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Integrating Chemical Information Instruction into the Chemistry Curriculum on Borrowed Time: The Multiyear Development and Evolution of a Virtual Instructional Tutorial

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Supporting Information

ABSTRACT: The impetus to incorporate instruction on the efficient and responsible practice of chemical information literacy into the undergraduate chemistry curriculum has become exceptionally urgent. At Rider University, Chemical Information Instruction (CII) has accordingly evolved from face-to-face sessions into online modules to embed information literacy skills into an Organic Chemistry II course. Through multiple methods of evaluation and assessment of student learning, the e-tutorial grew from a series of seven modules narrated by the science librarian, hosted on the University Libraries intranet, and created with labor intensive e-learning authoring software, into a series of 14 modules complete with detailed storyboards, narrated by the Organic Chemistry professor, hosted freely on the Internet, and created with simpler user-friendly software. This article describes the technological development, feedback-driven revisions, and assessment of student learning outcomes of this virtual tutorial series, while a companion article in this *Journal* addresses the execution and assessment of an accompanying capstone research report.

KEYWORDS: *Second-Year Undergraduate, Chemoinformatics, Organic Chemistry, Distance Learning/Self Instruction, Internet/Web-Based Learning, Multimedia-Based Learning, Testing/Assessment, Standards National/State, Student-Centered Learning*

INTRODUCTION

Project Development and Rationale

Scientific information literacy is not rooted in mere scientific knowledge.[1,2] The ability to evaluate the validity of resources, read and extract technical information discerningly and accurately, and to synthesize, communicate, and ultimately formulate informed, responsible decisions that impact both personal well-being and global welfare, requires far more than memorization and regurgitation of scientific data.

For decades, the American Chemical Society (ACS) Committee on Professional Training (CPT) has recognized this necessity for chemical information literacy in preparing undergraduate chemistry students for the professional environment. Since 2008, institutions of higher education with ACS-certified Bachelor's degree programs have been mandated to embed skill-building opportunities into the curriculum which foster their graduates' abilities to effectively search and critically evaluate the peer-reviewed scientific literature.[3,4] Furthermore, the Chemistry Division of the Special Libraries Association (SLA) and the ACS Division of Chemical Information have collaboratively devised a set of complementary information literacy competencies for undergraduates[5] which expand upon these ACS-CPT guidelines as well as recommended best practices from the Association of College & Research Libraries (ACRL).[6,7] These criteria specify that students must not only have access to databases or other resources with sufficient coverage of the chemical literature, but that such access must be accompanied by deliberate instruction on effective searching techniques, with an ultimate goal of enabling chemistry students to "read, analyze, interpret, and cite the chemical literature"[4] toward answering chemical questions in both the research laboratory and classroom. These recommendations by both the ACS and various library professional organizations overwhelmingly indicate the perceived importance of student proficiency with chemical databases and the primary literature, as an essential preparative tool for future chemistry professionals.

Despite such recommendations, a recent survey[8] by the American Association of Colleges & Universities (AAC&U) reports that 72% of private and nonprofit employers believe colleges should place more emphasis on "the ability to locate, organize, and evaluate information from multiple sources" as an essential learning outcome, a troubling figure that has actually increased since the original implementation of that survey.[9] Project Information Literacy[10] has likewise found that employers are largely unsatisfied with new hires' persistence in research; they prefer their workers to research and evaluate a variety of resources, but find that their new college graduate employees are finding merely tolerable resources instead.[10]

The need to establish sustainable, transferable information literacy via chemical information instruction (CII) has become unquestionably urgent. However, as described in a companion article in this *Journal*,[11] the size, composition, and teaching load of the faculty, number of majors, credits required for graduation, and even administrative factors can be prohibitive toward introducing CII into the college curriculum as a separate course[12−16] or capstone seminar.[17,18] Such is the case for the Department of

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Chemistry & Biochemistry at Rider University, a primarily undergraduate institution that graduates 5−15 ACS-certified majors each year. Thus, in academic year (AY) 2009−2010, a close collaboration between the organic chemistry faculty and university librarians was established to develop tools for CII delivery that would be cost- and time-effective.

In 2009, several professor-librarians had received a grant from the University's Distance Learning Advisory Committee to create virtual tutorials that would enable the teaching of online courses. The funds received were used to purchase equipment (headphones and microphones) and software required to record, edit, and ultimately publish e-tutorials.[19,20] The librarians were also tempted to use their new technologies to explore virtual tutorials for teaching information literacy in traditional classes, with the purpose of "flipping" courses to move the instruction from the classroom to the dorm room.

This article herein describes a six-year collaborative process in which the organic chemistry faculty and librarians have engaged to create, produce, and cyclically revise an integrative online tutorial for CII, including instruction on how to efficiently use *SciFinder* to search the primary literature. In accord with the recommendations of the ACS, SLA, and ACRL for the provision of database access at institutions of higher education, Rider University subscribes to *SciFinder* as its main tool to search the chemical and biomedical literature: its user-friendly interface, expanded periodical and patent base, and recent offering of unlimited user access to member academic institutions[14] makes it attractive and affordable for primarily undergraduate institutions such as ours. Though Chemical Abstract Services (CAS) offers its own set of tutorials on how to use the features available through *SciFinder*, the e-modules created by the chemistry faculty and librarians are catered specifically toward Rider University undergraduates: novices not only to the *SciFinder* database, but even more importantly to the literature research process itself. Students need to know more than merely *how* to use the chemical drawing tool, to "remove duplicates" from a search, or to sort by commercial availability; they need instruction on *why* and *in what situations* they would benefit from using these strategies. The virtual tutorial accordingly integrates the *SciFinder* searching process with several modules that outline how to use the bibliographical information to search for and access resources via the Rider Universities Libraries catalog or other means, and how to efficiently read, extract, and critically think about the information within these articles, toward writing a research report, devising an experimental procedure, or any other task requiring precedent from the chemical literature.

A companion article in this *Journal*[11] describes a semester-long research assignment, in which students in Organic Chemistry II iteratively practice and apply their skills in information literacy (from the virtual tutorial) toward composing a proposal on a specific disease area and the drugs employed in its treatment. Because the majority of students in this course are Biology, Biochemistry, and postbaccalaureate premedical students meeting their chemistry requirements, the research report was intentionally designed to connect biology (disease etiology) with chemistry (drug structure, function, and synthesis). Together, these two companion articles demonstrate that students from *all* science disciplines—not just chemistry majors—gain valuable and transferable skills in scientific information literacy from this 13-week integrated assignment that usurps minimal classroom time from the instructor teaching Organic Chemistry II.

TOOLS FOR CHEMICAL INFORMATION INSTRUCTION

Traditional Instruction of Information Literacy

In the past, when library instruction was requested by a chemistry or biochemistry instructor at Rider University, the science librarian would conduct 30 or 60 min class-integrated research instruction sessions to teach students how to use *SciFinder* and other library resources.[20,21] Other models for in-class teaching of basic *SciFinder* searching to undergraduates in a non-seminar disciplinary chemistry course have been reported by Rosenstein,[22] Gawalt and Adams,[23] Ferrer-Vinent,[24−26] and most recently Graham and co-workers,[27] and Swoger and Helms[28] in this *Journal*. Although the introduction of Chemical Abstract Services' Academic Unlimited Access program[14] has undoubtedly facilitated university librarians and faculty in introducing large classrooms of students to *SciFinder* at one time, the primary impetus for creating a virtual tutorial series was to minimize the amount of time spent in class on CII instruction. First of all, at Rider University, most standard classrooms are not equipped with sufficient computer stations to allow for students to follow along and mimic searching functions during classroom demonstrations. Even more importantly, there is already insufficient class time to go into depth on effective searching methods and other aspects of chemical information literacy. The extent of content coverage in Organic Chemistry II at Rider University is similar to second-semester organic chemistry courses across the country, wherein a continually growing body of reaction types, transformations, electron-pushing arrow mechanisms, and their applications in synthesis must be forced into a mere 39 standard lecture hours over 13 weeks. Comprehensive chemical information instruction could not be incorporated into the class without confiscating time spent on other critical course content, especially when considering that between 2013 and 2015, an average of three lectures each spring semester were sacrificed due to inclement weather in the northeast. For these reasons, our primary aim for CII instruction was to enable the development of meaningful, sustainable skills in scientific information literacy and writing, without compromising the challenging level of content and practical organic chemistry skills delivered in the course. This seemingly irresoluble challenge was envisioned to be permissible using a flipped-classroom approach,[29,30] wherein students would be responsible for information literacy instruction *outside* of the classroom.

Flipped and Virtual Instruction of Information Literacy

An Internet search reveals a variety of white papers and guides that have been made freely available to enable literature searching and organization of chemical information. The Wikibook *Chemical Information Sources*,[31] for example, provides direct links to major databases for searching the chemical literature, and compiles links to Web sites created by various institutions that address general skills such as literature searching and scientific communication. Furthermore, there is no dearth of books outlining how to effectively search,[32,33] read, write, and cite,[34,35] and ethically use[35] the chemical literature. Even though there are plentiful Internet and print resources that would enable CII outside of the classroom, supplementary print resources can be cost-prohibitive to students, and just as important, these resources may not be personally relevant or interactive enough to convince students to recognize their value outside of the classroom.

Online video streaming is likewise a plausible tool for the delivery of chemical information instruction outside of the classroom.

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However, although streaming video has been critically evaluated as an adequate replacement for live lectures,[36] paving the way for virtual chemistry instruction in higher education[37−50] as well as open access resources such as massive open online courses (MOOCs) and Kahn Academy, online videos have been used almost exclusively to supplement the teaching of chemical concepts and content outside of the classroom; there are only two published examples of their use in instruction of information literacy.[16,51] This was originally surprising, because online tutorials could be particularly transformative for any institution dedicated to promoting information literacy with minimal impact on time, money, and staffing resources. In 2010, the chemistry professor and librarians at Rider University responded to this opportunity and created a virtual tutorial that would fill this gap in chemical information instruction, and potentially serve as a model for similar institutions of higher education. Table 1 highlights the structure and formatting of the original 2010 virtual *SciFinder* tutorial.

Not only did the very first *SciFinder* tutorial series (Table 1) addressed the seven topics that were believed (at the time) to be the most relevant to Rider Organic Chemistry II students, but also the tutorial content was presented in a manner that followed the top principles for effective instructional design of multimedia tutorials:[53] it was (1) narrated in a conversational style, (2) adhered to the "segmenting principle" by breaking the content up into seven short tutorials,[54,53] and (3) depicted screen-captures of *SciFinder* searches, demonstrating the "multimedia principle" that graphics are remarkably conducive to learning.

■ BEST PRACTICES GUIDING TUTORIAL REVISIONS

One potential danger in taking CII out of the classroom is that it could allow for instructional complacency. This is why frequent changes, additions, and deletions to the *SciFinder* tutorial are crucial to its successful implementation, so that the individual modules (1) visually echo the latest changes to the *SciFinder* interface, (2) maintain relevance with respect to the accompanying research assignment,[11] and (3) increasingly align with the expected learning outcomes of each individual module (Supporting Information). The *SciFinder* tutorial series has accordingly been revised every year since its initial implementation, guided by the instructional design principles of Clark and Mayer,[53] and utilizing modern technologies to increase student learning and engagement. These cyclical revisions are informed by multiple tools including the previous cohort's tutorial viewing statistics, *SciFinder* usage statistics, interlibrary loan requests, satisfaction surveys, and the achievement of expected learning outcomes as determined by the quantitative assessment of skills. Such multitiered feedback obtained throughout the semester provides crucial insight into the aspects of the virtual tutorial that were most successful, least successful, or perhaps missing altogether, all of which guide changes for the next generation's tutorial. As an example, Table 2 outlines notable student feedback received after the first 2010 iteration of the *SciFinder* tutorial series containing seven modules (Table 1), as well as the subsequent changes made to address the perceived shortfalls.

For every year between the first generation of the *SciFinder* tutorial and its current iteration, assessment of student learning and student feedback such as that in Table 2 has informed changes to existing modules and the addition of seven new modules: accessing *SciFinder* from off-campus; effectively searching the Rider University Library catalog; document types; chemistry journal titles and abbreviations; searching on *SciFinder* by reaction scheme; and how to (a) read, and (b) cite a scholarly chemistry article. Although such constant and substantial revisions may appear time-consuming, modern technology and storyboarding tools further (described vide infra) facilitate revisions so that the faculty member can change them over the course of a few hours without help from an instructional designer.

Narration Changes

One of the initial changes made was that of narration. Ben-Dror[54] recently confirmed that a familiar narrator increases student learning efficiency as students receive more social cues and can picture the instructor in their mind. This research is consistent with Mayer's observations on vocal cues,[55] that a familiar voice "may affect the degree to which a learner feels a social response to the instructional

Table 1. Structure and Content Differences between the First Generation (2010) and Current Generation (2015) *SciFinder* Tutorial[a]

Spring 2010		Spring 2015	
Software	Adobe Captivate	TechSmith Camtasia Studio 8	
Hosting	RU Libraries Web site	YouTube, SpringShare LibGuides, linked from RU Libraries Web site	
Availability	RU Libraries intranet	Unrestricted Internet access	
Narrator	Science librarian	Chemistry faculty	
Modules	**Time**	**Modules**	**Time**
1. Introduction: The Chemical Research Process Starts Here	4:22	1. Introduction: The Chemical Research Process Starts Here	4:22
2. Registering and Accessing SciFinder	3:19	2. Registering and Accessing SciFinder	3:19
		3. Accessing SciFinder from Off Campus	1:20
3. General Searching	7:05	4. General Searching	7:05
4. Refining Searches	5:17	5. Refining Searches	5:17
		6. Finding an Article at Moore Library	8:34
5. Interlibrary Loan	7:57	7. Interlibrary Loan	7:57
		8. Document Types	5:34
		9. Chemistry Journals and Abbreviations	1:39
6. Searching by Chemical Substance	6:51	10. Searching by Chemical Substance	6:51
7. Searching by Chemical Structure	5:28	11. Searching by Chemical Structure	5:28
		12 Searching by Reaction Scheme	7:12
		13. How to Read a Scholarly Chemistry Article	6:26
		14. Proper Citation of Chemical References	4:24

[a]Current generation of tutorial modules can be found on the Rider University Libraries Research Guides Web site at http://guides.rider.edu/scifinder.

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Table 2. Selected Student Feedback from the First Generation of the *SciFinder* Tutorial (2010), and Actions Taken To Address Those Comments in the Next Generation Tutorial

Student Feedback	Action Taken
"SciFinder had none of my sources available."	Add a module that addresses how to find resources using the Rider University Libraries catalog online
"I found Science Direct to have much more relevant information."	In the Introduction module, intentionally address the differences between SciFinder (a comprehensive search engine) and Science Direct (Elsevier journals platform) and Medline (a database which SciFinder searches)
"Every article that was good to use was not available. I had to buy a copy if I wanted to use it. Until the library can update their science journals do not assign a research paper."	Improve module on Interlibrary Loan to stress how to use it responsibly, at no cost
"The history was very hard to find."	Add a module that address the types of literature (primary, secondary, tertiary) and their utility
	Add a module that investigates the general format of a peer-reviewed article, and the type of information that can be found in each section

method." Since students interact more with the chemistry professor than the science librarian, particularly after removing chemical information instruction from the classroom, having the chemistry professor narrate the tutorial adds familiarity and comfort, and instills a sense of personal responsibility within the student viewers.

Addressing Visual and Auditory Learning Styles

Clark and Mayer[52] recommend the complementary use of both on-screen written text and audio narration to describe concepts in multimedia tutorials. Such practice is not only a noteworthy attempt to reach both visual and auditory learning styles, but it has further been theorized that learners process verbal and visual information in separate channels, and that each channel can only process a limited amount of information at once.[53] Toward this end, subsequent tutorial generations have all included visual text, along with action-guided narration, to aid in the presentation of complex concepts and tasks.

Storyboarding Process

Storyboarding is a preproduction process for the creation of any multimedia project. As shown in Figure 1, storyboards provide a comprehensive plan, in terms of action and narration, to be used in the execution and recording of each module.[56] Such a technique was not known to the chemist or science librarian who produced the initial *SciFinder* tutorial series; thus, when the new emerging technologies librarian, with expertise in incorporating instructional design techniques into curriculum development, was hired at Rider University in 2012, tutorial quality was drastically improved, and revisions considerably facilitated. Most importantly, storyboards enable the isolation of the exact time frame of a desired revision. This assists faculty in effectively identifying desired changes to audio and visual content, allows the instructional designer (or student multimedia development assistant) to rearrange the media as needed, and provides a blueprint for multimedia editing and development such as screen capturing, voice narration, and the addition of text captions, callouts, or interactive objects.

Attention to "Working Memory" in Tutorial Design

Even the most engaging lesson can tax the limited capacity of the brain's working memory. Most brains can handle "short chunks" of 3−5 min,[52,53] although Kraft, Rankin, and Arrighi[57] found that their series of 5−12 min chemistry tutorials were sufficiently short to keep their students engaged and on task. While the librarians and chemist were unable to cut all of the virtual modules to fewer than 5 min, it was believed that student learning could be enhanced by adhering to other instructional design guidelines. Modules were intentionally designed, and continually revised, in accordance with the "modality principle" of using speech over written words, and in adherence with the "redundancy principle" so as to not describe graphics on the screen.[52] Furthermore, since a learner's attention can be split by extraneous information ("coherence principle") care is taken to remove all nonessential audio, text, and operations to minimize demands on the students' working memory.[52,58]

File Format Changes

Other significant revisions to the *SciFinder* tutorial between 2010 and 2015 resulted from the decision to change the recording and publishing software. The initial tutorials were produced as .swf files on Adobe Captivate, reputed as one of the premier tutorial publishing tools due to its interactive features such as embedded quizzes.[20,60] However, in order to implement the advanced features, one must be an advanced user and have substantial time to spend on video development. It has been estimated that creating feature-rich simulations with Adobe Captivate can take an average of 380 h of production for 1 h of e-learning (i.e., 12 modules, 5 min apiece).[60] This is above the 40−80 h typically spent on storyboarding, 120 h on editing/producing/testing, 20−40 h on script narration, and 20−40 h on narration recording.[59,60] Just as time efficiency is important in teaching CII and research writing, saving time in the tutorial creation and revision process is equally important. Furthermore, .swf files are actually a disadvantageous file format, because they can only be viewed on desktop and laptops computers and not certain tablets[61] or other increasingly popular mobile devices.

Since the original *SciFinder* tutorial did not exploit the advanced interactive features of Adobe Captivate, the collaborating faculty and librarians decided to make the tutorial modules more accessible by exporting the videos as .mp4 files, permitting them to be uploaded to YouTube as opposed to the Rider University intranet. In addition to taking advantage of YouTube's device agnosticism, YouTube (1) is very familiar to students, (2) makes closed captioning simpler to create and edit after video production, and (3) allows for the individual module videos to be queued in a playlist and watched in one streamed viewing, if desired. Students can create their own playlists, share videos, and even bookmark them at a specific time that might be relevant to their individual needs. Furthermore, in using YouTube, a viewer could opt to see closed captioning in a variety of colors and text backgrounds, which makes the videos accessible to viewers with visual and hearing impairments.[62]

Another unintended benefit of this shift was the access to YouTube analytics, which provides detailed feedback with regard to tutorial usage. When the tutorial modules were posted on the Rider University intranet, the instructor relied on self-reporting as the primary analytic to probe the utility of individual modules. YouTube analytics provides far more data with essentially zero time commitment, by giving accurate total view-counts for each of the 14 modules on a daily basis, as well as the average minutes watched, per user.[63] User data can be viewed with respect to these metrics over specific time periods, on a daily, weekly, or monthly time scale, in a variety of graphical formats. The *SciFinder* tutorial

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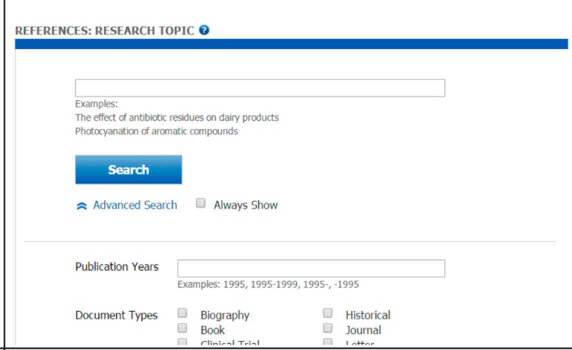
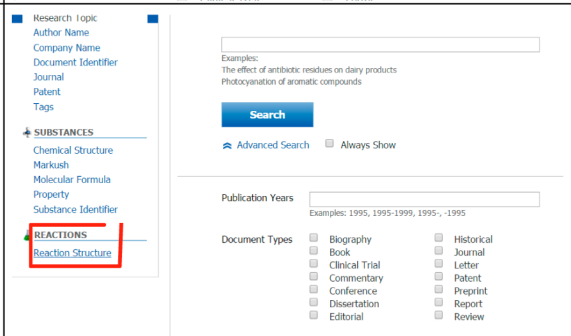
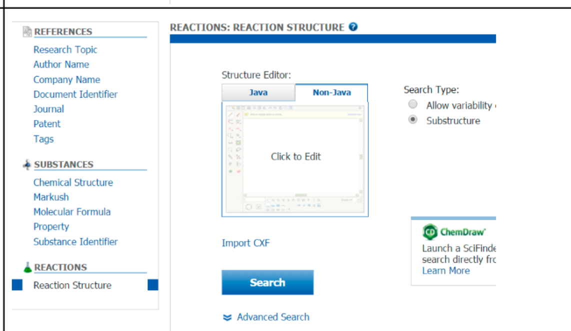
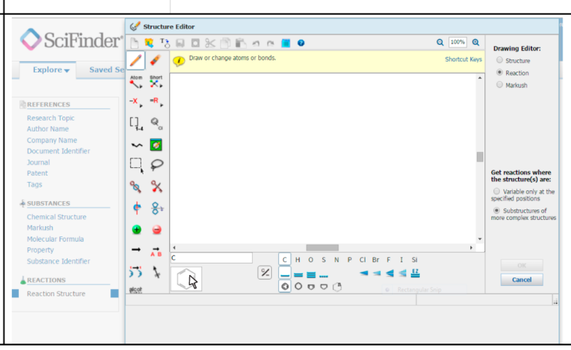
Script	Screenshot	Instructions
To demonstrate searching by reaction structure, we will use a Grignard reaction of acetophenone, a common reagent in commercial synthetic processes.		SciFinder Search Page and chemical structure
Click "Explore Reactions" Reactions" at the top of the main SciFinder webpage,		Bring mouse to Reaction Structure (under Reactions) and highlight it with a red box.
and open the drawing editor as in the previous module.		Move mouse to Click to Edit (in the structure editor)
(pause until editor opens) First, click on the benzene tool.		Allow Structure editor to open. Zoom in. This image the lower left corner of the structure editor. Click on the benzene tool (the hexagon shape where the cursor is)

Figure 1. Example of a partial storyboard for *SciFinder* tutorial (2015) Module 12: Searching by Reaction Scheme. *SciFinder* graphics and logo reprinted with permission from Chemical Abstract Services (CAS), a division of the American Chemical Society.

usage statistics presented in Table 3, for example, were facilely obtained by YouTube analytics.

e-Authoring and Publishing Software

The substitution of .swf files for .mp4 files further enabled the switch from Adobe Captivate to TechSmith's Camtasia Studio 8 for tutorial production. Although the interactive features are not as plentiful, the ease of usability of this e-authoring tool makes editing accessible and far less time-consuming, even to the untrained faculty member who can now make quick changes to both the storyboard and tutorial itself, to address any immediate needs of the students or capstone assignment.[11]

■ ASSESSMENT OF STUDENT OUTCOMES

Student Satisfaction and Self-Perception of Skills

Student feedback regarding the virtual tutorial has become increasingly positive with each new generation of the tutorial. Each semester, a course-specific midterm and final survey are distributed to the class (Supporting Information), which asks students to rate their perceived utility of each of the individual *SciFinder* tutorial modules in empowering them to (1) effectively use *SciFinder* to search the chemical and biomedical literature, (2) find and obtain references using the Rider University Libraries catalog and interlibrary loan (ILL) system, (3) discern

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Table 3. Student Perception of Relative Utility[a,b] of Each Module of the *SciFinder* Tutorial between 2010 and 2015[c]

Tutorial Module[d]	2010	2011	2013	2014	2015
M1: Introduction	35	50	90	99	94
M2: Registration	40	64	91	99	94
M3: Remote Access	N/A	N/A	91	99	94
M4: General Searching	35	63	97	93	94
M5: Refining Searches	35	63	97	87	94
M6: Finding an Article	N/A	54	81	87	84
M7: Interlibrary Loan	5	50	81	81	94
M8: Document Types	N/A	45	87	81	94
M9: CASSI Tool	N/A	41	82	95	88
M10: Substance Search	25	63	88	81	94
M11: Structure Search	20	32	66	81	88
M12: Reaction Search	N/A	23	66	81	83
M13: Article Reading	N/A	50	87	81	77
M14: Citations	N/A	N/A	75	87	83

[a]Reported as percentage of students in each cohort who rated the tutorial module as "good" or "excellent". [b]N/A indicates that particular module did not yet exist in the overall tutorial for that year. [c]Assessment was not performed in 2012. [d]Full title for each module can be found in Table 1.

between types of literature, and/or (4) read, critically evaluate, and cite the chemical literature. These surveys also inquire about students' satisfaction with the *SciFinder* database itself, as well as its impact on their ability to compose their capstone assignment.[11] Personal evaluations between 2011 and 2015 overtly indicate that students perceive the *SciFinder* tutorial series, as well as the *SciFinder* database itself, as highly valuable. Selected comments are as follows:

The ability to pause and follow along with the tutorial made it easier to use SciFinder on a step-by-step basis.

I liked that I could go back to the modules and use as a reference if I forgot how to do something or to find new ways to find the sources I needed.

SciFinder was so insanely useful for the report. I seriously don't think that I would have been able to finish it if it wasn't for the ability to search by chemical structure. In addition, looking up relevant articles on the SciFinder database really sped up the research process, and the ILL service was phenomenal.

This report greatly improved my abilities to search and find primary articles relevant to the topic of interest. I have already put that skill to good use for other classes that were taken this semester.

While researching for this report, I found a lot of sources using the sources that were cited in a given article. This was interesting because I could see where the source got their background information from, and I would go and read that article.

I liked SciFinder because it was a fast and straightforward tool to find journal articles and other reference sources, especially due to the ability to sort search and refine results in many ways.

I really enjoyed SciFinder, I use it for all the different sciences not just organic chemistry. I thought it was relatively easy to use.

The research paper was a great assignment. It improved my ability to read and interpret difficult scholarly articles. It was also a great way to connect concepts covered in class to real world applications.

I had the most difficulty with wording for searches (spring 2015)

I had issues accessing links to articles initially, there was some weird pop-up blocker on. I think that might be useful to talk about in one of the modules. (spring 2015)

With regard to the *SciFinder* tutorial, comments indicate that students appreciate the ability to follow along at their own pace, and to bookmark important content that they know may be critical to understand later during their research process. It is also notable that students are using their expertise with *SciFinder* to perform literature searches for other nonchemistry science courses, that they are responsibly using the library's interlibrary loan service, and that they are able to extract relevant information—even exploiting the utility of references cited—from the articles themselves. While the feedback has been overwhelmingly positive, the penultimate quote from spring 2015 indicates that students still exhibit some difficulty in choosing appropriate search terms in *SciFinder* to return relevant sets of journal articles and patents. As such, stronger emphasis will placed on using appropriate search terms in Module 4 for the spring 2016 generation of tutorials. The last comment underscores the need for Rider student-specific tutorials which not only address searching strategies for *SciFinder*, but also give attention to common struggles our students have with unrelated issues such as Internet browser compatibility or other technological issues that frequently arise.

Students are also asked to provide their personal opinions on the utility of each module. Table 3 represents a general increasing trend in the perceived utility of each module from 2010 and 2015, reflective of both the continually evolving modules as well as the improved capstone assignment design[11] that demands effective usage of the chemistry search engine.

SciFinder Tutorial Usage

Rider University Libraries have two avenues for gathering viewing statistics on its in-house tutorials: YouTube and Springshare's LibGuides product. Table 4 shows the usage analytics of the *SciFinder* series of tutorials in 2014, which is compared with another house-made virtual tutorial for *Experian Simmons OneView*, an advanced business database.

Between the months of January and April, the students most likely to be accessing Rider University's *SciFinder* tutorial are those in Organic Chemistry II, which had only 20 students in spring 2014. In comparison, the Rider Libraries has a series of tutorials to help its hundreds of introductory marketing students use *Experian Simmons OneView*. Interestingly, these marketing students are required to use the database, but they do not appear to use the instructional tutorial, as evidenced by the low view counts. Table 4 includes the number of times each tutorial or module was watched between January and April of 2014, calculated by YouTube analytics for *SciFinder* and SpringShare's LibGuides for *Simmons OneView*. While the actual percentage of the video that was watched on each individual viewing may superficially appear to be low, this value must be corrected to represent that this is the average for each individual viewing: after one full viewing, students rewatching a tutorial do not need to attend to its entirety for a mere refreshment of skills or concepts. For example, even though there were only 20 students in the spring 2014 cohort, module 3 regarding off-campus access to *SciFinder* was watched 118 times. It is likely that most of these sessions were watched on more than one occasion by each of the 20 students, and that the flexibility offered with regard to video bookmarking, fast-forwarding, and replay allowed for viewers to pinpoint the exact clip needed, obviating the need to review the entire video. The third column in Table 4 hence represents the

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Table 4. Spring 2014 Usage Statistics for Online Tutorials/Modules Created by Rider University Libraries for the Purpose of Information Literacy Instruction

Tutorial	Total Views[a]	Percent Watched[b]	Average Views pp[c]
SciFinder (N = 20)[d,e]			
1: Introduction	280	45%	1.8
2: Registration	50	61%	1.97
3: Remote Access	118	69%	2
4: General Searching	228	62%	2.63
5: Refining Searches	147	64%	2.99
6: Finding an Article	61	57%	1.90
7: Interlibrary Loan	101	39%	1.71
8: Document Types	135	42%	2.34
9: CASSI Tool	92	69%	2.11
10: Substance Search	93	74%	1.33
11: Structure Search	113	65%	1.37
12: Reaction Search	136	52%	1.59
13: Article Reading	114	55%	1.85
14: Citations	51	55%	1.02
Total	**1719**		
Simmons OneView (N = 300)[d]			
1. Home	550	N/A[f]	N/A[f]
2. Using Simmons OneView	46	N/A[f]	N/A[f]
3. Media Planning	24	N/A[f]	N/A[f]
4. Quick Tutorials	15	N/A[f]	N/A[f]
Total	**635**		

[a]Views represent the number of times the tutorial or module was watched between January and April of 2014. [b]Value indicates the average percentage of video tutorial that was watched on each individual viewing. Since YouTube analytics provides the estimated minutes watched of a specific video in a session, the average percent watched during this time period was calculated by comparing the number of minutes each module was viewed to its full time length, indicating a proportion of completion. [c]Value represents the average number of times each student viewed the tutorial. This calculation takes into account the YouTube estimated minutes watched and the number of students in the course in spring 2014. [d]*SciFinder* tutorials were assumed to be primarily watched by students in Organic Chemistry II (20 students), while using *Simmons OneView* tutorials were assumed to be primarily watched by students in introductory business courses (300 students). [e]Full title for each module can be found in Table 1. [f]This data is not available as these tutorials are available in flash (.swf) format and not hosted on YouTube.

average number of times the tutorials were viewed by each student, indicating that each *SciFinder* module was accessed an average of at least once if not twice per student. In contrast, it is apparent that marketing students hardly use the University-made *Simmons OneView* tutorial; and anecdotally, the librarians report that business students rely on library staff far more heavily to navigate them through the *Simmons OneView* searching tool. In general, the overall usage of each module for *SciFinder* is far greater than any other virtual tutorial created by the university library.

This concrete popularity of the *SciFinder* tutorial is complemented by the high traffic of Rider University students using the search engine itself. Figure 2 indicates a 600% increase in overall *SciFinder* usage at Rider University between 2009 and 2015, specifically during the spring semester months. Before 2010, no such assignment was given in Organic Chemistry II, and the gradual increase in usage between 2009 and 2015 was undoubtedly reflective of improved tutorial instruction, assignment design, and the resultant perceived relevance of *SciFinder* as

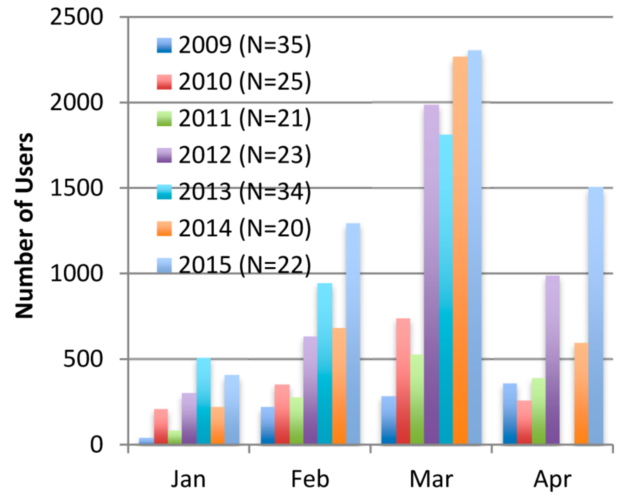

Figure 2. Number of *SciFinder* search sessions in spring semesters between 2009 and 2015. *SciFinder* graphics reprinted with permission from Chemical Abstract Services (CAS), a division of the American Chemical Society. Number of *SciFinder* sessions not reported for April 2013.

a search tool. It is not surprising that the height of usage is in the month of March, when the annotated bibliography is due prior to the rough draft of the capstone assignment.[11]

ASSESSMENT OF CHEMICAL INFORMATION LITERACY SKILLS

SciFinder Proficiency Assessment

After students submit their final research reports,[11] they are required to take an online quiz which intentionally evaluates their skills in chemical information literacy (Supporting Information). To our knowledge, assessment efforts to evaluate skills in literature searching, resource retrieval and evaluation, and article comprehension have been mostly evaluative and not task-oriented.[16,64] Although Gawalt and Adams[23] asked students to perform directed searching tasks in different databases, these tasks were open-ended, and results likely varied widely between students, making the outputs accordingly nonquantitative and certainly difficult to comparatively evaluate across a cohort. The organic chemist alternatively designed a multiple-choice quiz (embedded in the course's Canvas learning management system) that consists of four or five specific situational prompts requiring students to use their information literacy skills to find the most appropriate references for a specific topic using *SciFinder*, refine their searches, determine if their desired articles can be retrieve through the Rider University Libraries system or via interlibrary loan, and extract specific information from these articles (Supporting Information). The situational prompts are very specific, and executed by the professor immediately before deployment to the class, so that the search results remain current and unchanged over the week in which the students are permitted to take the quiz. Although the initial development of the quiz was somewhat time-consuming, each yearly deployment that followed merely required changes to the multiple-choice so that the answers reflect the most recent changes to the *SciFinder* database. Box 1 depicts an example of a situational prompt and the associated learning outcomes assessed with each question.

As shown in Figure 3, the 2010 and 2011 quiz statistics were lower than expected, and it was determined that this was likely due to the additive nature of the quiz, which listed 12 questions

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Box 1. Exemplar Scenario from Spring 2015 Proficiency Quiz for Assessment of Chemical Information Literacy, and Associated Expectations of Student Learning outcomes

Scenario 2 You have just been assigned a report to outline the professional research career of **Michael Thomas Crimmins.** Your assignment is to present the experimental data and proposed electron-pushing arrow mechanism of his signature reaction methodology, as well as the breadth of molecular targets to which this methodology was applied. You must further present a complete synthetic outline for one of these molecular targets, and finish by discussing all the awards and accolades received by Dr. Crimmins as a result of his groundbreaking research. Use this scenario to help answer questions #4–6.

4. You set out to gain a general understanding of his research before your search to his articles. What is the title of Dr. Crimmins' most recent review? (**SLO: searching by author, refining by document type, sorting by date**)

(a) Synthetic Applications of Intramolecular Enone-Olefin Photocycloadditions
(b) Application of Oxazolidinethiones and Thiazolidinethiones in Aldol Additions
(c) Ketene Diethyl Acetal: First Update to Document Cited in CA149:223390
(d) Amino Acid Derived Heterocyclic Chiral Auxiliaries: The Use of Oxazolidinones, Oxazolidinethiones, Thiazolidinethiones, and Imidazolidinones
(e) I do not know

5. What is the title of the journal in which this review article was published? (**SLO: using the CASSI tool**)

(a) Mod. Meth. Rxns.
(b) Modern Methods in Stereoselective Aldol Reactions
(c) Chem. Rev.
(d) Org. Synth.
e) I do not know

6. Refine your search to find Crimmins' most recent article (not necessarily review article) published with his graduate student, Kyle A Emmitte. Do we have access to this article through the Rider Library? Is it in print? If not, how can we access the article as easily as possible? (**SLO: returning to an original result set, refining by author, using the RU Libraries catalog, understanding interlibrary loan**)

(a) No—there is no way we can access the article
(b) No—but we can access it for FREE via ILL
(c) No—but I can purchase it for $30 from the publisher website
(d) Yes—print
(e) I do not know

based on one initial situational prompt. Thus, if a student performed the initial part of the search incorrectly, but all of the other parts correctly, all of their answers would still be incorrect based on their first answer. In 2012, the quiz was altered to a more modular format, wherein students are now asked to perform four or five separate searching tasks, and answer three questions based on each task such as the one presented in Box 1 (Supporting Information). Because the questions are multifaceted, it is still somewhat difficult to pinpoint the tasks in which the students excel, and those in which still need development. Still, the results provide a proper platform by which the *SciFinder* tutorial and individual modules can be evaluated with respect to student achievement of learning objectives, and subsequently modified to benefit the next year's cohort of students. Figure 3 summarizes the student performance on these quizzes between 2010 and 2015, only including the skills which were assessed at least three times during this period (as prompts and questions are subject to change). Other learning outcomes that have been assessed but are not shown in Figure 3 include citation format, refining by yield, refining by catalyst or reagent, accessing SciFinder from off-campus, refining by author, refining by key word, and using interlibrary loan. The *y* axis reflects the percentage of students of a specific cohort that correctly answered the question relating to a particular student learning outcome (*x* axis) of the *SciFinder* quiz.

A general upward trend in skill improvement is seen for most skills iteratively assessed during this time period, with two prominent deviations. Student proficiency with subject searching while excluding duplicates (Figure 3) seems to have remained steady over the years with little improvement. In the future, our assessment will likely include one question asking the students "All of the following hits might be selected *except*" to test the students' capacity to understand the importance of the *relationship* between search terms. Furthermore, the skill of abstract reading still remains low without an increasing trend, indicating that Module 13 must be further improved for the next term's cohort.

Figure 4 also depicts the general upward trend in chemical information literacy skills between 2010 and 2015, and concomitantly indicates that the standard deviation in general quiz performance per cohort is decreasing. This may be representative of the impact of the upgraded assessment instrument, the continued improvement of the *SciFinder* tutorial, or both.

Evaluation of Student Usage of Academic Libraries and Interlibrary Loan

One skill that has often been underestimated and under-examined in chemical information literacy instruction is a student's ability to find and access the articles they have discerned to have importance, so that they could subsequently read, critically think about, and communicate its content. In response to early student feedback (2010–2012) that the library did not provide access to the articles that students found on *SciFinder*, continual revisions were made to the original tutorial in order to better (1) teach students to effectively navigate the Rider University Libraries catalog to search for their resources in print or online, (2) give students step-by-step guidance on how to use the University's interlibrary loan process in conjunction with the bibliographic information provided on *SciFinder*, and (3) underscore the importance of looking for resources early so that interlibrary loan can be used in a responsible and timely fashion. On the surface, it appeared as if these cyclical tutorial revisions have finally succeeded, as the general usage of interlibrary loan by Organic Chemistry II students exploded in 2014 (Table 5); however, its misuse became apparent at the same time.

Toward this end, the collaborating faculty and librarians have begun evaluating the number and quality of interlibrary loan (ILL) requests from the students in Organic Chemistry II (Table 5). Poor quality ILL requests are defined as requests that are unworthy of fulfillment, and include submitted requests with incomplete biographical information: for non-English language references (no such requests were initiated by non-native English speakers); for articles that were available at the Rider University Libraries, through its online subscriptions, or via open access on the Internet; for nonpublished abstracts, posters, and oral presentations; and requests which were duplicates of previous

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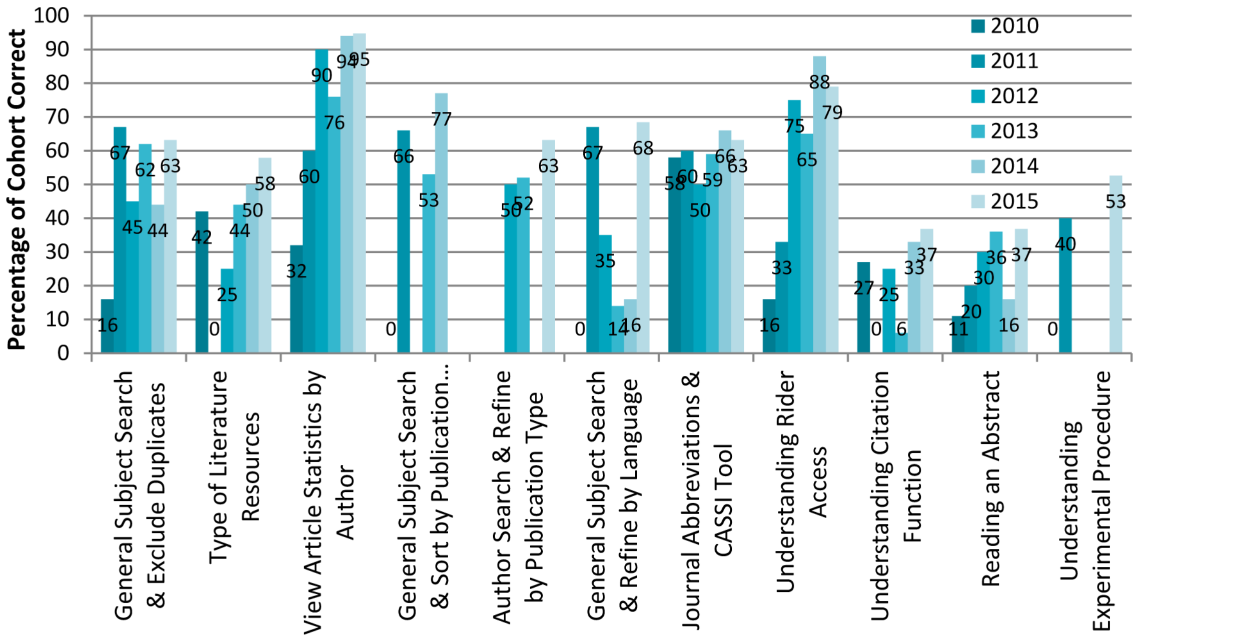

Figure 3. Assessment of student learning outcomes for chemical information literacy in Organic Chemistry II between 2010 and 2015, as determined by performance on individual questions from the *SciFinder* proficiency quiz. Columns without a data number indicate that skill was not tested in that year's assessment.

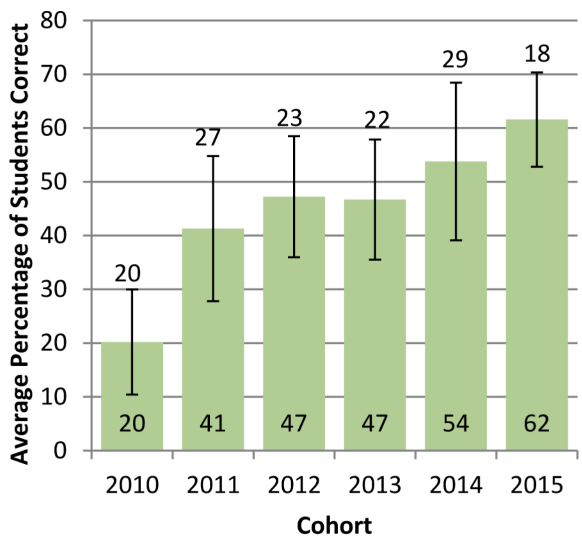

Figure 4. Comparison of average correctness for each cohort on *SciFinder* proficiency quiz between 2010 and 2015, with error lines indicating the standard deviation in scores for those cohorts.

Table 5. Interlibrary Loan (ILL) Usage for Organic Chemistry II Students between 2013 and 2015

		2013[a]	2014[a]	2015[a]
Number of students in cohort		34	20	22
ILL requests	Total	4	77	30
	Articles	3 (75%)	68 (88%)	26 (87%)
	Books/chapters	0	7	3
Poor requests	Nonpublications	1 (25%)	2 (2.6%)	1 (3.3%)
	Non-English	0	6 (7.8%)	2 (6.7%)
	Rider available	0	6 (7.8%)	2 (6.7%)
	Available online	0	9 (12%)	2 (6.7%)
	Duplicate requests	0	4 (5.2%)	0
	Incomplete/incorrect requests	1 (25%)	28 (36%)	5 (17%)

[a]Percentages in parentheses represent that number as a percent of total ILL requests (row 2) for the spring semester for that particular year.

ones. These observations thus guided the tutorial revisions for the spring 2015 iteration: the module on interlibrary loan was modified to stress the importance of discerning the type of reference, being vigilant about the article language, completing the interlibrary loan form with the essential citation information, and ensuring the resource's unavailability at Rider or on the Internet. It is likely that all of these changes embedded into the tutorial led to a significant decrease in the number of total interlibrary loan requests in 2015, as the percentage of invalid requests also decreased significantly.

■ CONCLUSION

A series of virtual tutorials on chemical information instruction have been created for use alongside a capstone research assignment for Organic Chemistry II.[11] A multimethod approach is used to assess the effectiveness of each tutorial module in reaching its learning objectives, and to accordingly guide revisions for the next year's cohort. This cyclical revision and implementation process will continue annually as new students enroll in Organic Chemistry II, as the information literacy standards dictated by the ACS,[4] SLA,[5] and ACRL[7] continue to evolve, as the *SciFinder* interface is continually updated, and as new instructional technologies become increasingly accessible. Current generation of tutorials are publically available at http://guides.rider.edu/scifinder.

It is anticipated that the described virtual tutorial and instruction model could be successful in all chemistry classrooms, and would be particularly beneficial to those with limited instructor and curricular resources. Recommendations for CII tutorial creation and implementation are as follows:

(1) Tutorials should be split into short, relevant modules to facilitate resource accessibility and retention.

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(2) Tutorials must be audibly and visibly salient, and use familiar and relaxed narration.
(3) Tutorials should be published in a format that provides user analytics.
(4) Tutorials should be assigned with an accompanying project that ensures the use of *SciFinder* (or other desired database) to complete that project.
(5) Tutorials should include modules that integrate the general instruction of efficient searching, reading, and citation practices, with institution-specific modules for using the library catalog and other resources.
(6) Achievement of student learning objectives should be evaluated at the end of each academic year, so that significant revisions can be incorporated into the next tutorial generation.
(7) Since tutorial development requires a massive time commitment and diversity of skills, collaborations between chemists, science librarians, and technology librarians are ideal.

Future Considerations

Although the combination of summative and formative assessment efforts provide invaluable feedback on student usage and proficiency with the *SciFinder* tutorial (as well as the searching tool itself), the proficiency quiz is still somewhat flawed in that it can be difficult to assess individual skills and learning outcomes, as each question examines multiple skills additively. One way to better parse out the individual skills and weaknesses would be through *observation*. In the next course/tutorial iteration, the chemist and librarians plan to recruit at least half of the Organic Chemistry II cohort to use screen capture and voice capture technology to have students record themselves completing the *SciFinder* quiz. This process integrates well-known methodologies performed by other researchers,[65,66] and would allow the collaborators to directly observe student patterns (and thus proficiencies) in chemical searching.

Furthermore, to ensure that our students sustain their chemical information literacy skills throughout their upper-level courses and beyond, the practice of literature research and writing must be deliberately integrated vertically into the chemistry and biochemistry curriculum. To this end, the organic chemist has recently incorporated the *SciFinder* tutorial series and proficiency quiz into two upper-level courses: Advanced Organic Synthesis and Spectroscopy (CHE 350) and Physical Organic Chemistry (CHE 420). The low-stakes quiz reminds students that the virtual CII tutorial is available, and allows them to quickly refamiliarize themselves with specific tools and concepts, particularly *SciFinder* searching strategies that may not have been relevant in Organic Chemistry II such as searching by reaction scheme or refining by commercial availability. More importantly, all five full-time Rider University Chemistry and Biochemistry faculty exhaustively incorporate writing and literature research into their upper-division courses. It is not necessary, and is somewhat antithetic, for these faculty members to deliberately embed the *SciFinder* tutorial and related activities into their 300- and 400-level courses. The tutorial modules are openly available to all Rider University students—not just sophomores in Organic Chemistry II—and as long as students are continually required to search and critically think about the chemical literature, their impact and associated outcomes will be vertically sustainable. Tools to assess the quality and extent of such skill retention and transferability are currently under development within our department, and will be prudent for evaluating our graduates' preparedness for the workforce in accordance with ACS-CPT guidelines.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00427.

A list of expected learning outcomes for each of the 14 current tutorial modules (PDF)
Spring 2015 iteration of *SciFinder* proficiency quiz (PDF)
Spring 2015 online survey for self-assessment of *SciFinder* tutorial usage (PDF)

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Notes

The authors declare no competing financial interest.

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