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Replacing the Traditional Graduate Chemistry Literature Seminar with a Chemical Research Literacy Course

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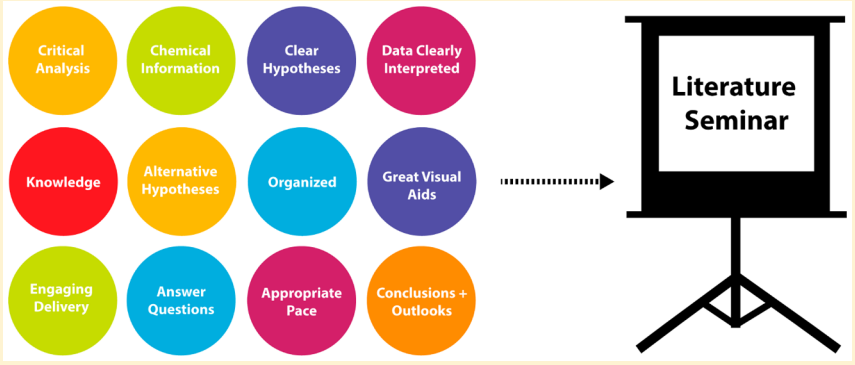
Supporting Information



ABSTRACT: A new graduate chemistry course was introduced in the Department of Chemistry at The University of Alabama. The new course, CH584—Literature and Communication in Graduate Chemistry, replaced a second year graduate student literature seminar requirement. Course topics included chemical information resources, critical analysis, scientific writing, scientific presentations, and peer-review. CH584 was well received by both the chemistry faculty and chemistry graduate students. This article discusses the detailed implementation and content taught in CH584. Moreover, we present our experiences teaching CH584 as well as potential revisions.

KEYWORDS: *Graduate Education/Research, Chemoinformatics, Curriculum, Communication/Writing*

INTRODUCTION

Graduate student seminars are an important component of Ph.D. programs across many chemistry departments.[1] Departmental seminars are likely one of the most challenging tasks for students to complete. In order to successfully deliver a compelling seminar, students must master a multitude of skills such as clear and engaging communication, great organization, preparation of excellent visual aids, and an advanced knowledge of the topic such that a critical analysis can be presented. Moreover, there are few other tasks a student is expected to complete within a chemistry curriculum capable of generating so many opinions and faculty lists of do's and don'ts—we have a few of our own lists circulating around! Key factors to the success of any seminar preparation are a thorough ability to use the chemical literature and the subsequent critical evaluation of the science. A well-researched topic coupled with a thoughtful analysis most often produces an effective and compelling department seminar.

Over the past several decades, a tremendous amount of progress has been reported on teaching students how to effectively navigate the chemical literature,[2] either through workshop exercises,[3−5] course/seminar integration,[6−13] or as stand-alone courses.[14−16] Several reports have also appeared discussing the steps to take after locating the desired chemical information; that is, how to effectively evaluate, communicate, and critically analyze the chemical information.[17−21] Jensen et al. in 2010 cleverly referred to this important skill as chemical research literacy.[17] Such research literacy skills are shared in a number of professional society guidelines such as the American Chemical Society Committee on Professional Training's recommendations on chemical information skills[22] and the Association of College & Research Libraries information literacy standards.[23]

Historically, at The University of Alabama (UA), chemistry graduate students were required to complete a literature seminar during their second year of residence. The chemistry literature seminar included a 30 min department presentation and a 10 page research paper on a primary chemistry literature topic. While each student was paired with a literature seminar advisor that provided guidance and feedback on the seminar and research paper, there was little formal instruction given to students. As a result, student presentations and research papers varied significantly in content, style, and quality. The major disappointment was that student presentations were often too simplistic, passive, and lacking of deeper understanding. They

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Table 1. Outline of Topics and Chemical Literature Discussed in CH584—Literature and Communication in Graduate Chemistry

Week (s)	Topic	refs
1−2	**Introduction and Chemical Information Resources**	25−27
	Expectations of course, grading rubrics, academic research libraries, organization of chemical information, and chemistry databases.	
2−3	**Critical Analysis of the Literature**	28−34
	Multiple hypotheses, disproof, and Ockham's Razor−The Scientific Method. Students also critically evaluate primary chemistry research articles and lead a discussion in class.	
4−5	**Student Critical Analysis Lightning Talk Presentations**	-
	Advisors select a primary research article for students to focus on for the remainder of course. Students present a 5 min Lightning Talk on: (1) the main hypothesis; (2) the main evidence; and (3) any alternative hypotheses and conclusions.	
6−7	**Scientific Writing**	25, 26
	Avoiding plagiarism, overview of research paper, cover letters, typography, and scientific writing.	35−37
8	**Scientific Presentations**	26, 38, 39
	Overview of a literature seminar, organization, content, style, formatting, and delivery.	
9−15	**Peer Review of Research Papers and Seminars**	-
	In-class time for students to peer-review papers, seminar slides, and seminar delivery.	
16	**Presentations and Evaluation**	-
	Official student seminars, all chemistry faculty and graduate students are invited to participate with evaluation. Final research papers due.	

were a survey of the literature—a "book report" of facts, not a *critical* analysis of a specific chemistry topic. Bowyer and Kaydos describe similar experiences and dissatisfaction in their senior undergraduate seminar program at Hobart and William Smith Colleges, which led them to completely redesign the course into a successful theme-based and discussion intensive seminar.[24] In the fall of 2012, we too decided to completely redesign our graduate literature seminar. The new chemical research literacy course presented herein is the result of a collaboration between the UA Department of Chemistry and University Libraries. To our knowledge, the chemical literature is absent of reports outlining a full semester chemical research literacy course that replaces a graduate level literature seminar. In this article, we discuss the course design of our new graduate course, CH584—Literature and Communication in Graduate Chemistry, details of the course lectures, and opportunities moving forward.

COURSE DESIGN AND OBJECTIVES

CH584—Literature and Communication in Graduate Chemistry is a 3-credit course focused on teaching chemical research literacy, with a major theme of evaluating the chemical literature critically. All UA second year chemistry graduate students (∼15) are required to attend and successfully complete CH584 in order to fulfill the literature seminar Ph.D. requirement in the UA Department of Chemistry. CH584 debuted in the fall of 2013 and is offered once per year during the fall semester. The course is co-taught by a faculty member in the Department of Chemistry (P.A.F. or S.A.W.) and a Science and Engineering Librarian in the University Libraries (V.F.S.). Major course topics include chemistry information resources, critical analysis of the literature, student-led peer-review, scientific writing, and scientific presentations. Students are tasked with communicating a critical analysis of a primary chemistry research article through a 10-page research paper and a 20 min oral presentation. In addition, students are expected to actively participate in class discussions.

Throughout the course, students receive structured guidance and feedback on their research papers and seminars from the instructors and their class peers. CH584 meets twice per week for a total of 2.5 h of class time. Most of the course lectures and discussions are designed around published chemical literature articles and essays (Table 1); however, two books are required for CH584 including *The ACS Style Guide* edited by Coghill and Garson[25] and *Scientific Writing and Communication* by Hofmann.[26] An outline of the course lectures and activities are presented in Table 1. A detailed discussion of the CH584 course content is presented below.

Weeks 1−2: Introduction and Chemical Information Resources

In the first 2 weeks of CH584, we discuss the course syllabus, grading rubrics (Supporting Information), expectations for the course, and chemical information resources. One activity that we enjoy leading is having students work together and discuss what they think are components of an excellent research paper and seminar. We then review the grading rubrics together and, not surprisingly, the majority of assessment measures we chose match up well with what our students expect to find in an excellent research paper and seminar!

Chemical information is introduced with lectures on the modern academic research library, organization of chemical information, where to find chemistry literature guides (e.g., books, online libguides, and annotated bibliographies), UA library services, and an overview of searching the chemical literature with SciFinder, Reaxys and Web of Science. Our primary focus was on the process of searching the chemical literature and discussing different strategies for locating information. Students are highly encouraged to experiment with a variety of chemical information resources and to maintain a literature search notebook similar to a laboratory notebook. Such a record can provide students with a valuable resource for learning and reflection. We also briefly cover citation management software (e.g., RefWorks, Endnote) by showing students how to import reference records into the software, how to organize references within the software, and how to use the dynamic citing features within word processing software.

Weeks 2−5: Critical Analysis of the Literature

The critical analysis section of CH584 is about challenging students to apply the Scientific Method to their reading and evaluation of the chemical literature. To accomplish this goal, we first needed to have a discussion of the Scientific Method and how science works (or does not work!). Students read four chemical literature essays on the scientific process for our in-

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class discussions that were authored by Chamberlin,[28] Platt,[29] Hoffmann et al.,[30] and Buskirk et al.[31] In Chamberlin's essay "The Method of Multiple Working Hypotheses" published in 1897, students are introduced to a discussion of the importance of proposing not one hypothesis, but multiple hypotheses throughout the course of exploration and experimentation.[28] In his 1964 article "Strong Inference", Platt introduces a systematic method of performing science with multiple alternative hypotheses, devising crucial experiments, and the importance of focusing on disproof.[29] The Hoffmann essay provides a thorough discussion of Ockham's Razor and how to approach a scientific problem when there are two equally competing hypotheses.[30] Lastly, the commentary authored by Buskirk and Baradaran entitled "Can Reaction Mechanisms Be Proven?" along with responses by Brown, Lewis, Yoon, and Wade provide a wonderful closing lecture for in-class discussion on the Scientific Method.[31]

After our in-class discussions on the aforementioned reading assignments, we work with students to develop a version of the Scientific Method based on their knowledge of science and what they learned from the readings. Then, we bring the discussion back to critical reading and evaluation of the chemical literature. Reading the chemical literature is no different than an exercise with the Scientific Method. When students understand the scientific method, they will understand how to critically evaluate the literature; that is, once you know how science works, you can evaluate science!

Students are then tasked with reading an additional four chemistry research articles, two were poor examples of science and two were exemplary examples of science. There are many infamous examples of bad science, pseudoscience, and pathological science previously discussed in the literature that are excellent for this exercise.[32−34,40,41] Conversely, there are also many exemplary examples of science in the literature. We solicited our chemistry faculty for research articles they thought were excellent, and then selected two of these to use as examples in class. Students were asked to complete a reading assignment for each article before our in-class discussions that focused on locating the author's main hypothesis, the main evidence, developing alternative hypotheses, and summarizing the main conclusions.

To conclude our critical analysis discussions, students were each assigned a unique primary chemistry article selected by their research advisors. Each student was then required to critically read the article and present a 5 min lightning talk (2−3 slide limit) briefly describing the main hypothesis, main evidence, any alternative hypotheses, and the conclusions. Notably, it was not expected at this point in the course that students understood the majority of the article, rather it was a preliminary exercise to help guide students. The selected article that each student presented in their lightning talks would serve as the primary article to be discussed in their research papers and seminars.

Weeks 6−7: Scientific Writing

In week 6, students begin writing their research papers. The research papers are a critical analysis of their advisor-selected primary article from the chemical literature. While the primary articles are selected for the students, the students are required to locate related articles and information in the chemical literature for developing their introductions, conclusions, and outlooks sections. Moreover, students were encouraged to incorporate related articles into their research paper critical analysis. For example, similar articles may provide valuable ideas for generating alternative hypotheses and future experiments. After reviewing the expectations and grading rubrics for the research papers, we discuss several scientific writing articles and book chapters including a scientific typography overview,[37] *The ACS Style Guide*,[25] and two excellent essays that introduce key concepts to achieving great scientific writing.[35,36] Next, we review plagiarism and the importance of correctly paraphrasing and generating independent explanations. Chapter 8 in Hofmann's book provided a good foundation for our lecture on plagiarism. We then worked through many of the suggested scientific writing principles and exercises in Chapters 1−6 from the Hofmann *Scientific Writing and Communication* book.[26] Our approach was to first present and explain a scientific writing guideline such as the importance of using precise language, placing familiar old information before introducing new information, and placing subjects near verbs.[26] Then, we directed students to work in small groups to apply a particular guideline by revising example scientific writing from either the Hofmann book or each other's research paper writing.

Week 8: Scientific Presentations

During week 8, students are close to finishing a first draft of their research papers and, therefore, begin working on a first draft of their presentation slides. Similarly to our lectures on scientific writing, we began our discussion of scientific presentations with two essays on scientific presentations published in the chemical literature by Cassidy[38] and Hawker.[39] Chapter 28 on oral presentations in the Hofmann text also provided great material for our discussion on scientific presentations.[26] While there are numerous appropriate design styles and organization of slides that lead to successful presentations, we did urge each student to not overcrowd slides and to dedicate entire slides for each hypothesis and main point discussed. A typical outline of seminar slides in CH584 was as follows:

1. Background information
2. Hypothesis of main paper discussed
3. Main evidence that supports or refutes hypothesis
4. Alternative hypotheses, suggested experiments, and any critical analysis thoughts
5. Conclusions
6. Outlooks

We concluded our time discussing scientific presentations with several mini-software lessons on how to capture high quality figures from publications, how to modify figures (e.g., axes labels, annotate, etc.), how to draw simple science cartoon illustrations, how to draw chemical structures in ChemDraw, and how to import chemical structures into presentation slides. These skills are likely overlooked in many seminar courses, which is unfortunate given the importance of presenting clear visual aids in a seminar. For capturing high quality figures from publications, there are several approaches. If the publisher has a full-text HTML version, often high quality images of the figures will be available directly within the HTML webpage as a JPEG or another suitable image file format. However, if an HTML version is not available, one of the best methods we have found is to save the entire article PDF as a maximum quality JPEG using Adobe Acrobat Pro. This process will create a high quality JPEG image for each page within the PDF document. Then, use any basic graphics editor to select only the desired figure(s), cropping out the unwanted parts of the page. Unfortunately, even if a high quality figure is obtained from an article, often the

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figure is not suitable for a presentation slide as the original figure was designed for a journal article, not a presentation. This led us to then showing students how to adapt figures for their presentation slides by using the Shapes and Text Box tools within PowerPoint. For example, small font sizes on figure axes can be modified by placing a white box over the original axes labels, and then relabeling the axes with a larger font. We also demonstrate that the Shapes Tools, Smart Art, and Text Box features in PowerPoint can be used to annotate figures and to create simple science cartoon illustrations. The last mini-software lesson was a brief tour of drawing chemical structures in ChemDraw and importing the structures into PowerPoint. Most of our students were already comfortable using ChemDraw. However, we did note that the common "ACS Document 1996" style for chemical structures is acceptable for presentation slides, but a style with thicker bond lines is more appropriate for presentation slides and is made available to students.[42] Importing ChemDraw structures into PowerPoint is generally straightforward and can be accomplished by simple copying and pasting. However, if problems arise, students are shown how to save the chemical structures as an alternate file format (e.g., JPEG, PNG) that can then be imported into the presentation slides.

Weeks 9−15: Peer-Review of Research Papers and Seminars

A significant portion of CH584 was devoted to peer-review and practice. We first discussed the scientific peer-review process and covered tips for providing helpful reviews such as focusing foremost on the science (hypotheses and relationship to data) and providing specific suggestions for improvement (i.e., avoiding the simplistic "Great Job!" feedback). Each student was paired with two reviewers for the research paper. One reviewer was in the same chemistry division as the student (e.g., Inorganic, Biochemistry) and the other student was in a different division. A worksheet was provided for reviewers that guided them to provide helpful reviews. For example, reviewers were asked to summarize the manuscript, discuss the main strengths and weaknesses, and then suggest specific revisions for improvement. Reviewers were also asked to grade the research papers using the written research report rubric (Supporting Information). After completing the reviews, students met with each other in-class to discuss their reviews and ask questions. Students then incorporated the revisions and turned in a revised draft for instructor feedback. The final revised research papers were due at the end of the course (week 16). A similar peer-review exercise was performed with the seminar slides. After incorporating slide revisions, each student then delivered a practice presentation to the class. Both the students and instructors graded the seminars using the oral presentation rubric and provided feedback on the content and delivery.

Week 16: Presentations and Evaluation

Students presented their official CH584 seminar to the class, graduate students, and chemistry faculty. All of the student presentations were completed throughout 1 day. Grading of the presentations was completed by the CH584 students, CH584 instructors, and chemistry faculty present during the seminars. We took the average of the student evaluations and weighed this average as one faculty evaluation. The faculty evaluations were then averaged for their final seminar grade. The revised research papers were also due at week 16 of the course. The research papers were graded by the course instructors and chemistry faculty. These scores were averaged to produce the final research report grade.

COURSE RESULTS, DISCUSSION, AND FUTURE OPPORTUNITIES

The majority of students who completed CH584—Literature and Communication in Graduate Chemistry, produced higher quality research papers and oral seminars compared to our chemistry graduate students prior to 2013, where there was no formal seminar instruction class. Chemistry faculty at UA responded positively to the course indicating that they preferred the new format and recommended the course be continued. Faculty recommended two key improvements to the course. The first was to improve student seminar introductory material. Some of our students struggled with placing their specific topic in a broader chemistry context. The second suggested revision was to form chemistry division groups of students (e.g., an Inorganic Group). This would allow groups to coordinate more practice time for presentations outside of class (vide infra). Moreover, we may be able to incorporate these groups more broadly within the peer-review section of the course. However, we do find it beneficial when students review chemistry that is outside of their specialty focus area, so a balance will be sought with forming chemistry division groups for peer-review and other activities.

We found students to be actively engaged in the course and responsive to the required assignments and revisions. Two recurring suggestions collected from class feedback are that students felt their critical thinking and scientific writing skills were much improved. However, students would have liked more time for seminar presentation practice in class and peer-review from other chemistry faculty members on their written research reports. We allotted nearly 10 class sessions for peer-review and practice, so it is unlikely we will be able to add more in-class time for seminar practice; rather we believe we can make in-class time more effective by forming division student peer-review groups. Students could first practice their seminars with their groups outside of class, and then practice in class. This way, the in-class presentation has already been practiced and revised once, creating an environment for more efficient in-class discussion and feedback. To address the students' request for more chemistry faculty input on their research papers, we will encourage research advisors to review a draft of student's CH584 research paper before the final paper is due.

Notably, it would be advantageous to devote more time for teaching students how to navigate and locate chemical literature, particularly with advanced search strategies using SciFinder and Reaxys. However, our main focus of CH584 was instead to concentrate on how to critically evaluate and communicate chemical information after it is located, as described earlier as chemical research literacy (vide supra). To address this desire, we plan to offer more chemical information and database training in a University Libraries workshop series designed for first year chemistry graduate students. Potential themed topics that would allow demonstration and comparison of a wide variety of chemical and other information databases (both subscription and open web resources) include the following:

1. Finding articles, books, patents, preprints, conference papers, and other technical literature
2. Searching substances and reactions
3. Substance physical and chemical properties

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J. Chem. Educ. XXXX, XXX, XXX−XXX

4. Locating spectra
5. Substance commercial availability, pricing, safety, and hazards

We consider the process of locating chemical literature and critically evaluating chemical literature equally important. As such, with the addition of first year workshops, future second year graduate students attending CH584 will be more prepared to focus on the evaluation of chemical literature, not the discovery.

Most topics, lectures, and activities in CH584 were well received by our students including our work with critical analysis, scientific method, scientific writing, scientific presentations, and peer-review. When reading and analyzing scientific literature, it was particularly helpful in CH584 to stress the importance of locating author's hypotheses and focusing on the main data. Student's quickly noticed that many hypotheses are not clearly stated in the scientific literature, and thus, some interpretation of the author's introduction or conclusions is necessary. Synthetic organic papers presented a challenge for students to formulate clear hypotheses. This, however, provided a unique opportunity to discuss the nature of hypotheses in synthetic papers. For example, new synthetic methods are often promoting efficiency, novelty, safety, selectivity, or some other advantage over prior methods. And most importantly, every reaction is a hypothesis! As such, while the style of synthetic organic papers is vastly different than other chemistry disciplines, the underlying scientific methods used are analogous.

We also found that students struggled with the assigned critical reading assignments, particularly the essays by Chamberlin on multiple hypotheses[28] and Hoffmann on Ockham's Razor.[30] Perhaps it is not surprising that students struggled with these essays as they are unlike the traditional chemistry research article and heavy on scientific philosophy. To address this, we created a reading guide that provided background information and selected key paragraphs within the essays for focus. Despite our efforts, we still noticed many students struggling to understand the main concepts within these scientific essays, and therefore, these students were not able to actively participate in class discussions as much as we would have liked. As such, alternative sources discussing aspects of the scientific method may be more accessible for early graduate students. Moving forward, for our critical discussion readings, we will likely select chapters from *The Art of Scientific Investigation* by Beveridge[43] and/or *Advice for a Young Investigator* by Cajal.[44] We hypothesize that the writing in these books will be more accessible for our students compared to the previously chosen essays.

CONCLUSIONS

In the Department of Chemistry at The University of Alabama, we successfully replaced a second year graduate literature seminar with a full semester chemical research literacy course, CH584—Literature and Communication in Graduate Chemistry. The impetus behind this change was a result of large variations in the style and quality of student seminars during past years. CH584 provided a formal and consistent framework to help guide students in communicating a critical review of a chemistry topic. CH584 course topics included chemical information resources, critical analysis, scientific writing, scientific presentations, and peer-review. Chemistry faculty and student feedback was overall very positive. Suggestions and potential revisions to the course included placing a stronger emphasis on research topic background material, forming peer-review groups based on chemistry division, additional faculty feedback on student research papers, and selecting alternative readings for the critical analysis lectures. A revised CH584 course incorporating the aforementioned changes will be taught during fall 2015.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00512.

Grading rubrics for oral seminar (PDF)
Grading rubrics for written research report (PDF)

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Notes

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REFERENCES

(1) Laidler, K. J. The graduate student seminar. *J. Chem. Educ.* **1971**, *48* (10), 671−674.
(2) Garritano, J. R.; Culp, F. B.; Twiss-Brooks, A. Chemical Information Instruction in Academe: Who Is Leading the Charge? *J. Chem. Educ.* **2010**, *87* (3), 340−344.
(3) MacMillan, M.; Shaw, L. Teaching Chemistry Students How To Use Patent Databases and Glean Patent Information. *J. Chem. Educ.* **2008**, *85* (7), 997−999.
(4) Rosenstein, I. J. A Literature Exercise Using SciFinder Scholar for the Sophomore-Level Organic Chemistry Course. *J. Chem. Educ.* **2005**, *82* (4), 652−654.
(5) Swoger, B. J. M.; Helms, E. An Organic Chemistry Exercise in Information Literacy Using SciFinder. *J. Chem. Educ.* **2015**, *92* (4), 668−671.
(6) Somerville, A. N.; Cardinal, S. K. An Integrated Chemical Information Program. *J. Chem. Educ.* **2003**, *80* (5), 574−579.
(7) Esteb, J. J.; McNulty, L. M.; Magers, J.; Morgan, P.; Wilson, A. M. Technology for the Organic Chemist: Three Exploratory Modules. *J. Chem. Educ.* **2010**, *87* (10), 1074−1077.
(8) Graham, K. J.; Schaller, C. P.; Jones, T. N. An Exercise To Coach Students on Literature Searching. *J. Chem. Educ.* **2015**, *92* (1), 124−126.
(9) Tomaszewski, R. A Science Librarian in the Laboratory: A Case Study. *J. Chem. Educ.* **2011**, *88* (6), 755−760.
(10) 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* (4), 487−491.
(11) Gawalt, E. S.; Adams, B. A Chemical Information Literacy Program for First-Year Students. *J. Chem. Educ.* **2011**, *88* (4), 402−407.
(12) 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

DOI: 10.1021/acs.jchemed.5b00512
J. Chem. Educ. XXXX, XXX, XXX−XXX

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* (12), 1835−1843.
(13) 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* (12), 2071−2077.
(14) Abrash, H. I. A course in chemical information retrieval. *J. Chem. Educ.* **1992**, *69* (2), 143−146.
(15) Ricker, A. S.; Thompson, R. Q. Teaching chemical information in a liberal arts curriculum. *J. Chem. Educ.* **1999**, *76* (11), 1590−1593.
(16) Currano, J. N. Learning To Search in Ten Easy Steps: A Review of a Chemical Information Course. *J. Chem. Educ.* **2005**, *82* (3), 484−488.
(17) Jensen, D.; Narske, R.; Ghinazzi, C. Beyond Chemical Literature: Developing Skills for Chemical Research Literacy. *J. Chem. Educ.* **2010**, *87* (7), 700−702.
(18) 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* (4), 617−624.
(19) Singiser, R. H.; Clower, C. E.; Burnett, S. C. Preparing Ethical Chemists through a Second-Year Seminar Course. *J. Chem. Educ.* **2012**, *89* (9), 1144−1147.
(20) 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* (6), 741−744.
(21) Dennie, D.; Cuccia, L. A. Six Degrees of Separation"—Revealing a "Small-World Phenomenon" through a Chemistry Literature Search Activity. *J. Chem. Educ.* **2014**, *91* (4), 546−549.
(22) 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 May 13, 2015).
(23) ACRL Information Literacy Competency Standards for Higher Education. http://www.ala.org/acrl/standards/informationliteracycompetency (accessed May 13, 2015).
(24) Bowyer, W. J.; Kaydos, J. A. A novel format for seminar during the senior year of the college chemistry curriculum. *J. Chem. Educ.* **1997**, *74* (2), 184−185.
(25) Coghill, A. M.; Garson, L. R. *The ACS Style Guide: Effective Communication of Scientific Information*, 3rd ed.; Coghill, A. M., Garson, L. R., Eds.; American Chemical Society: Washington, DC, 2006.
(26) Hofmann, A. H. *Scientific Writing and Communication Papers, Proposals, And Presentations*; Oxford University Press: New York, 2010.
(27) Currano, J. N.; Roth, D. L. *Chemical Information for Chemists: A Primer*; Royal Society of Chemistry: Cambridge, U.K., 2014.
(28) Chamberlin, T. C. Studies For Students: The Method of Multiple Working Hypotheses. *J. Geol.* **1897**, *5*, 837−848.
(29) Platt, J. R. Strong Inference - Certain Systematic Methods of Scientific Thinking May Produce Much More Rapid Progress Than Others. *Science* **1964**, *146* (364), 347−353.
(30) Hoffmann, R.; Minkin, V. I.; Carpenter, B. K. Ockham's Razor and chemistry. *Bull. Soc. Chim. Fr.* **1996**, *133* (2), 117−130.
(31) Buskirk, A.; Baradaran, H. Can Reaction Mechanisms Be Proven? *J. Chem. Educ.* **2009**, *86* (5), 551−558.
(32) Labinger, J. A.; Weininger, S. J. Controversy in chemistry: What counts as evidence? Two studies in molecular structure. *Angew. Chem., Int. Ed.* **2004**, *43* (20), 2612−2619.
(33) Labinger, J. A.; Weininger, S. J. Controversy in chemistry: How do you prove a negative? The cases of phlogiston and cold fusion. *Angew. Chem., Int. Ed.* **2005**, *44* (13), 1916−1922.
(34) Epstein, M. S. Using Bad Science To Teach Good Chemistry. *J. Chem. Educ.* **1998**, *75* (11), 1399−1404.
(35) Gopen, G. D.; Swan, J. A. The Science of Scientific Writing. *Am. Sci.* **1990**, *78* (6), 550−558.
(36) Spector, T. Writing a Scientific Manuscript - Highlights for Success. *J. Chem. Educ.* **1994**, *71* (1), 47−50.
(37) Yefcheck, G. Typography for Scientific and Business Documents v1.8. http://www.yefchak.com/typography/ (accessed May 22, 2015).
(38) Cassidy, H. C. Professional presentation of scientific papers. *J. Chem. Educ.* **1963**, *40* (7), 373−376.
(39) Hawker, C. J. Effective Presentations-A Must. *Angew. Chem., Int. Ed.* **2013**, *52* (14), 3780−3781.
(40) Langmuir, I. Pathological Science. *Phys. Today* **1989**, *42* (10), 36−48.
(41) Turro, N. J. Paradigms lost and paradigms found: Examples of science extraordinary and science pathological - And how to tell the difference. *Angew. Chem., Int. Ed.* **2000**, *39* (13), 2255−2259.
(42) Shaughnessy, K. H. Shaughnessy Research Group Presentation and Writing Templates. http://bama.ua.edu/~kshaughn/research/group/resources/templates.html (accessed September 15, 2015).
(43) Beveridge, W. I. B. *The Art of Scientific Investigation [Rev. ed.]*; Norton: New York, 1957.
(44) Ramón y Cajal, S. *Advice for a Young Investigator*; MIT Press: Cambridge, MA, 1999.

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