skeptically engage with the sources of information that they found related to their project topic. In addition, it extended into the social aspect of information creation and publication, since much information that students saw was through social media. Students had to keep a skeptical mind when viewing information, and they made the effort to seek and analyze the sources of that information. Additionally, the activities required the students to look at primary literature in comparison to the information they saw online and in other forms of media. This allowed them to explore a variety of "Authorities" of scientific information and use the PseudoBS Meter as a qualitative metric. The key word of this authority frame is "skepticism," and skeptical reading of materials was expected to be a significant long-term takeaway of this project for these students.

The other Framework that connected strongly to this video project was the frame "Information Creation as a Process." Through the course of researching their topics, students began to understand the process marketers use to build a believable, yet pseudoscientific, foundation for their consumer products. They were then able to apply this understanding of "the significance of the [information] creation process (*28*)" to the creation their own information product, i.e. their video.

Future Plans for Improvement

The video project has undergone some modifications since its inception, focused largely on improving the rubric. Previously, for example, the students were encouraged but not required to use the PsuedoBS Meter. This will now be a requirement. In the future, the SALG surveys will be adjusted to focus more directly on not only the development of the critical thinking skills and information literacy skills of the students but also on how the project and its outcomes may be correlated to student performance in the class. Direct data about students' development of information literacy skills will be acquired by matching questions between the Pre- and Post Surveys. While the project's goals of improving critical thinking skills and information literacy are important, it is equally important to help the students connect what they are seeing in the media to general chemistry concepts. The link between chemical concepts and information literacy will be another significant area of focus in the future.

For the benefit of the students, they will be encouraged to practice public speaking, perhaps with short presentations in class or in front of a camera, so that they are less nervous when it is time to record their videos. This can be accomplished in Discussion in concert with some of the pseudoscience assignments.

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Conclusion

As Carl Sagan stated, "Wherever possible there must be independent confirmation of the 'facts (*29*).'" General Chemistry students at UW-Sheboygan were tasked with finding and researching a topic of pseudoscience in connection with chemistry, then developing a video project and summary to describe what they found. The purpose of this exercise was to develop and enhance critical thinking and information literacy skills in connection with general chemistry concepts. Students must be given the tools to be able to take information presented to them, regardless of the media source, and make an accurate value judgment about that information. The activities described herein contributed to improved student abilities to think critically and to the development of information literacy skills. The result would be to alter each student's perception when they look at scientific and pseudoscientific information presented to them. The informed skepticism developed from this project would hopefully give them the tools needed to be able to distinguish scientific information from pseudoscientific hokum.

References

1. Wombles, K. *Too Good To Be True: Facebook As A Medium To Spread Pseudoscience*; Science 2.0; http://www.science20.com/countering_tackling_woo/too_good_be_truefacebook_medium_spread_pseudoscience-88065 (accessed June 29, 2016).
2. Francl, M. The Internet helps spread pseudoscience, and how to fight it. *Chem. Eng. News* **2015**, *93*, 13.
3. Francl. M *The dangerous chemophobia behind its popular story about childhood arthritis*; http://www.slate.com/articles/health_and_science/medical_examiner/2013/02/curing_chemophobia_don_t_buy_the_alternative_medicine_in_the_boy_with_a.html (accessed July 11, 2016).
4. National Science Board. *Science and Engineering Indicators−2000*; NSB-00-1; National Science Foundation: Arlington, VA, 2000.
5. National Science Board. *Science and Engineering Indicators−2002*; NSB-02-1; National Science Foundation: Arlington, VA, 2002.
6. National Science Board. *Science and Engineering Indicators−2004*; NSB 04-1, NSB 04-1A; National Science Foundation: Arlington, VA, 2004.
7. National Science Board. *Science and Engineering Indicators−2014*; NSB 14-01; National Science Foundation: Arlington, VA, 2014.
8. *Dental-Professional.com*; http://www.dental-professional.com (accessed June 16, 2016)
9. McCoy, T. Amid measles outbreak, anti-vaccine doctor revels in his notoriety. *The Washington Post*; https://www.washingtonpost.com/news/morning-mix/wp/2015/01/30/amid-measles-outbreak-anti-vaccine-doctor-revels-in-his-notoriety/ (accessed February 2, 2015).

10. Lynas, M. Even in 2015, the public doesn't trust scientists. *The Washington Post*; https://www.washingtonpost.com/posteverything/wp/2015/01/30/even-in-2015-the-public-doesnt-trust-scientists/ (accessed November 17, 2015).
11. Omer, S. B.; Salmon, D. A.; Orenstein, W. A.; deHart, P.; Halsey, N. Vaccine refusal, mandatory immunization, and the risks of vaccine-preventable diseases. *N. Engl. J. Med.* **2009**, *360*, 1981–1988.
12. Kim, S. S.; A., J.; Rivers, P. A.; Kronenfeld, J. J. Effects of Maternal and Provider Characteristics on Up-to-Date Immunization Status of Children Aged 19 to 35 Months. *Am. J. Public. Health.* **2007**, *97*, 259–266.
13. Natural News. http://www.naturalnews.com (accessed May 25, 2016).
14. Food Babe. *http://foodbabe.com* (accessed May 25, 2016).
15. Hoyt, C. The Doctors Are In. The Jury Is Out. *New York Time*; http://www.nytimes.com/2008/02/17/opinion/17pubed.html?pagewanted=all (accessed November 15, 2015).
16. Kloor, K. When Media Uncritically Cover Pseudoscience. *Discover Magazine*; http://blogs.discovermagazine.com/collideascape/2013/04/26/when-media-uncritically-cover-pseudoscience/#.Vko_y9-rSRs (accessed July 10, 2015).
17. DeGregori, T. R. *Pseudo-Science and the Media: Problems and Lessons.* Cato Institute http://www.cato.org/publications/commentary/pseudoscience-media-problems-lessons (accessed July 16, 2015).
18. Allen, E. S.; Burke, J. M.; Welch, M. E.; Rieseberg, L. H. How reliable is science information on the web? *Nature* **1999**, *402*, 722.
19. Anderson, J. Q.; Rainie, L. *Millenials will benefit and suffer due to their hyperconnected lives*; http://www.pewinternet.org/files/old-media/Files/Reports/2012/PIP_Future_of_Internet_2012_Young_brains_PDF.pdf (accessed August 23, 2016)
20. de Milt, C. The value of the history and philosophy of science in the training of graduate students in chemistry. *J. Chem. Educ.* **1952**, *29*, 340–344.
21. Kamsar, J. W. Utilizing a historical perspective in the teaching of chemistry. *J. Chem. Educ.* **1987**, *64*, 931–932.
22. Schwartz, A. T. The history of chemistry. Education for revolution. *J. Chem. Educ.* **1977**, *54*, 467–468.
23. Head, A. J.; Eisenberg, M. B. How College Students use the Web to conduct everyday life research. *First Monday.* **2011**, *16*, 4.
24. The UW Colleges does have complete access to all ACS journals, so that is the focus of discussions about journals. Few other journals are made directly available to our students, though they do have access via interlibrary loan from the UW System comprehensive institutions.
25. Vaccine Truth. http://vaccinetruth.com (accessed May 25, 2016)
26. *Student Assessment of Their Learning Gains*; http://salgsite.org (accessed October 15, 2015).
27. *UW Colleges Senate Policy Institutional Personnel Policy Affecting Faculty and Academic Staff #301.01 Administering the Student Survey of Instruction*; http://www.uwc.edu/sites/uwc.edu/files/imce-uploads/employees/senate/

Publication Date (Web): October 20, 2016 | doi: 10.1021/bk-2016-1232.ch014

policies/ip301.01_administering_the_student_survey_of_instruction_2015-01-22.pdf (accessed August 17, 2016).
28. ACRL. *Framework for Information Literacy for Higher Education*. http://www.ala.org/acrl/standards/ilframework (accessed June 20, 2016).
29. Sagan, C. *The Demon-Haunted World: Science as a Candle in the Dark*; Ballantine Books: New York, 1995; pp 245−267.

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Chapter 15

Student Engagement Through Writing: An Undergraduate e-Journal Project

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The development of strong communication skills is important in scientific endeavors. We report here on the development of a strongly scaffolded essay writing project that has been incorporated into a first-year course in nanoscience. Various instructional events are timed throughout the semester to provide just-in-time support for students as they work on the project. The undertaking is structured around final publication in an online journal, hosted by the university's library, for the top submissions. The journal is powered by open-source software that manages a double-blind peer review process along with expert reviews. Students edit their submissions informed by this feedback and are graded on both their submissions as authors and also the reviews they submit on their peers' work. Scaffolding activities include reading primary literature articles, strategic search strategies, scientific writing skills, academic integrity, and peer reviewing. Students strengthen their writing skills and familiarize themselves with the communication side of the competitive scientific enterprise as about a quarter of the submissions are then selected for publication in the e-journal.

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Introduction

Literacy and communication skills are widely acknowledged as being central goals of a well-rounded STEM education (*1–3*). The role of the scientist is said to include not only the understanding of past and current science theories and experiments, the planning and execution of new experiments to test new hypotheses and develop new theories, but also the communication of those results and ideas to the wider science community and the public at large. This communication component is as integral to the role of the scientist as are the experimental and theoretical aspects.

Writing is one of these important modes of scientific communication. The production of reports and journal articles is widely seen as the most visible evidence of scholarly accomplishment. As a student matures into a professional scientist, it is expected that their written communication skills will grow proportionally. A successful educational program will include activities to aid in this growth.

A complementary perspective views writing as performing an essential pedagogical role, enabling an engaging activity that can help a student construct new meaning and knowledge about a subject. The need to reason through an argument in order to produce a written document can be transformative to one's way of thinking. Writing not only allows one to put their thoughts down, but the act of doing so can also shape the final form those thoughts may take.

These two perspectives have been implemented in various ways over the years. Writing as Professionalization (WAP) (*1*) or Learning-to-Write (LTW) (*4–13*) activities focus on both the technical and conceptual aspects of writing well, particularly within the context of reporting on or arguing in a scientific forum. The companion approach – often called Writing-to-Learn (WTL) (*2*, *3*, *14–21*) – focuses more on using writing as a tool to encourage learning and in particular, the development of skills such as critical thinking (*22*, *23*). Occasionally, other writing activities are employed in classrooms (*24–26*), often with a disciplinary learning goal as the principal objective.

While communication skill development is perceived as being central to a successful science education program, it nevertheless seems to have taken a secondary role in most undergraduate science, technology, engineering, and mathematics (STEM) programs of the past. While most programs would include some arts electives that would often require essay writing, the application of these skills in a science context was not emphasized. Occasionally a program would include a science writing course which, while being effectively taught by writing professionals, could be perceived by the student as being separated from their science education.

Curriculum committees housed in a science department tend to create a practical science curriculum. Writing is not explicitly taught except when passed off to external units (such as the English Department) in the form of electives. This is done while they also proclaim the importance of writing and speaking well.

In the authors' experience in reviewing proposals for new courses and programs as they progress towards the faculty Senate for approval, the applicants will commonly explain how their course will address literacy and communication learning objectives by indicating that the students will be required to write lab reports. While some will distinguish between formal and informal lab reports, it is our view that either task represents a rather modest effort in promoting and developing these communication learning objectives.

An additional problem arises with the types of writing assignments generally given in STEM courses. Instructors often require written lab reports, assign the writing of short essays, and may even allocate class time for a series of oral presentations from the students. And while the best instructors provide feedback to the students on their performance with suggestions for improvement, often time is not dedicated in class to actually teach these written or oral communication skills in advance of the assignment. By contrast, we would not think to give a conceptual chemistry assignment without having discussed in some fashion the theories and mathematical foundations relevant to that task. But in essence, this is what is done with these communication activities. Perhaps it is believed that students should have brought those skills with them from high school or developed them in their arts electives. While students will have been taught some useful tools for organizing their thoughts and structuring their arguments in these other forums, the translation of those ideas into the scientific realm is neither a trivial nor an obvious task. Instructors in STEM disciplines should not be surprised as they lament the state of student writing when in their classes they have only assigned and graded student written work but have never actually taught those skills in the classroom.

Since the STEM learning community believes that writing well in a manner that communicates scientific ideas effectively and persuasively is an important, even central, characteristic of a successful scientist, instructors should be more prepared to make honest space for it in the curriculum. Some might respond to this request by augmenting the number of arts electives, and that could benefit the students. From the authors' perspective, however, we feel that science educators need to assume a greater responsibility for making space for the development of these skills in STEM curricula and actually teach these communication skills.

To this end, the authors' have embedded a science writing task in a first semester science course for students in the nanoscience major in our B.Sc. program. This has become a substantial component of the course and has been developed over several years through a close collaboration between the course instructor (Thomas) and a university librarian (Pritchard) at the University of Guelph.

Origin

In 2008 the University of Guelph launched a new undergraduate major in Nanoscience, sponsored jointly by the Department of Chemistry and the Department of Physics. To support this major, 13 new courses were developed, including a first-year course entitled "Introduction to Nanoscience" which one of the authors (Thomas) was responsible to develop. Since it was a new course, it was not bound to an existing body of content. This proved to be very valuable

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since the introduction of a substantial writing activity to an existing course would require the removal of some content, which can prove difficult for many reasons. It was judged important to include a substantial writing activity in the course but the course developer had never undertaken the assigning and grading of extensive written work in the past. To aid with this task, help was sought from a liaison librarian (Pritchard) for guidance in how to effectively grade student essays.

Rather than just responding directly to the inquiry, help was provided that expanded the scope of the project, making it considerably more meaningful and worthwhile. An electronic journal was developed using the open-source journal management software called Open Journal Software (*27*) which is hosted by the university library. The software is part of the Public Knowledge Project (*28*), a multi-university initiative to develop open-source software to support scholarly communities. The journal is called "da Vinci's Notebook (*29*)" and is at the center of the academic activity described herein. Figure 1 is a screen shot of the homepage for the journal showing the table of contents for Volume 6. The journal recreates the professional scientific writing environment that includes electronic submission, the management of a double-blind peer-review process, submission of revisions, the adjudication results, and finally the online publication of the accepted papers. This Writing-as-Professionalization (WAP) activity helps to engender student engagement by inspiring them towards becoming published scientific authors by the end of their first semester, while also providing them with an introduction to this important aspect of a competitive scientific career. This instructor/librarian collaboration has continued and has enabled the joint delivery and refinement of the course each year by adjusting and expanding the various scaffolding activities.

The Assignment

While this is a first-year course, the enrollment is restricted to students enrolled in the nanoscience major (*30*) and as such the class size is typically 20 students. They are assigned to write an article of about 1500 words on a nanoscience topic and are asked to pitch the level of the essay to be understandable by an informed layperson. The overall scope is explained at the beginning of the course and the description of the editorial process outlined. Students soon appreciate that they are to become both scientific authors and peer reviewers as they register with the journal for both roles. The Open Journal Software manages the entire process. For the first offering of the course, the assignment was set to be a 750-word essay, but it became very clear that this provided insufficient opportunity for the students to develop their ideas effectively. The 1500-word essay has since proven to be more successful.

Assigning students to write an essay is not unusual. However, in the sciences, it *is* unusual to actively teach students about the essay development process and so the establishment of a more holistic essay assignment became the desired objective. We perceived a large difference between teaching the creation of an essay as compared to just assigning the task, and sought to close this gap with meaningful activities designed to teach students different aspects of the scientific writing process. The collaboration between instructor and librarian proved critical in developing these supporting assets. From the outset, it was determined that if this writing project was truly important, then it was essential to demonstrate that importance by making space for teaching it in the course. Creating this space during the development of the course made it easier to accomplish. Even once established, it continues to be essential to guard against efforts to squeeze out these in-class communication activities in preference to the insertion of more traditional science content. The course was once taught by another faculty member whose one recommendation for the course was to move all the writing associated activities to handouts or seminars outside of the class, which would make room for more academic pursuits. This is precisely what we want to ensure does *not* happen.

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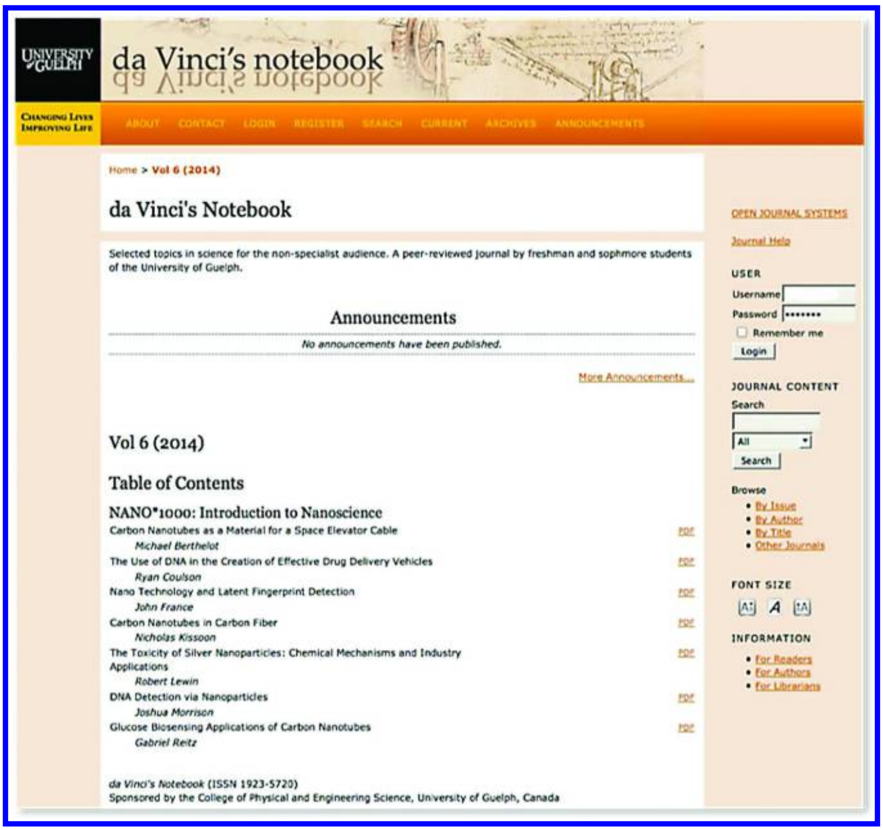

Figure 1. Home page for the on-line journal "da Vinci's Notebook (29)" showing the Table of Contents for Volume 6 (2014). The journal has been created using Open Journal Systems software specifically for the purpose outlined in this paper. Reproduced with permission from the University of Guelph, College of Physical and Engineering Science.

The Scaffolding Activities

The scaffolding activities are the distinguishing features that enhance the educational aspects of the assignment. During the first offering of the course, the need for each of these activities became apparent. The semester at the University of Guelph is 12 weeks long which affords us 36 one-hour classes. We needed to insert these activities at the right time during the semester to support their essay writing process in a "just-in-time" manner.

Reading a Journal Article

The class consists of first-semester students who arrive straight out of high school. Their exposure to scientific writing is negligible and generally confined to more popular science writing. They have not been exposed to the ideas of evaluating others' writing nor to assess the possibility that something found in print may actually be wrong. Critical evaluation skills are yet to be considered by them, much less developed. The first step is to help them learn to read journal articles for as they choose their topic, they will need to scan the literature and select papers to read in order to develop their ideas.

These articles can be foreboding and overwhelming to them. Reading the primary literature remains a demanding task even for experienced scientists. Knowing how to approach the primary literature in an efficient and effective manner is important. We take one lecture and instruct students in a three-prong approach which we have called "Sniff, Browse, and Study" (see Figure 2). These three approaches are employed depending the depth to which one wants to explore a certain paper or correspondingly the length of time one has available. Each year, we select a paper from the recent literature and work through it during one class period, highlighting these three levels of analysis.

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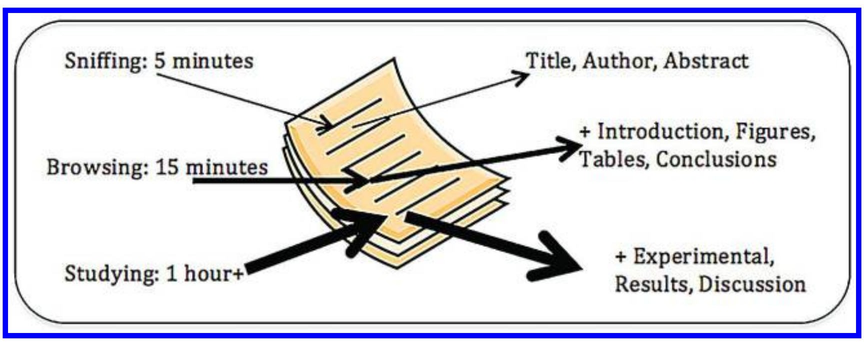

Figure 2. The three levels of exploring a journal article, based upon the amount of time spent and the components of the journal investigated.

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Sniff – 5 Minutes – A Basic Idea of the Subject

We first suggest that a 5-minute reading would just look at the title, authors, and abstract. What do you know of these authors already? Who is the principal investigator? Do you understand the title? What is the general subject area? If the abstract is well-written, you should be able to understand the purpose or goal of the research and identify the principal claims that are being made.

Browse – 15 Minutes – A Rough Understanding of the Work

With more time available, or perhaps when the 5-minute read suggests we need more details, we look more deeply at the article by reviewing the figures and tables and their captions, along with a reading of the conclusion section. A well-written journal article probably started with the identification of the figures and tables that the authors wanted to highlight. They then expanded their paper by writing around these items. Understanding the figures means understanding the paper's central theme. What experiments were completed? Is the data convincing? Do the figures correlate well with the claims being made in the conclusions section of the paper? What do you still not know about the work?

Study – 1 Hour or More – Tackle the Paper in Detail

The rest of the paper provides the details and explanation necessary to fully understand the significance and applicability of the work. Why this particular substance? Could you replicate the synthesis? … the analysis? What theories have been used to explain the work? How solid are their conclusions? How does the work of others underpin this work? After studying this paper in detail, you should be able provide a couple of sentences on these 8 conceptual areas (*31*): (1) What was the authors' purpose? (2) What question did the authors address? (3) What point of view characterized this particular work? (4) What were the authors' assumptions? (5) What data and evidence was produced in the paper? (6) What theories, laws, or principles guided the author's analysis? (7) What were the conclusions and interpretations presented in the paper? (8) What are the implications and consequences of this work?

While it will take a career to finely hone the skills to implement this approach, it nevertheless provides the students with a framework to start looking for material on which to base this writing assignment.

Selection of Topic

The original intent was to provide students the opportunity to scan the literature and bring forward a topic that was of interest to them. However, it soon became clear that these first-semester students were not able to do this effectively. Rather than being liberating, it became a frustrating burden to them. In conjunction, when they did select a topic, they commonly adopted one which was either too broad or too narrow for their skills and for the 1500-word limit on the essay. Since the students clearly needed substantial guidance in this initial phase, the process provides two supporting activities. First, a lecture period is employed to introduce a method to help in refining and narrowing the students' topic. The method consists of a brainstorm-collate-decide loop (see Figure 3), which students follow at least three times. This helps them generate a collection of terms related to their beginning area, review them, cluster them into similar ideas, and pick one, which then becomes the general area for the next iterative loop. Two to three times through this loop usually helps students to narrow the scope of their proposed topic. Additionally, it is sometimes essential to get them started with some ideas taken from a list of about 30 appropriate topics provided by the instructor. Just viewing the list often sharpens their sense of what is needed in the topic selection process. Even though they are permitted to draw directly from the supplied list, most still end up selecting their own topics.

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Strategic Literature Search Methods

The librarian takes a lecture class to discuss the methods for searching the academic literature. She selects a nanoscience topic and refines it following the strategy suggested above and instructs them in the following procedure for searching the literature (see Figure 3). First they search the web through Google or Wikipedia and harvest related terms, building up a keyword chart with their related terms which are both broader and narrower. With this completed chart, they find that they have created a list of terms upon which they will base their literature search. This is approached both through the university's electronic resources as well as appropriate scientific databases available to the university, such as Web of Science or Google Scholar. The use of word truncation and wild card characters is demonstrated. Phrase searching and Boolean search parameters are explained. Finally, they are shown how to critically evaluate their results and how to use their keyword matrix to adjust their search parameters. With this, they are able to identify approximately three papers or more upon which they will base their essay.

Scientific Writing

Associated with the university library is a Writing Centre with a substantial number of professional and student peer writing guides. This includes some who focus on science writing in particular. We dedicate a class period to bring one of the science writing professionals to the class and they provide some introductory instruction in academic science writing. The instruction centers on building paragraphs to logically present an idea in an informed, persuasive manner. This is done by presenting a topic sentence, followed by the evidence relative to that topic, and a concluding sentence that highlights the significance of that idea. Students are also taught about passive vs. active voice, the proper use of pronouns, and methods to coherently transition between related ideas.

Academic Integrity

In conjunction with the academic writing piece, we invite another writing professional to instruct them regarding academic integrity in their writing. The importance of integrity in the academy and the motivation they should develop for aspiring to a career of integrity is discussed. At the University of Guelph, violations of academic integrity are grouped into four general areas: "(1) misappropriation of others' work, (2) misrepresentation of personal performance and fraud, (3) improper access to scholarly resources, and (4) obstructing others in pursuit of their academic endeavours (*32*)."

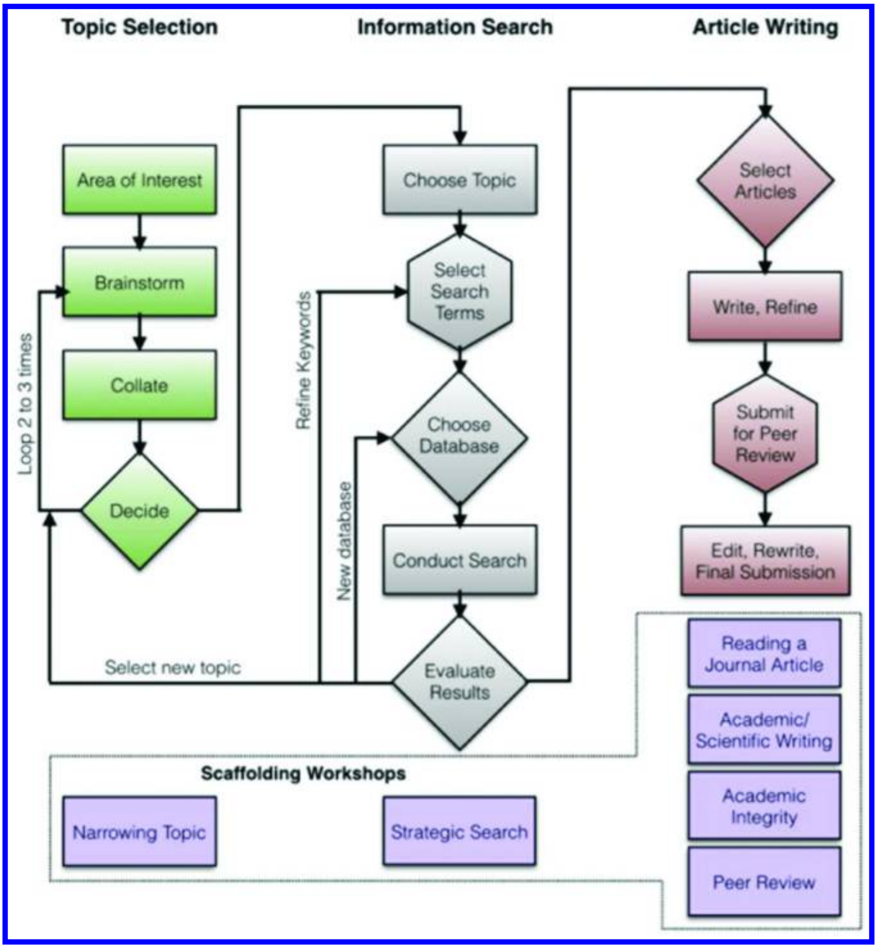

Figure 3. A flowchart of the overall essay writing strategy taught to students. The three phases of topic selection, information acquisition, and essay writing are highlighted. Also shown are the various scaffolding workshops provided at the appropriate time during the course.

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In our course, the focus of attention is on item (1) above as manifested in plagiarism. Students are taught to use no more than 20% paraphrased material in their work with no more than four of the same words in a row. The importance of fully understanding the source to which they are referring is emphasized. This is important in order to eliminate plagiarism. They are also instructed that their paraphrasing will involve four important aspects: (a) the adjustment of sentence structure, (b) the use of synonyms and alternate word forms, (c) the preservation of the original author's intent, and (d) proper citation methods. They then work through the process of appropriately paraphrasing scientific work and they study a number of examples of material that has been well paraphrased and some which do not meet the standards of integrity we are seeking to promote.

Peer Reviewing

Peer review is often an integral component of writing activities (*4*, *7*, *19*, *33*, *34*) and a very important component of this assignment is the double-blind peer review process. Too often, peer reviewing is used to decrease the instructor's marking load, but this misses an important opportunity for teaching about writing. We have developed a process for students to use when analyzing their peers' work and this guides the report that they provide back. While they evaluate three of their classmates' work we have found that this process of evaluation significantly contributes to their being able to critically assess their own work. We take a lecture period and discuss the peer review process with an emphasis on their report being specific and constructive while identifying the strengths, weaknesses, and errors in the paper. Throughout all this, they are instructed to be respectful in their comments. They focus on five aspects of the paper: the topic, the organization, the argumentation, the writing style, and the citation and referencing. After going through this three times, they are well prepared to receive the feedback from their peers regarding their own work and the editing can proceed more easily.

Expert Reviewing

The peer reviews the students receive are valuable, but the feedback from experts is still important at this stage of their development. As such they receive four more reviews. The course instructor provides feedback on the science in the article, with an aim to ensure they are understanding the work they are discussing and reporting it accurately. The librarian provides feedback on the citation and referencing used in the paper and the writing specialist also provides some critical comments on the work. An interesting twist has provided for a fourth quasi-expert review wherein we have paired with a fourth-year class in the same nanoscience major and have invited those students to also provide a critical review of the freshman students' work. These senior students took the same course three years earlier and have a unique perspective on the activity as their own writing skills have matured over the years. They take considerable pride in providing this feedback. The quality of their reviews are assessed by their course instructor and they receive a grade that accounts for 5% of their final grade in their own course.

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Grading Rubrics

Two rubrics have been developed over the years to assist in the grading of the course. One rubric (Tables 1 and 2) has been created to grade the written assignments. This is used first of all by the students in preparing their peer reviews. They see directly how this written work will be evaluated and submit their comments structured in a similar fashion. At the end of the course, the instructor uses the same rubric to determine a final grade for each student's paper.

A second rubric (Table 3) that is used to evaluate the peer reviews has been developed. Students are also aware of this rubric when they write their reviews and the instructor assesses their work according to this rubric.

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The Schedule

All of these activities are spaced throughout the semester to match a timetable that helps to keep the students on track with their assignment. Table 4 shows the week in which the specified activity is presented or when an item is required to be submitted. Students first submit their essay in week 9. It has been found that it is best to not to refer to this first submission as a "draft" document. This activity attempts to mimic the scientific journal writing process, and professional scientists must always submit their best work to the journal, even though they know it will be critically reviewed by others whose comments they often adopt during further editing. As educators, we do not want students to submit an incomplete document, believing they will fix it up for the final submission. Nevertheless, it is only the final submission and the peer reviews they submit which contribute to their course grade.

The Outcome

By the end of the semester, all students will have submitted an essay that has been prepared during the better part of a 12-week semester. It has been reviewed by three peers and as many as four professionals who have all provided feedback regarding both content and organization. They have also been reviewers themselves, looking critically at the work of others and reflecting on their own submission in light of what they learn from the perspective of being an evaluator. All of this converges to the submission of a final document which is then graded according to the published rubric and is combined with other course components to obtain the final grade.

Table 1. Page 1 of the Rubric Used by the Instructor to Grade Students' Essays

Dimension/ Performance	***Exemplary 3 Exceeds Expectations***	↔ □	***Beginning 0 Does Not Meet Minimum Requirements***	*Sc-ore*
Topic & Length Definition Completeness Length of Paper	Topic clearly defined, narrow enough for article of this length AND Paper includes informative discussion of context and significance AND Paper within (or just slightly over) 1,500-word limit (excluding references)	↔ □	Topic poorly defined and/or too broad for article of this length AND/OR Superficial handling of context and/or significance AND/OR Paper well exceeds 1,500-word limit or falls below 1,200 words (excluding references)	**/3**
Organiza-tion	Organized in a logical, easy-to-follow sequence, from introduction, step-by-step through body, to clear summary, conclusion	↔ □	Disorganized; lacking introduction and/or conclusion; sequencing within body not obvious and/or illogical	**/3**
Argumenta-tion	Clear, focused, well-articulated, evidence-based; science is accurate and correctly explained	↔ □	Fails to stay on topic; main points unclear; science incorrectly explained; lacks appropriate evidence	**/3**
Use of English	Rare errors in spelling, grammar, punctuation; accurate and appropriate use of terms; smooth transitions between ideas	↔ □	Frequent errors in spelling, grammar, punctuation; inaccurate and/or inappropriate use of terms (e.g., jargon, colloquialisms)	**/3**
Academic Writing Style	Objective; concise in making points; important scientific terms/concepts defined properly and used precisely	↔ □	Informal writing style (e.g. uses personal pronoun, many contractions, slang), and/or fails to define important scientific terms/concepts; and/or expresses opinion rather than presents evidence	**/3**
TOTAL				**/15**

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Table 2. Page 2 of the Rubric Used by the Instructor to Grade Students' Essays

Dimension/ Performance	*Exemplary 100% Exceeds Expectations*	*Accomplished 70% Meets Expectations*	*Beginning 0% Does Not Meet Minimum Requirements*	*Score*
Number and Type of Sources	Uses more than four sources including one book, one review article, and one appropriate website	Uses four sources including one book, one review article, and one appropriate website	Uses fewer than four sources OR lists four but is missing one or more of the required types	/2
Quality of Sources	All sources are of high quality (e.g. current, accurate, authoritative) AND appropriate to the topic	All sources are reliable and appropriate to the topic	One or more sources are of questionable quality and/or are unrelated to the topic	/3
	100% Meets Expectations		**0% Does Not Meet Requirements**	
Citations	Each source cited at least once within the body of the paper	n/a	Not all sources are cited within the body of the paper	**/1**
Style	Citing & referencing conforms to ACS NanoLetters style throughout	n/a	Citing & referencing does not conform to ACS NanoLetters style OR uses it inconsistently	**/1.5**
TOTAL				**/7.5**

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Table 3. Rubric Used by Instructor to Grade Students' Peer Reviews. Each Student Reviews the Work of Three Peers in the Double Blind Review Process, Which Is Assigned and Submitted through the Open Journal Software System.

Dimension/ Performance	***Exemplary*** *2 Exceeds Expectations*	***Accomplished*** *1 Meets Expectations*	***Beginning*** *0 Does not meet Minimum Requirements*	*Score*
Number of Reviews	Not applicable	Reviewer submitted three reviews	Reviewer submitted less than three reviews	/1
Content of Review Strengths Weaknesses Errors	Identifies at least one strength, one weakness and one error AND provides specific, constructive feedback on how to improve and/or correct the manuscript	Identifies at least one strength, one weakness and one error in the manuscript	Fails to identify one strength, one weakness and one error in the manuscript	/2
Communication of Ideas in Review Clarity Organization Respect	Comments expressed in clear, precise language, logically constructed and concise; language and tone consistently respectful	Key points understandable; review logically organized; word choice and phrasing demonstrate sensitivity to author of manuscript	Review unclear, poorly organized, and/or uses harsh or careless language and tone	/2
TOTAL				/5

Table 4. Schedule of Scaffolding Events and Submission Deadlines Paced Throughout the Semester

Introduction of Assignment	Week 1	
How to Read a Journal Article	Week 2	
Selection of a Topic	Week 3	Submit for approval
Strategic Literature Search Methods	Week 4	
Scientific Writing/Academic Integrity	Week 6	
Peer Review Workshop	Week 9	
Complete Essay	Week 9	Submit
Peer Reviews completed	Week 10	Submit
Peer and Expert Reviews returned	Week 11	Receive them back
Edit Final Document	Week 12	Submit

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After the semester's end, the course instructor assumes the role of journal editor and reviews the papers to select a subset for publication. Those papers which have stood out as being particularly clear, informative, and communicative are earmarked for publication in the electronic journal. At the beginning of the next semester, those students so identified are invited to meet again with the science writing specialist from the library to go over their paper once more to ensure an excellent product. Following their final editing, they resubmit the edited version and the journal editor (the course instructor) formats the papers to fit a consistent journal presentation, creates that volume's table of contents, and uploads the documents for public viewing (an example of the first page of a student's paper is shown in Figure 4). And the students call their parents to view their work online.

While the learning objectives around this activity can be accomplished in any classroom environment, the online publication of student work in the form of da Vinci's Notebook contributes to the Writing-as-Professionalization objective and encourages student engagement. The support of the library is essential for this publication. The journal discussed herein is 1 of 17 academic journals that are currently hosted by the University of Guelph library using the same software platform. Journal editors can be fully trained to maintain and modify the website itself as well as upload all content. The library, however, maintains IT support that can help at any level, including the uploading of content and the creation of the next issue's table of contents. With the library's commitment, the online journal format is manageable with little technical expertise required of the editor, whose extent of technical involvement can vary significantly depending upon their interests.

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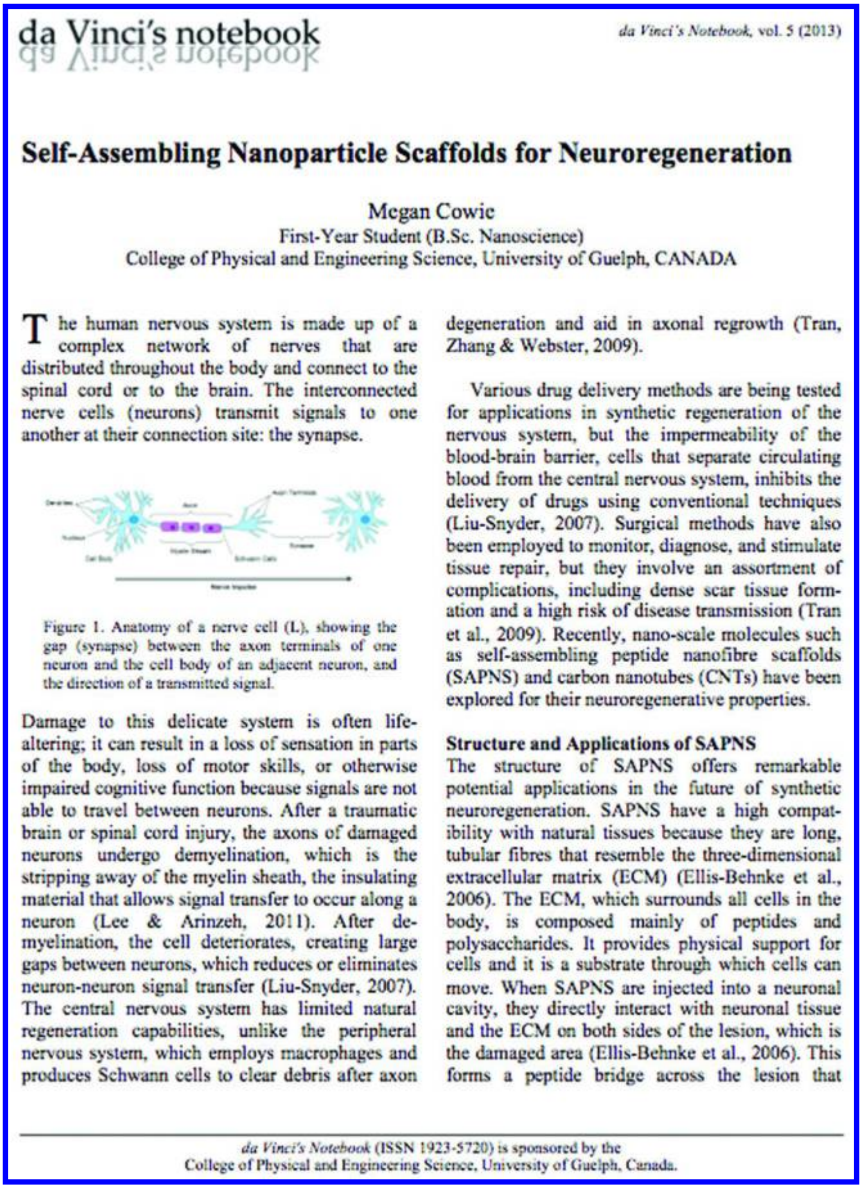

da Vinci's notebook

da Vinci's Notebook, vol. 5 (2013)

Self-Assembling Nanoparticle Scaffolds for Neuroregeneration

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The human nervous system is made up of a complex network of nerves that are distributed throughout the body and connect to the spinal cord or to the brain. The interconnected nerve cells (neurons) transmit signals to one another at their connection site: the synapse.

Figure 1. Anatomy of a nerve cell (L), showing the gap (synapse) between the axon terminals of one neuron and the cell body of an adjacent neuron, and the direction of a transmitted signal.

Damage to this delicate system is often life-altering; it can result in a loss of sensation in parts of the body, loss of motor skills, or otherwise impaired cognitive function because signals are not able to travel between neurons. After a traumatic brain or spinal cord injury, the axons of damaged neurons undergo demyelination, which is the stripping away of the myelin sheath, the insulating material that allows signal transfer to occur along a neuron (Lee & Arinzeh, 2011). After demyelination, the cell deteriorates, creating large gaps between neurons, which reduces or eliminates neuron-neuron signal transfer (Liu-Snyder, 2007). The central nervous system has limited natural regeneration capabilities, unlike the peripheral nervous system, which employs macrophages and produces Schwann cells to clear debris after axon degeneration and aid in axonal regrowth (Tran, Zhang & Webster, 2009).

Various drug delivery methods are being tested for applications in synthetic regeneration of the nervous system, but the impermeability of the blood-brain barrier, cells that separate circulating blood from the central nervous system, inhibits the delivery of drugs using conventional techniques (Liu-Snyder, 2007). Surgical methods have also been employed to monitor, diagnose, and stimulate tissue repair, but they involve an assortment of complications, including dense scar tissue formation and a high risk of disease transmission (Tran et al., 2009). Recently, nano-scale molecules such as self-assembling peptide nanofibre scaffolds (SAPNS) and carbon nanotubes (CNTs) have been explored for their neuroregenerative properties.

Structure and Applications of SAPNS

The structure of SAPNS offers remarkable potential applications in the future of synthetic neuroregeneration. SAPNS have a high compatibility with natural tissues because they are long, tubular fibres that resemble the three-dimensional extracellular matrix (ECM) (Ellis-Behnke et al., 2006). The ECM, which surrounds all cells in the body, is composed mainly of peptides and polysaccharides. It provides physical support for cells and it is a substrate through which cells can move. When SAPNS are injected into a neuronal cavity, they directly interact with neuronal tissue and the ECM on both sides of the lesion, which is the damaged area (Ellis-Behnke et al., 2006). This forms a peptide bridge across the lesion that

da Vinci's Notebook (ISSN 1923-5720) is sponsored by the College of Physical and Engineering Science, University of Guelph, Canada.

Figure 4. First page of a student's article in the da Vinci's Notebook journal. Reproduced with permission from reference (35). Copyright College of Physical and Engineering Science, University of Guelph (2013).

Flener Lovitt et al.; Integrating Information Literacy into the Chemistry Curriculum
ACS Symposium Series; American Chemical Society: Washington, DC, 2016.

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Future Plans

We continue to review and adjust this writing activity each year. Anecdotal reports from instructors in senior science courses wherein these nanoscience majors are classmates with chemistry and physics majors indicate that the nanoscience students demonstrate better communication skills than their peers who have not been through this process. We feel it is important to continue and expand these opportunities for students.

One improvement that could be implemented would be to provide a series of paragraph-level writing assignments throughout the course. The science writing instruction really focuses on creating well-developed paragraphs and student work that regularly returns to these principles will likely contribute to a better final essay and to writing habits that will serve them well for the rest of their careers.

To make a lasting improvement, however, it is believed that the adoption of similar activities in other courses will be important. The challenge, of course, is that those existing courses are already filled with science content that instructors would be loath to shrink to make space for the new activity. This is a common problem. One might hope that the extensive scaffolding in this first semester course would reduce the amount required in the future. But it would be folly to return to the common practice of simply assigning and grading essays without meaningful instructional time dedicated to it in the class. Students in this major do have such an assigned activity in a third-year class which focuses instead on oral presentations and they have two activities in their curriculum in which they produce poster presentations as part of two different lab courses. Anecdotal evidence of the success of these activities was produced during the summer 2015 semester when the College of Physical and Engineering Science at the University of Guelph held its annual Summer Student Poster Presentation competition. Out of the 48 entrants, two of these nanoscience students were awarded first place and second place overall providing a fine example of successful future scientists communicating their work persuasively to a broad audience.

Summary

In conclusion, we report the development of a heavily scaffolded writing activity built into a first-year science course designed to promote the communication skills of science students. It is framed around the publication of their work in an online journal so as to promote science writing as an important aspect of their development as science professionals. Numerous in-class activities have been developed to support this activity throughout the semester, including instruction around reading scientific literature, writing in a scientific style, searching the research literature, and the promotion of academic integrity in their work. Another important feature engages the student in a peer reviewing role, which not only helps them learn to assess others' work, but also provides insight into their own writing as they view the process both from the point of view of the producer and from that of the consumer. After several years, this activity has proven to provide a solid foundation for science students' written communication skill development and preparation for their careers as professional scientists.

References

1. Moskovitz, C.; Kellogg, D. *Science* **2011**, *332*, 919–920.
2. McDermott, M. A.; Hand, B. A *J. Res. Sci. Teach.* **2010**, *47*, 518–539.
3. Reynolds, J. A.; Thaiss, C.; Katkin, W.; Thompson, R. J., Jr. *CBE – Life Sci. Educ*. **2012**, *11*, 17–25.
4. Gragson, D. E.; Hagen, J. P. *J. Chem. Educ*. **2010**, *87*, 62–65.
5. Whelan, R. J.; Zare, R. N. *J. Chem. Educ*. **2003**, *80*, 904–906.
6. Wallner, A. S.; Latosi-Sawin, E. *J. Chem. Educ*. **1999**, *76*, 1404–1406.
7. Walker, J. P.; Sampson, V. *J. Chem. Educ*. **2013**, *90*, 1269–1274.
8. Van Bramer, S. E.; Bastin, L. D. *J. Chem. Educ*. **2013**, *90*, 745–750.
9. Tilstra, L. *J. Chem. Educ*. **2001**, *78*, 762–764.
10. Robinson, M. S.; Stoller, F. L.; Horn, B.; Grabe, W. *J. Chem. Educ*. **2009**, *86*, 45–49.
11. Paulson, D. R. *J. Chem. Educ*. **2001**, *78*, 1047–1049.
12. Deiner, L. J.; Newsome, D.; Samaroo, D. *J. Chem. Educ*. **2012**, *89*, 1511–1514.
13. Cole, K. E.; Inada, M.; Smith, A. M.; Haaf, M. P. *J. Chem. Educ*. **2013**, *90*, 1316–1319.
14. Burke, K. A.; Greenbowe, T. J.; Hand, B. M. *J. Chem. Educ*. **2006**, *83*, 1032–1038.
15. Vázquez, A. V.; McLoughlin, K.; Sabbagh, M.; Runkle, A. C.; Simon, J.; Coppola, B. P.; Pazicni, S. *J. Chem. Educ*. **2012**, *89*, 1025–1031.
16. Schroeder, J. D.; Greenbowe, T. *J. Chem. Educ. Res. Pract*. **2008**, *9*, 149–156.
17. Yore, L. D. *J. Deaf Stud. Deaf Educ*. **2000**, *5*, 105–122.
18. Rudd, J. A., II; Greenbowe, T. J.; Hand, B. M. *J. Chem. Educ*. **2007**, *84*, 2007–2011.
19. Shibley, I. A., Jr.; Milakofsky, L. M.; Nicotera, C. L. *J. Chem. Educ*. **2001**, *78*, 50–53.
20. Cooper, M. M. *J. Chem. Educ*. **1993**, *70*, 476–477.
21. Schultz, G. V.; Gere, A. R. *J. Chem. Educ*. **2015**, *92*, 1325–1329.
22. Chamley-Wiik, D. M.; Haky, J. E.; Galin, J. R. *J. Chem. Educ*. **2012**, *89*, 502–508.
23. Gupta, T.; Burke, K. A.; Mehta, A.; Greenbowe, T. J. *J. Chem. Educ*. **2015**, *92*, 32–38.
24. Franz, A. K. *J. Chem. Educ*. **2012**, *89*, 497–501.
25. Henary, M.; Owens, E. A.; Tawney, J. G. *J. Chem. Educ*. **2015**, *92*, 90–95.
26. Stout, R. P. *J. Chem. Educ*. **2010**, *87*, 1163–1165.
27. *Open Journal Software*; https://pkp.sfu.ca/ojs/ (accessed Oct. 28, 2015).
28. *The Public Knowledge Project*; https://pkp.sfu.ca/ (accessed Oct. 28, 2015).
29. *da Vinci's Notebook*; http://davinci.lib.uoguelph.ca/index (accessed Nov. 16, 2015).
30. *Calendar link to the Nanoscience Major in the B.Sc. Degree Program at the University of Guelph*; https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c10/c10bsc-nano.shtml (accessed on 16 Nov. 2015).

31. Paul, R.; Elder, L. *The Miniature Guide to Critical Thinking Concepts and Tools*, 7th Edition; Foundation for Critical Thinking Press: Tomales, CA, 2014.
32. *University of Guelph Calendar*; https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml (accessed 19 Mar. 2016).
33. Guilford, W. H. *Adv. Physio. Educ.* **2001**, *25*, 167–175.
34. Carr, J. M. *J. Chem. Educ.* **2013**, *90*, 751–754.
35. Cowie, M. *da Vinci's Notebook* **2013**, 5.

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Ye Li was the Chemistry Librarian at the University of Michigan during the time when she co-edited this book. Her recent scholarly contribution in chemical education focuses on assessment and intervention design for improving information literacy under the context of problem-solving learning. She is also dedicated to using Wikipedia editing in classroom as a learning tool to deliver both subject concepts and information literacy skills while contributing to public good. Ye is currently the Scholarly Communications and Instruction Librarian in the Arthur Lakes Library at the Colorado School of Mines. She received her PhD in Chemistry and Master in Library and Information Science from the University of Iowa.

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