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Introducing Graduate Students to the Chemical Information Landscape: The Ongoing Evolution of a Graduate-Level Chemical Information Course

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Supporting Information

ABSTRACT: The University of Pennsylvania's doctoral chemistry curriculum has included a required course in chemical information since 1995. Twenty years later, the course has evolved from a loosely associated series of workshops on information resources to a holistic examination of the chemical literature and its place in the general research process. The introduction of enhanced group assignments, a term project that aims to teach another researcher to search, and final examination questions that test a student's ability to navigate the literature efficiently help new PhD students develop the information skills that they will need to succeed in their graduate research and beyond.

KEYWORDS: *Upper-Division Undergraduate, Graduate Education/Research, Chemoinformatics, Curriculum, Collaborative/Cooperative Learning, Computer-Based Learning, Hands-On Learning/Manipulatives, Learning Theories*

INTRODUCTION

In 1995, the Chemistry Department of the University of Pennsylvania (Penn) instituted a mandatory course in chemical information as part of its doctoral program in chemistry. The chemistry librarian offered the course as a degree requirement outside of the regular graduate curriculum.[1] The course was originally designed by Carol Carr in 1995; in 1999, this author enlarged it from a single-section, eight-week course into a ten-week course taken during the first year of the students' graduate study. The students were divided into sections according to their research concentrations and received ten interactive lectures that introduced key databases and search tools in chemistry and the related sciences, accompanying in-class and homework assignments, and a term project. The instructor made small annual alterations to the structure and content of the course in response to student feedback, and a detailed description of the 2002 curriculum and format of the course was published in a previous issue of the *Journal of Chemical Education*.[2] By 2002, each of the four sections of the course consisted of 11 class sessions: ten interactive lectures accompanied by in-class assignments and one exam. Students were expected to complete a homework assignment after each lecture, as well as an end-of-semester term project. In order to pass the course, students were required to complete all homework assignments, the term project, and the final exam and to score a minimum of 70% of all possible points.[2] Each year, the instructor submitted a list of all students who had passed the course to the graduate coordinator, who recorded the information as part of the students' files.

The instructor employed the same general framework from 2002 until the course was added to the university's Course Register in 2009, the rationale for which is described in the Supporting Information. At 20 years old, Penn's chemical information course remains one of only a few graduate-level chemical information courses described in the literature this century.[3] It has a course number, CHEM 601, and a new name, Chemical Information: Organization and Retrieval, and it is still going strong. Continual curricular alterations are geared toward enhancing student learning and retention of the material taught. This article highlights the changes that led to the structure of the 2013−2014 iteration of the class, comparing it to the previously described 2002 iteration, and discusses the gradual shift in instructional focus from using chemical databases to finding and using chemical information. It presents specific alterations to the course content and assignments and closes with a description of the serendipitous discoveries of effective new techniques born of necessity in the 2014−2015 academic year, as well as plans for the next iteration.

STRUCTURE OF THE 2013−2014 ITERATION

Logistics and Layout of the Semester

The general organization of CHEM 601, Chemical Information: Organization and Retrieval, during the 2013−2014 academic year still closely resembled that of the 2002 iteration. The students were divided into four sections, aligned with the four basic areas of research performed at the University of Pennsylvania: organic chemistry, inorganic and materials chemistry, physical and theoretical chemistry, and biological chemistry. In order to more evenly distribute the instructor's workload between the fall and spring semesters, the biological and inorganic sections of the course were taught in Fall 2013, and the organic and physical chemistry sections were taught in Spring 2014; in previous years, all but the biological section had been taught in the spring semester. The 2013−2014 sections had between 5 and 7 students each; enrollments in previous and subsequent years have ranged from 1 to as many as 21

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Table 1. Comparison between the 2002 and the 2013−2014 Iterations of the Chemical Information Course

Aspect of Course	2002 Iteration[2]	2013−2014 Iteration
Requirement status	Required for degree	Required for degree
Credit	Zero credits; not included on transcript	0.5 credits; included on transcript
Semester taught	Biological section taught in fall semester; Organic, Inorganic, and Physical sections taught in spring semester	Biological and Inorganic sections taught in fall semester, Organic and Physical sections taught in spring semester
Number of classes	10 classes and a final exam	14 classes and a final exam
Requirements for passing	Complete all homework assignments, term project, and final exam	Complete all homework assignments, term project, and final exam;
	Score at least 70% of all possible points	Score at least 70% of all possible points
		Meet basic content mastery requirements
Responsible conduct of research module	None	2-Class module discussing ethics of scholarly communication and reference management; CITI Responsible Conduct of Research modules assigned as homework
Group work requirement	None but group work optional on in-class assignments	Group work required
Format of in-class assignments	Three search questions that could be answered individually or in groups	One of three possible group assignments: search-based questions, write-your-own question, write a memo based on search results
Format of homework assignments	Five search-based questions	Five search-based questions
Term project	Guide to the literature on a subject of your choice	Guide to the literature on a subject of your choice; double-blind peer review of another student's project
Final exam	1.5 h in duration; offered on the last day of class; search questions resembled those on the homework	2 h in duration; offered during the final exam period; search questions required the use of several resources each
Assessment of student performance	Students assigned a score of Pass or Fail, depending on whether or not they completed all course requirements	Students assigned a letter grade according to an absolute scale based on accrual of points (see Box 1)

students depending on the demographics of the first-year class. Each section had one 1.5-h class meeting per week for 14 weeks, with an optional 1.5-h review session held during the reading period, and a 2-h final exam held during the final exam period. All classes met in an electronic classroom so that the students could follow along with search examples and perform in-class assignments and activities. Since the university does not permit instructors to assign required course activities during the reading period, students' term projects were due just before the end of classes, with a peer review activity and final homework assignment due on the last day of classes. All four sections of the course employed the Canvas courseware system to distribute materials to the students, collect and return assignments, and keep track of grades. Table 1 compares key features of the 2013−2014 iteration of CHEM 601 with the previously published description of the 2002 iteration.

The inclusion of CHEM 601 in the Course Register directly resulted in three very positive changes to the structure and implementation of the course. The expanded time frame, born of having a proscribed start and end date for the course each semester, gave the instructor more time to cover the material and thus enabled her to focus more on concepts than on keystrokes. The result was a course that taught students how to think about finding information, rather than giving them a series of workshops on how to use specific databases. Since the course was listed alongside the other chemistry classes, a few advanced undergraduate students began to discover the class and request permission to enroll. Since the undergraduate students were taking many of the same classes as the graduate students and were performing independent research, as well, this did not change the class culture greatly, and the undergraduates, having chosen CHEM 601 as an elective or having had it recommended to them by their faculty advisors, tended to be extremely engaged and eager to learn the content. Finally, all students received formal recognition of their completion of the course in the form of a line on their transcripts. University policy did not permit graduate students to take a required course pass/fail, so, the students began to receive letter grades in the class, necessitating a change to the grading scheme.

In order to pass the new course, students were still required to complete all homework assignments, submit a term project, and take the final exam. These tasks were designed to demonstrate the students' level of proficiency in certain skills related to the retrieval, evaluation, and use of chemical information. Each activity that they completed earned them between 10 and 110 points. All points earned by the end of the semester were totaled, and, assuming that the students completed all the required activities and met the course proficiency requirements, the instructor assigned grades using an absolute grading scale based on the total number of points accrued (Box 1).

Organization of Course Content

The flow of the CHEM 601 syllabus in 2013−2014 represented another departure from the previously published iteration of the course. The increased number of course meetings resulting from the inclusion of the class in the Course Register led the instructor to examine the topics being taught, as well as the order and ways in which they were presented. The resulting structure was an adaptation of a massive curricular overhaul begun in 2009, with the goal of framing the topics taught in the context of a scientist looking for information as he or she proceeds through a project. The new framework served three purposes: it illustrated the types of literature that could be used at different stages of the research process; it placed the resources in context with one another; and it emphasized the fact that the tools introduced at Penn are examples of broader categories of resources, with the hopes that students would be able to apply the techniques learned to other tools in those categories later in their careers. While the exact order of topics and resources taught in the various sections differed, the general

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Box 1. Required Proficiencies for the Organic Chemistry Section of CHEM 601

All students who complete following requirements for the course will receive a letter grade. The only way to learn information searching techniques is through practice, and success searching the chemical literature greatly assists laboratory; therefore, to receive a grade, you must turn in every weekly assignment, as well as the term project and the final exam. Assigned grades are based on your understanding of both search techniques and abstract concepts presented in class. All organic chemistry students are expected to master the following concepts in order to pass the course:

- Structure of the chemical literature and the purposes of each genre
- Techniques of evaluating information retrieved
- Research and publication ethics
- Topic searching techniques, including the appropriate use of Boolean logic
- Comprehensive author searching
- Substance and property searching by structure, formula, and chemical identifier
- Complex substructure and reaction searching
- Use of citation information to evaluate authors, institutions, and journals, as well as the limitations of these techniques

Mastery of the above concepts will be demonstrated through appropriate performance on homework assignments and the final exam. If these criteria are met, grades will be assigned on the following absolute scale, based on the percentage of the total points received. There are 650 possible points.

96 - 100%	A+
90 - 95%	A
85 - 89%	A-
80 - 84%	B+
75 - 79%	B
70 - 74%	B-
0 - 69%	F

outline of the semester appears in Table 2, and a sample syllabus from a section of the 2013–2014 course, along with one from the corresponding section of the 2002 course, appears in the Supporting Information.

Different topics carried different weight and appeared in slightly different orders in the various sections, based on the relative importance of each topic or technique for scientists in each discipline. For example, while the section on protein sequence and structure searching lasted for three concurrent sessions at the heart of the biological chemistry section, it formed a single class close to the end of the physical chemistry section.

The reasons behind the change in structure had their roots in intelligence that the instructor gleaned from the final exam performance, term projects, and student course evaluations of past classes. The model used between 2000 and 2009 consisted of a roughly aligned series of workshops introducing specific search systems and tools available to researchers at the University of Pennsylvania. Topics were arranged in a semilogical order, but exceptions were made to fit the instructor's travel schedule and to ensure that no two sections were searching SciFinder Scholar at once, given the fact that Penn's license permitted a limited number of individuals to access that tool simultaneously. While this semihaphazard arrangement of topics taught students how to structure effective searches in a wide variety of databases, it did not do a stellar job of teaching them the layout of the information landscape or the relative strengths of the multitude of available tools. Students frequently had difficulty differentiating between many resources that, to their minds, performed similar functions, and this difficulty was exemplified in their performance on the final exam, which asked them to select the optimal tool to find the answer to research-type questions.

Introduction of a Responsible Conduct of Research Module

The expansion of the syllabus also allowed for expansion of individual topics within the course, one of which was the Responsible Conduct of Research (RCR) module. This module was first introduced in Fall 2006, at the request of the graduate committee, members of which were concerned about the number of recent, high-profile retractions from prominent journals.[4] The committee suspected that funding agencies would soon begin mandating training in responsible conduct; moreover, the faculty members wanted to ensure that their students had a baseline understanding of research and publication ethics before entering research groups and beginning to publish. Since the chemical information course was the only course required of all Penn's chemistry graduate students and since most ethical issues in chemistry centered on the publication of research, this seemed a logical place to insert a required training module.

The RCR module began as a one-session class on publication ethics, inserted into the syllabus at the start of the semester. By 2013–2014, it had evolved into a two-class module consisting of background learning about the publication process, ethics in scholarly communication, and reference management. Students were required to read the National Academies Press pamphlet *On Being a Scientist*[5] and Chapter 1 of *The ACS Style Guide*[6] prior to the start of the first class. During the class, they discussed the responsibilities and pitfalls facing authors, reviewers, editors, and readers in the ethical communication of science and then divided into groups to discuss six case studies dealing with publication ethics and the use of previously published or unpublished material in research. The students discussed or led discussions about their case studies at the beginning of the second class, which closed with a demonstration of reference management software. As a homework assignment, the students were required to work through the CITI Responsible Conduct of Research modules.

Structure of Individual Classes

Individual classes in 2013–2014 had a very similar structure and flow to those in 2002, and a sample class outline for the organic chemistry section of the course appears in Box 2. The instructor began each class by asking the students if they had any questions about their upcoming homework assignments. She would also make comments on the previous week's assignments, although, to maximize the amount of class time available to devote to new material, she attempted to post most such comments in the "Announcements" section of the class Canvas site. After the question/answer period, the instructor began teaching the topic of the day. In order to minimize the amount of lecturing done in the class, the class was frequently assigned background reading, usually in the form of handouts written specifically for the class or of chapters from *Chemical Information for Chemists: A Primer*,[7] the organization of which was inspired by the CHEM 601 syllabus. Material from the readings became assumed knowledge, as she and the students discussed the topic of the day and used one or more

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Table 2. General Outline of the Content Taught in All Sections of CHEM 601 in the 2013−2014 Academic Year

Topic	Description	Tools/Techniques Employed[a]	Sections Taught[b]
Introduction to the Literature of Chemistry, Research and Publication Ethics, and Finding Background Information			
Overview of the chemical literature	Focuses on the primary, secondary, and tertiary literature as they fit into the chemical research process and discusses the points of the process at which each is best used	Discussion only: Brainstorming exercise	ALL
Responsible conduct of research and publication ethics	Duties and ethical responsibilities of authors, reviewers, editors, and readers at each stage of the publication process	Discussion only: Brainstorming, case studies, and CITI RCR modules	ALL
Finding and using tertiary literature	Tools and techniques for locating books, treatises, and overviews on a topic	Franklin, Penn's online catalogue	ALL
		Knovel	
Searching the Primary Literature Using Secondary Search Tools			
Topic and author searching	Complex Boolean queries, journal and author impact metrics, and a brief discussion of the peculiar economics of chemical information	Web of Science	ALL
		Scopus	
Searching using controlled vocabulary and subject indexing	Effective searching using natural language searching, *Chemical Abstracts* index terms, MeSH terms, and Mathematical Subject Headings	SciFinder	ALL
		MEDLINE and PubMed	Biological/ Organic
		MathSciNet	Physical
The patent literature	Patents as scientific information sources and how to find them	SciFinder	ALL
		Derwent Innovations Index	
		The Lens	
		Espacenet	
Multidatabase searching	Techniques of searching multiple databases simultaneously and eliminating duplicate records	SciFinder: *Chem. Abstr.* and MEDLINE	ALL
		EI Village: Inspec and Compendex	Inorganic/ Physical
Non-Text-Based Search Techniques: Structures, Properties, and Sequences			
Structure-based searching	Searching by structure, substructure, and reaction in SciFinder, Reaxys, and other tools that permit structure searching	Basic substructure searching	ALL
		Advanced substructure searching	Organic/ Inorganic
		Graphical reaction searching	ALL
Properties-based searching	Using substance identifiers and property information to search tertiary handbooks and databases	Finding properties of know substances	ALL
		Profiling substances by properties	
		Locating and analyzing crystal structure data	
Searching for biological molecules	Finding information on proteins, nucleotides, genes, and genomes using resources from the NCBI and the Protein Data Bank	BLAST sequence similarity searching	Biological/ Physical[c]
		VAST structure similarity searching	Biological
		PyMOL and protein visualization	Biological

[a]A sample list of resources taught, complete with the resource or publisher URL of each, appears in the Supporting Information [b]The code ALL indicates that the topic was taught in all sections, while subdicipline terms (Biological, Inorganic, Organic, Physical) indicate that a topic was taught in only one or two sections. [c]These topics are taught to physical chemists only when the research interests of the class as a whole warrant it; if they do not, an in-depth look at organic and inorganic crystal structures is substituted.

appropriate information resources to demonstrate the skills under discussion. Occasionally, the students undertook group or individual activities during the "lecture" part of the class (search exercises, breaking down topics into constituent concepts, molecular analysis, etc.); sometimes, the lectures consisted of a series of demonstrations that the students could replicate on their own computers if they wished. At the end of the lecture and class discussion, the students had time to meet in groups and begin working on their group assignments, which were usually due by the end of the business day following the class at which they were assigned. Each class was followed by a homework assignment, and all homework assignments were due one business day after the next class.

■ ASSIGNMENTS AND GRADING

Group Assignments

The 2013−2014 iteration of CHEM 601 employed group assignments in lieu of the in-class assignments used in the previously-described iteration of the course. (A description of the in-class assignments used in the 2002 iteration of the course and an example used in one section appear in the Supporting Information.) This change was the result of an interesting workshop on team learning that the instructor attended at the 2012 Biennial Conference on Chemical Education.[8] She decided that the students' learning would be enhanced by the interactions and peer coaching inherent in true group work.

The workshop presenters had discovered that, by grouping together all students who preferred individual work or who felt that they end up doing all of the work in a group setting, they minimized the chances of a single individual taking over a whole group.[8] They gave their students a multiple-choice question at the beginning of the class asking them to describe their opinion toward group work. Some options indicated a positive opinion toward group work, while others indicated opposition toward group work. Those whose selections indicated that they enjoyed and benefited from group work

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Box 2. Outline for a Sample Class on Advanced Substructure Searching in the Organic Chemistry Section of CHEM 601

Pre-work
Read Ch. 5 of *Chemical Information for Chemists: A Primer*, which introduces the key concepts behind substructure searching

In Class
Handouts
Comprehensive Reaxys handout
Two class examples
Group assignment
Lecture
Q/A Time
Substructure Theory: Ensure class has a working understanding of connection tables, R-groups and variables, and topology
Resource: Introduce the history, coverage, and quirks of Reaxys
Class Example 1
Work as a large group, highlighting substructure features described in lecture and indicating how to implement them in the database
Class Example 2
Work as a break-out activity, with students working in pairs or groups to practice skills
Group Discussion
Solve Class Example 2 in the large group, discussing students' strategies
Begin Group Assignment

Group Assignment
Select a molecule and design a substructure search that will use specific search techniques, discussed in class, to retrieve structurally similar molecules. Due by 5PM the day after class.

Homework
Five questions asking students to perform substructure searches. Exemplary group assignment topics are eligible for inclusion on homework. Posted the day after the group assignments are submitted; due 6 days later.

were grouped together, while those who felt that they always ended up doing all of the work formed other groups.[8]

The instructor attempted to emulate the practices recommended in the workshop and devised her own group-work question, which she appended to her regular start-of-semester questionnaire (Box 3). However, the demographics of the PhD students at the University of Pennsylvania made the assignment of groups slightly more challenging. In addition to looking at the students' preferences when it came to group work, the instructor needed to ensure that, when possible, there was an even division of domestic and international students across the groups, as well as a reasonable gender distribution. For this reason, she chose to assign the groups after the first class discussion so that she could get a sense of each student's personality, as well as their group-work preferences. This method was quite successful and resulted in very few dysfunctional groups.

In addition to mandating group work on the "in-class" assignments, the instructor changed the content of the assignments. Prior to 2012, most assignments had taken the form of search questions, similar to those found on the homework assignments. While instantaneous feedback from the instructor was beneficial to the students, in terms of skills practiced, the students derived very little benefit from the in-class assignments that they did not also derive from the identically formatted homework assignment. The new group

Box 3. Questionnaire Given to the Students on the First Day of Class, Based on Muller and Knowles's Guidelines[2]

Name: ______________________________

Adviser's Name: ______________________

Names of 2-3 researchers whose work interests you:

3-5 SPECIFIC topics in chemistry that interest you:

Which of the following best describes your feelings or past experience of working on group projects or assignments, either in a classroom or workplace environment?

a) I enjoy working in groups because it helps me to understand the material better and be more productive than working independently does.
b) I don't see the relevance of group work and prefer to work independently.
c) I don't have very much experience working in groups, but the idea appeals to me.
d) I dislike working in groups because I usually end up doing most or all of the work.
e) Other (please describe below).

assignments took one of three forms. Some assignments required students to write and then solve their own homework-style question using the skills learned during class. To incentivize good performance, the instructor gave the students a carrot: each week, she would consider including a maximum of one excellent question on the homework assignment. Another type of assignment asked the students to perform searches on a topic of interest and then produce some sort of output using the information retrieved (write a memo to the boss, e-mail an absent colleague, etc.). An example of this type of group assignment from the 2013–2014 iteration of the course appears in the Supporting Information. Finally, in certain cases the students received homework-like assignments, requesting that the students locate specific pieces of information using the tools taught, but these were mainly presented in conjunction with topics (BLAST searching, crystal structure analysis, beginning substructure searching, etc.) for which it would have been difficult for the students to generate queries on the fly.

Homework Assignments

The content of the homework assignments did not change greatly between 2002 and 2013. Students in the 2013–2014 classes were given five questions per week to answer, performing searches using the appropriate tools. On a few assignments (Journal Impact, Author Impact, Patents), the students were asked to compare metrics or databases and give their assessment of the overall utility of each, but otherwise the questions requested that the students use certain tools to locate specific pieces of information or information on specific topics. Students were required to state their search strategies or take screen shots of their progress through the search, in addition to providing the final answer to the question.

In 2012, the instructor began experimenting with electronic submission and grading of assignments. The Canvas courseware system made it very easy for the students to submit digital files, and the fact that they were completing their homework digitally

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using screen shots made this desirable to the students. The instructor used tools within Canvas to assemble the assignments, which she then saved to a folder on Drop. She used iAnnotate to convert the documents to pdf files and graded them on her iPad, using a stylus to handwrite annotations. Graded assignments were then uploaded to Canvas as soon as they were finished, grades were assigned using the SpeedGrader feature, and students could view their assignments immediately. This allowed her to repurpose class time previously used to collect and return papers. There were only two downsides to this method: some students had difficulty viewing the instructor's annotations when using a phone or tablet (although they were clearly visible on a PC), and the instructor had to work harder to learn the students' names.

Term Project

The term project for the class was to create a guide to the literature on the subject of a student's choice, an assignment that has not changed much in substance since the class's inception in 1995. The guide was to be pedagogical in nature so that individuals unfamiliar with both the topic and the resources available at Penn would be able to use the guide to learn to search for material on that topic.

As time progressed, the instructor found that students were simply generating a laundry list of different types of literature and tools and demonstrating searches in them; thus, the term project was not presenting them with any benefit that they were not already gaining from the weekly homework assignments. Therefore, she altered two things about the term project. First, she changed the wording of the assignment sheet so that the emphasis was on the pedagogic aspects of the guide. The students were still required to demonstrate searches for books, overviews, patents, review articles, and Web sites; perform cited reference searches; and indicate the relative strengths of databases when searching for information on a given topic. However, they were now also required to describe the part of the research process in which each resource or literature genre is most useful. The instructor redistributed the points accordingly, and students received more points for explaining why they used a particular resource type. Sample term project assignment sheets from the 2002 and 2013–2014 iterations of the course appear in the Supporting Information.

In 2005, the instructor added a double-blind peer review component to the term project. This was inspired by a seminar on teaching and learning given at the University of Pennsylvania in the spring of 2004. When the students submitted their term projects, the instructor anonymized them and then redistributed the anonymous papers to a student reviewer, when possible in a different section of the class than the author. The student reviewers were asked to review the project, paying close attention to how well the authors explained the utility of the different resources and techniques of searching for them. Since the reviewers were from a different section of the class, they frequently had not had the same level of training in the resources under discussion. The goals of the peer review assignment were 3-fold: it offered the students the experience of reviewing a paper, it allowed them to learn tools and strategies for finding information from their peers, and it made them think closely about how they would explain the resources to someone else.

The instructor graded the term projects, assigning a numeric score for the paper using a predetermined rubric, prior to reading the student review. She then read and graded the review, based on how well it critiqued the original paper. Therefore, each student received a score for the term project that he or she wrote, as well as 20 points for the review that he or she wrote of another student's paper, and nobody's grade was influenced by the review written by another student.

The peer review assignment had an immediate effect on the quality of the term projects. From 2004 to 2005, the papers jumped from being poorly written laundry lists of resources and searches to being more descriptive studies of using a body of literature to research a particular topic. The reasons behind this change are uncertain; it is possible that the instructions to the reviewers, which were distributed at the beginning of the semester along with the term project assignment, gave students a better idea of what the instructor wanted in a term project. However, it is equally possible that the students cared more about presenting shoddy work to their peers than to their librarian.[9]

Final Exam

The final examination remained relatively unchanged since the 2002 iteration of the class; however, changes to the structure of the questions between 2002 and 2013 reflect changes to the emphases of the course. In 2002, many of the questions asked students to locate a single piece of information, and most pieces of information could be found using a single resource. The wording of the questions gave clues to the most effective databases to use to find the information.[10] The instructor's goal in writing these final exams was to determine whether or not students were able to quickly select the appropriate database to locate a particular type of information.

The 2013 exams had fewer questions, but the questions were more complicated. Instead of guiding students to a specific database to find a specific fact, the questions were designed to force students to adopt an efficient information gathering process. Instead of fishing for a specific resource, the questions could be answered using several different tools; however, one tool would generally lead to a more efficient research pathway than others. Since the final exam was timed, students had a better chance of completing the exam if they chose the "path of least resistance".

Box 4 presents a question taken almost verbatim from a 2012 final exam, now given to students as a sample that they can use to study for the final. The most efficient approach would have the student perform an author search in Web of Science and an author search in MathSciNet and then use in-database refinements and links to obtain the answers to all of the rest of the questions. While it is possible to perform separate searches for each section of the question, it is much less efficient, and students who chose to work in that way had great difficulty completing the final exam in the allotted time.

■ FUTURE PLANS

The 2013–2014 iteration of CHEM 601 was extremely successful; students' grades were good, and course evaluations, which were, for the most part, extremely positive, indicated that the course had helped the students to understand how practitioners in the field of chemical information ask and answer questions. The students particularly enjoyed the group work, and their performance on the group assignments was universally excellent, particularly the assignments requiring them to perform searches and use the results retrieved as the basis for a persuasive narrative, so, the instructor elected to keep those assignments as written for the following year's

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Box 4. An Example of the Style of an Exam Question from the 2013 Iteration of CHEM 601

You have been asked to serve as an external reviewer on the promotion committee of PROFESSOR XXX in the Mathematics Department at MAJOR RESEARCH UNIVERSITY (MRU). XXX is an associate professor doing research in combinatorics, a field that is unfamiliar to you. You are impressed by her/his application, but you would like to know how s/he stacks up against others in his field.

a. You first decide to learn a little bit about XXX's publication practices. How many articles has s/he published in his entire career? How many of these were published since s/he came to MRU?

b. Looking at XXX's work since he came to MRU, would you say that s/he is influential in his field? Please justify your answer with evidence from the literature.

c. Look at the two journals in which XXX has published her/his two most influential papers. Are they quality journals in their field? How do you know?

d. A person's colleagues can frequently tell you a lot about the person and his research. Who is XXX's most frequent collaborator? Where does s/he work, and how many articles has s/he written? Does s/he appear to be influential?

e. *(BONUS)* You want to gauge how involved XXX has been in other aspects of the publication process. How many reviews of other people's work has s/he written? Please give the reference for the most recent work that he reviewed.

classes. Although the students agreed with previous classes that too much homework was assigned for a half-credit class, the instructor has no plans to change this aspect of the class; each homework question was designed to illustrate a different aspect of the database or skill taught, and the more skills the students practice, the greater will be their awareness of the capabilities of the information resources. Even if they do not remember how to perform a particular search in future years, they should remember that that type of search is possible.

The instructor had planned to repeat the 2013−2014 model verbatim the following year, but a necessary leave of absence required her to teach the class in a condensed format. Instead of teaching once a week for 14 weeks, she taught each section twice a week for 7 weeks. Mindful of the fact that students in previous years had thought the workload excessive in a regular semester, she reduced the amount of homework that the students needed to complete. While each class meeting still included a group assignment, she assigned only one seven-question homework assignment per week, encompassing two classes' worth of material. This meant that she needed to make slight modifications to the syllabus to ensure that complementary skills were taught back-to-back and thus appeared on the same homework assignment. The result was a syllabus that was even tighter and better organized than the previous year's, and student term projects, which indicate to the instructor the students' understanding of the information landscape and the ways in which each tool supports the research process, were superior to those of any previous class. As a result, the instructor plans to carry over as much of this organizational scheme as possible in the 2015−2016 academic year, while otherwise returning to the 2013−2014 model.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00594.

Changes to CHEM 601 and a sample list of information resources taught in 2013−2014 (PDF, DOCX)
Example syllabus, 2002 (PDF, DOCX)
Example syllabus, 2014 (PDF)
Group assignment, 2002 (PDF, DOCX)
Group assignment, 2014 (PDF, DOCX)
Term project assignment sheet, 2002 (PDF, DOCX)
Term project assignment sheet, 2014 (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

■ REFERENCES

(1) One of the main reasons for the "unofficial" status of the course was the fact that graduate students were only permitted to take a certain number of credit hours as part of their supported course load, and the University of Pennsylvania would not permit departments to offer courses bearing zero credits.

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