International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

Information literacy in science writing: how students find, identify, and use scientific literature

Kristin M. Klucevsek & Allison B. Brungard

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
VOL. 38, NO. 17, 2573–2595
http://dx.doi.org/10.1080/09500693.2016.1253120

Routledge
Taylor & Francis Group

Information literacy in science writing: how students find, identify, and use scientific literature

Kristin M. Klucevsek [a] and Allison B. Brungard [b]

[a]Department of English and Theater Arts, Duquesne University, Pittsburgh, PA, USA; [b]Bailey Library, Slippery Rock University, Slippery Rock, PA, USA

ABSTRACT

For undergraduate students to achieve science literacy, they must first develop information literacy skils. These skills align with Information Literacy Standards and include determining appropriate databases, distinguishing among resource types, and citing resources ethically. To effectively improve information literacy and science literacy, we must identify how students interact with authentic scientific texts. In this case study, we addressed this aim by embedding a science librarian into a science writing course, where students wrote a literature review on a research topic of their choice. Library instruction was further integrated through the use of an online guide and outside assistance. To evaluate the evolution of information literacy in our students and provide evidence of student practices, we used task-scaffolded writing assessments, a reflection, and surveys. We found that students improved their ability and confidence in finding research articles using discipline-specific databases as well as their ability to distinguish primary from secondary research articles. We also identified ways students improperly used and cited resources in their writing assignments. While our results reveal a better understanding of how students find and approach scientific research articles, additional research is needed to develop effective strategies to improve long-term information literacy in the sciences.

ARTICLE HISTORY
Received 10 June 2016
Accepted 23 October 2016

KEYWORDS
Faculty librarian collaboration; information literacy standards; undergraduate science literacy; science writing; primary research articles; embedded librarians

Introduction

To be better scientists, science faculty indicate that their students need stronger discipline-specific research and writing research skills, yet students lack enough practice (Coil, Wenderoth, Cunningham, & Dirks, 2010; Gonyo & Cantwell, 2015). One way to immerse students in these opportunities is through a writing course, where students are involved in a professional writing process that requires research in a field of their choice (Guilford, 2001). To be able to write within their fields, however, students must develop skills in scientific and information literacy. Information literacy standards for science and technology describe identifying a need for information, determining the type of information needed, and then finding, evaluating, and using that information ethically (Association

CONTACT Kristin M. Klucevsek klucevsekk@duq.edu 600 Forbes Ave, Pittsburgh, PA 15282, USA
Supplemental data for this article can be accessed 10.1080/09500693.2016.1253120.

of College and Research Libraries, 2006). The Association of College and Research Libraries (ACRL) adopted a new framework that applies this model to address higher-level critical thinking components, or threshold concepts, such as *Information Creation as a Process*, *Research as Inquiry,* and *Scholarship as a Conversation*. This framework supports the need for students to find and use primary research articles within their disciplines (Association of College and Research Libraries, 2015).

Using primary literature in science courses

It has become increasingly common to use primary literature articles as a teaching tool within the sciences. By immersing students in authentic primary literature, they learn and read science as inquiry (Phillips & Norris, 2009). Exposure to primary literature increases students' confidence in reading, critiquing, writing, and presenting research to a broader audience (Brownell, Price, & Steinman, 2013; Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006; Krontiris-Litowitz, 2013). In a writing course, exposure to primary research increases students' abilities to identify the main points of a scientific paper and interpret data (Brownell et al., 2013), which helps them further communicate the results. The benefits of primary research as a training tool also extend beyond undergraduate instruction. Early researchers become better writers through reading primary research articles as examples that help scientists focus and design their own writing (Shah, Shah, & Pietrobon, 2009).

While using primary literature articles is a worthy teaching strategy, some instructors may avoid using primary literature because of the technical content. Baram-Tsabari and Yarden (2005) found that exposing high school students to primary literature improved students' scientific inquiry, but that these students did not understand the content as well as those that read secondary literature. Secondary literature, such as reviews or books, would presumably be easier for students to read. Yet the importance of using primary texts lies in the ability to improve critical thinking and immerse students in the most authentic, discipline-specific discourse (Ford, 2009).

To alleviate some of the challenges of teaching primary research, one must first understand how students interact with these articles. Undergraduate students use structural elements of primary research articles, such as citations and methods, to decide if an article is scientific, especially when they are not experts on the topic (Bromme, Scharrer, Stadtler, Hömberg, & Torspecken, 2015). Therefore, students could learn the discourse features of scientific articles to help them identify primary articles. It may be helpful to also teach the scientific method in conjunction with the structure of an article. The scientific method is canonically described as a process by which one has a question, surveys the literature, forms a hypothesis, and then logically designs and performs an experiment to collect and analyze data. The scientist then compares the data to the hypothesis and often communicates findings through a primary research article. While in practice scientists use a more fluid and complicated process with feedback loops, our primary research articles present these steps in a specific structure and coherent story. By teaching this structure alongside the scientific method, we can help students understand the purpose and content of each part of the primary article. For example, this can be accomplished through scaffolding writing assignments that are steps in the scientific method to connect processes. Students can practice experimental design and data analysis and then write this in the method section of an article, or students can survey the literature and use this to write an introduction. This scaffolding design can increase cognition of the scientific method as well as improve writing skills (Coil et al., 2010). Even some early research scientists have difficulty writing research articles because they do not understand the difference between content and structure in primary research (Shah et al., 2009). This supports that the structure and purpose of primary articles become a foundation for undergraduate education.

The intersection between scientific and information literacy

Scientific literacy, though broadly defined, includes the ability to read and understand articles about science as well as to engage in conversations about the research. Scientific literacy also implies the ability to evaluate the quality of scientific information and the methods used to generate it (National Research Council, 1996). The scientific method and its presentation in primary research articles reflect the diverse nature of the science disciplines (Ford, 2009). Among the research published as primary, science disciplines may include observational case studies, hypothesis-driven studies, and theoretical work. Therefore, if we are to support truly scientifically literate students, we need to teach students how these primary research articles are a reflection of their discipline's research methodology. This starts with helping students find and identify these articles through information literacy.

According to the National Research Council,

> Any education in science and engineering needs to develop students' ability to read and produce domain-specific text. As such, every science or engineering lesson is in part a language lesson, particularly reading and producing the genres of texts that are intrinsic to science and engineering. (National Research Council, 2012, p. 76)

The outcomes for information literacy in the sciences, detailed in the *Next Generation Science Standards* (National Research Council, 2014), align *with Information Literacy Standards for Science and Technology* (ACRL, 2006). An information literate student must be able to: (1) Determine nature and extent of the information needed; (2) Acquire needed information effectively and efficiently; (3) Critically evaluate procured information and its sources and decide whether or not to modify the initial query or develop a new research process; (4) Use information effectively, ethically, and legally to accomplish a specific purpose; and (5) Recognize the need to keep current regarding new developments in her or his field. Enhancing scientific literacy through information literacy helps students learn to become better critical thinkers and communicators and ultimately transfer those skills within their chosen professions.

Library-integrated instruction

Integrating pedagogies for scientific literacy and information literacy cultivates students' abilities to understand, analyse, and evaluate scientific information and thus overall expand scientific knowledge (Porter et al., 2010). While faculty generally agree that students need fundamental skills in literacy and communication, faculty also report that they do not feel they have the time to do so effectively in the classroom (Coil et al., 2010; Gonyo & Cantwell, 2015). Additionally, not all science faculty may be equipped to teach literacy (Baram-Tsabari & Yarden, 2005; Ford, 2009). In one study, science faculty and researchers reported that they did not use the library website or the library as a resource to find information and they displayed a limited variety of search techniques (Haines, Light, O'Malley, & Delwiche, 2010), indicating that librarians could support their research by becoming a more integral part of the departments. However, without a direct connection between the faculty and the librarians, or a course and librarians, students may also underestimate the value of this resource.

One way to enhance information literacy instruction and integrate library instruction is to embed a librarian within a course or program. While some faculty may see time as a limiting factor for librarian integration, there are several benefits to this interaction. Librarians and science faculty share common goals in developing a deeper ability to find and use research articles. Embedding a librarian provides authentic course-integrated instruction at the time of need and allows the librarian to engage with the students at different stages of the research process. The librarian teaches effective search strategies and databases specific to a course topic, and then students develop and refine these skills. Many examples from the literature detail collaborations between science faculty and subject librarians to advance information literacy initiatives by involving a librarian several times within a course (Jacob & Heisel, 2008; Pritchard, 2010; Thompson & Blankinship, 2015) or even through a single lesson (Coil et al., 2010; Mc Goldrick, Marzec, Scully, & Draper, 2013), but this relationship should be more strongly emphasised or involve the library as an integrated, ongoing resource (Ferrer-Vinent & Carello, 2008). For example, having a librarian perform the instruction at more than one point during the semester, and in multiple courses, could establish a stronger long-term connection, as could supplemental material such as an online research guide. In another case of library-integrated learning, faculty paired an information literacy course taught by a librarian with a separate composition course to form an online learning community. Students who participated in the learning community model demonstrated significantly higher persistence and completion rates than students enrolled in the composition course only (Burgoyne & Chuppa-Cornell, 2015). This is another example of how more integrated instruction could improve information literacy, presumably greater than what could be achieved with a single lesson.

Motivation for the research

In our teaching experience as a science librarian and science writing instructor, we have noticed that stronger information literacy skills are required for complete scientific literacy. Specifically, we have seen students experience difficulty finding, identifying, and using primary literature. Therefore, in this case study, we investigated the effects of integrating information literacy skills into a science writing course and reported on students' practices with academic articles. We designed a course that mirrored the professional process of writing and publishing scientific journal articles and asked students to write literature reviews on a topic of their choice (Guilford, 2001). This process included items such as submitting a letter of inquiry to a journal editor, giving students a Guideline to Authors, and receiving both informal and formal anonymous peer review. We believed that this would give students the opportunity to build and refine their information literacy skills specific to their disciplines and interests, while simultaneously engaging in an authentic practice. To further enhance information literacy, we emphasised primary article structure and content in the course lessons and integrated a science librarian into the course, which were both novel methods to the course design. For the first time, there was a direct connection between students in this course and the library, an essential university resource. The science librarian helped students identify appropriate sources, use research databases, formulate search strategies, and evaluate resources at their point of need. Kingsley et al. (2011) reported that they were able to improve research strategies of first-year dental students with merely a one hour librarian-led instruction session, thus connecting students with evidence-based literature as opposed to sources obtained through Google. In our case study, where the students also initially reported using primarily Google, we used library-integrated instruction to teach and assess the research and writing process throughout a semester-long project. In addition to confidence levels, we objectively assessed information literacy in our students through these task-scaffolded assignments and course surveys. Our research aimed to identify student challenges and practices related to information literacy through three questions, each of which progresses through established information literacy standards for science and technology (Association of College and Research Libraries, 2006):

(1) How does librarian-led instruction develop students' skills in finding scientific literature?
(2) Can students identify and evaluate types of scientific literature?
(3) How do students use scientific primary research literature in their writing?

Methods

Course design

A science writing course was designed for the following majors: Biology, Chemistry, Biochemistry, Environmental Science, Physics, and Forensic Science. Enrollment was open to other majors as well. In this course, students participated in a mock publication of a literature review with peer review. Students began the semester by writing a letter of inquiry to an editor, proposing to write a literature review on a topic of their choice. Students submitted task-scaffolded assignments towards the Final Review, totaling over 65% of the final grade in the course (Table 1). The Final Review needed to be accompanied by a cover Letter to the Editor, which addressed the purpose of the review and what the author had done to address reviewers' comments. At the end of the course, students also wrote a news article.

Course activities

The course used group activity-based lessons and friendly competition to enhance motivation and participation rather than a lecture-style format. Data from this article include relevant activities, such as the Primary Research vs. Reviews Venn Diagram lesson. This lesson occurred during the same week as library instruction, but before the Annotated Reference assignment was due (Table 1). In this lesson, students received 10–20

Table 1. The progression of relevant lessons, assessments, and surveys described in the present study.

Week(s)	Lessons	Assessments	Surveys
1	Types of science writing		Pre-course
2	Database I library instruction	Topic choice	Pre-library
	Comparing primary and secondary articles (Venn Diagram)		
3	Database II library instruction	Annotated references	Post-library
	Applying the scientific method to the structure of primary research articles		
4	Ethically using and citing journal articles	Outline	
	Avoiding plagiarism		
	Secondary article content and structure		
5	Paraphrasing research		
	Analysing figures and tables		
6–9	Peer review	Review Draft I	
	Writing style for academic articles	Research guide reflection	
	Writing abstracts		
	Designing figures and tables		
10–12	Peer review	Review Draft II	
	Learning the academic publishing process	Anonymous peer review	
	Judging grants and posters		
13–15	Writing a cover letter	Final review	Post-course
	Science in the news	News article	
	Science communication for the public		

primary research and review articles from different disciplines and journals. In small groups, students created a Venn Diagram to compare and contrast the two types. In a class discussion, we used these examples to find format and content trends in each type but also used class discussion to emphasize that there is more than one way to tell if an article is primary. The canonical Introduction–Methods–Results–Discussion (IMRD) structure is not used by all journal formats and cannot be the defining element of primary research. In addition, there are systematic reviews and meta-analyses that also use this form, which deepens the discussion of journal article types. There are cues that can help one identify an article as primary and original research. For example, we discussed title content, verb choice in the abstract, and citations within figure legends as common distinguishing factors. By the end of class, students could use the Venn Diagrams they created to aid article identification when they began independently searching through databases. In another lesson activity, students described the scientific method and identified where each stage of this method can be found in a primary research article. This supported the ethical use of a primary research article for information related to original stages of the scientific method. This course also taught other lessons with some direct or indirect impact on the learning outcomes in the present study (Table 1).

Assessments

All writing assessments in this case study were scored and analyzed by the course instructor. The Research Reflection was analyzed by the librarian. Data from the following assessments are included in this article:

Research reflection

Students completed open-ended reflections using a blackboard throughout the semester. In the reflection, students indicated how they had used the online Science Writing Research Guide (Appendix A).

Review assignments

In the major writing assignment of the semester, students synthesised an original review on any research topic. Before writing the review, each student submitted an Annotated References assignment (Appendix B).This graded assessment evaluated students' abilities to identify reference type and format references on their chosen topic. In this assignment, students found and identified at least 10 potential journal article references for their review, with a minimum of 8 primary research articles required. Each draft increased in the number of required references. In Draft 1, students needed at least six primary research articles as references and a minimum total of eight references. In Draft II, students needed at least 9 primary references and a minimum total of 13 references. By the Final Review, students needed at least 11 primary references and a minimum total of 15 references. Students informally received feedback by both the instructor and librarian on reference choice related to their topic on an individual and ongoing basis. Therefore, to address their research topics, their reference choices expanded and evolved with the writing process. Each version of the paper also increased in length and number of components. By the Final Review, each paper included the following items in this order: A Cover Letter to the Editor, Title, Abstract, Key Words, Review Text (Introduction, 2–4 Main Text Sections, and Conclusion), Original Figures or Tables, and References in an American Chemical Society (ACS) citation style.

Anonymous peer review

While there were two times a semester when students participated in an informal peer review workshop, the Anonymous Peer Review was an opportunity for students to practice a professional skill (Appendix C). Students learned the process of scientific publishing and blind peer review as part of the class. In this assignment, they anonymously reviewed a peer's review article at the Draft II stage and made a recommendation for publication to the editor (the instructor). They supported this recommendation by describing how the review fit several criteria, including the proper identification and use of primary research articles. To protect anonymity, the instructor collected a copy of Draft II from each student and re-distributed the papers to peers. The instructor would also collect the peer review feedback. While the author would eventually receive a copy of the review, the identity of the anonymous peer reviewer would not be revealed to the author at any point.

News article

In the News Article assignment, students communicated findings from one recent primary research article to the general public. This research had to be outside the topic area of their Final Review. This assignment assessed how they applied their skills in finding and using primary research articles to write about a new topic.

Description of a reference check

On every review assignment that included references, students identified all secondary sources by marking them with asterisks on the reference list. This allowed the instructor or a peer to assess identification and proper use of the article as part of the assignment's rubric. The instructor performed reference checks on assignments to assess how students identified and used research articles. Often, these articles were not randomly chosen. In the annotated reference assignment, at least 2 out of 10 references were verified as primary or secondary for each student. More than two references would be checked for some students if additional reference titles sounded broader, and therefore could have been unidentified secondary articles. A reference check was also performed as part of the Draft I and Final Review rubric. Here, at least one reference would be checked for two items: (1) was the article identified correctly as a review or a primary research article? (2) If the article contains primary research, was the article used appropriately and paraphrased for research original to the article and reflective of the scientific method (e.g. hypothesis, methods, data, and conclusions)? This reference check represented only one category of the rubric. Failure on either item resulted in a failure in that category, regardless of the mistake. Students received their scores for the reference check, as well as which reference the instructor checked and the results of that analysis.

Pre- and post-course surveys

Students were given pre-and post-course surveys during the first week of courses and finals week, respectively. This class survey included confidence-based questions on a five-point Likert scale, as well as multiple choice responses and open-ended definition questions (Appendix D).

Library instruction and the science writing research guide

The librarian provided research database training for the students in two class sessions during weeks 2 and 3 of the semester. Following group training, each student used the databases to find research for their assignments with individual instruction from the librarian. The librarian returned later in the semester to answer student questions and met with students outside of class. This co-instruction was reinforced through the creation of a new learning tool for the course, an online Science Writing Research Guide, to facilitate course learning objectives (http://guides.library.duq.edu/sciencewriting). Because the guide is a key learning tool for the course, formal assessment was conducted through the Research Reflection and the post-class survey. As a result, the guide has evolved based on students' feedback each semester and serves as a permanent resource.

Pre- and post-library surveys

The library pre-survey, a six-item questionnaire, was developed to measure library research competencies. This was administered prior to database instruction. The post-library survey contained eight items, including an assessment of library instruction, and was administered after two course-integrated library training sessions (Appendix E).

Student demographics and study participation

There are four sections of Science Writing each semester. This study was conducted with Institutional Review Board approval over the Fall 2014 and Spring 2015 semesters. There were a total of 143 students (sophomores, juniors, and seniors) enrolled in the course. Of these students, 136 both consented to participate in this study and completed the course. For library instruction, only consenting students who completed both the pre- and post-library questionnaires were included in the data set ($N = 118$). For semester-long classroom assessments, only consenting students who completed pre- and post-course surveys were included in the data set ($N = 130$).

Results

Library instruction improves information literacy in science students

To better understand students' information literacy, we used pre- and post-library instruction surveys that measured their confidence and knowledge of database use. In the pre-survey, 77% of students reported no prior library instruction in a science course, as well as no prior use of science-specific databases (Table 2, Figure 1). Students also reported that they had no experience using SciFinder (73%), ScienceDirect (77%), and Scopus (88%), three significant science research databases available through the library's subscriptions (Figure 1). Therefore, the librarian provided hands-on training using these three databases: Scopus and ScienceDirect, both produced by Elsevier; and SciFinder, produced by Chemical Abstracts Service of the American Chemical Society.

The database instruction took place during two class sessions in a computer lab so that each student could participate in the demonstration. In the first half of each lesson, the librarian modelled the use of a database to the class to find primary research and review articles published in peer-reviewed journals. To demonstrate use, the librarian used controlled vocabulary examples to map scientific or concept terms within each database. Various types of resources are available through these databases, such as books and book chapters, and grey literature consisting of conference proceedings, dissertations, reports, and other publications that do not fit into the journal article category. These publication types were discussed as authoritative sources that support research needs beyond the scope of their Annotated References assignment. Following group training on a database, each student selected relevant databases to find research for the Annotated References assignment with individual instruction from the librarian. Here, they immediately applied what they learned in the first half of the class by searching for and identifying primary research and review articles about their chosen topics.

We assessed how the library instruction helped students become more confident in their research abilities through the library surveys. Students were asked to consider their confidence level when beginning to research scientific information. Using a Likert-type scale (1 = Strongly Disagree, 5 = Strongly Agree), they rated their opinions. In the library post-survey, 99% of the students reported that they strongly agreed or agreed that they felt confident when beginning to research scientific information, compared to the library pre-test, where only 70% felt confident (Table 3).

A main objective of the course was students' ability to use field-specific databases to find and identify primary and secondary journal articles. One of the open-ended questions

Table 2. Students' report of previous library instruction in the pre-library survey.

Previous library instruction	No	Yes – required	Yes – voluntary	Total
N	91	27	0	118
%	77.12	22.88	0	100

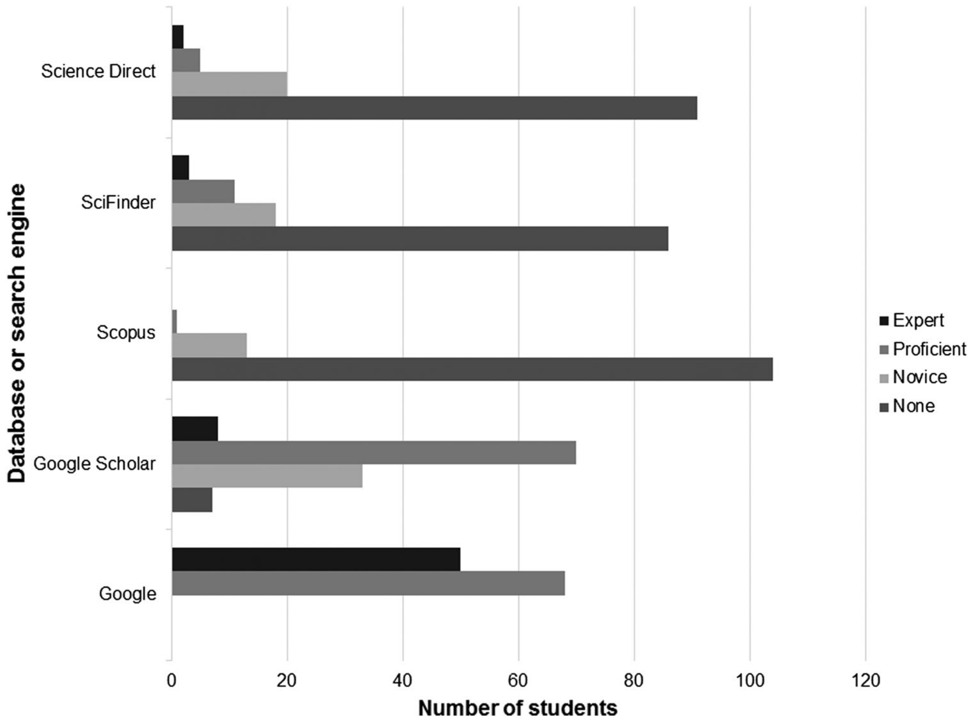

Figure 1. Students' reports of prior experience with research databases in the pre-library survey. Students ($N = 118$) completed the pre-library survey before the first database instruction lesson to rate their experience with each database or search engine (Science Direct, SciFinder, Scopus, Google Scholar, and Google).

in the library pre-and post-surveys addressed this objective. Here, students listed the steps they would take to find a primary research article. In the pre-library survey, 61% of students said they would first go to Google or Google Scholar to find information on their topic. In contrast, the post-library survey responses indicated that they would begin their research by first going to a specific database. Students demonstrated learning by briefly describing how they would go about finding a primary research article. These descriptions became more specific and refined in the post-survey. We qualitatively analysed these responses as direct evidence of changes in student learning. Sample quotations below compare individual responses before and after library instruction:

Table 3. Pre- and post-library surveys on students' confidence levels in their ability to use databases.

Confidence	Pre-test	Post-test
Strongly disagree	1	0
Disagree	10	0
Not sure	24	1
Agree	65	77
Strongly agree	18	40
N total	118	118

Pre-survey: *Not sure, honestly.*
Post-survey: *Refine results of the topic by selecting things like 'journal'. Look through the citations for original research.*

Pre-survey: *Search keywords and scan the articles.*
Post-survey: *Read the title, read the article, search for keywords stating that it was original research or not.*

Pre-survey: *Use JSTOR or Google Scholar.*
Post-survey: *Use PubMed, Scopus, SciFinder, etc. and look at the articles. Look for intro, methods, results sections. Go to a database and search using my keywords. Then check to see if the articles are reviews or primary research.*

Pre-survey: *Use Google Scholar.*
Post-survey: *Use one of the databases and search your topic, find articles with the format as primary research articles and then verify it as a primary research article.*

Pre-survey: *First I would try Google Scholar. Then, I would try one of the library's databases.*
Post-survey: *Go to a database and search using my keywords. Then check to see if the articles are reviews or primary research.*

In addition to library instruction during class time, we created a multi-faceted learning tool for the course to provide long-term support for information literacy. This online Science Writing Research Guide incorporated science research databases and video tutorials, as well as resources for distinguishing primary literature from review articles. The guide also included links to current science news items, the science faculty's newly published research, citation management tools, and relevant web portals. It was developed with a digital learning environment in mind and is linked within the course management system. Usage statistics showed that the Science Writing course guide ranked first out of all course specific guides and 9th out of 555 total research guides at the University the semester it was introduced and has since continued to be one of the most accessed online learning tools available through the library. To assess how the research guide supported student learning, students completed a reflection assignment. The Research Reflection was due after Draft I and before Draft II, therefore indicating student use of the guide during the writing process. Here, students described how they had used the research guide allowing us a direct way to qualitatively analyse how students use this resource. The majority of students (73%) stated that the database section was the most helpful part of the research guide. They also reported (97%) primarily using three databases, Scopus, SciFinder, and ScienceDirect, for their assignments, which directly aligned with library instruction. Furthermore, students used additional resources located on the online course research guide that were not taught in class, such as PubMed, ProQuest Science Journals, and Nature Journals. Students evaluated their successful use of these databases to locate articles in the Research Reflection:

> I used ScienceDirect. I'm going to use the other databases to find sources for my second draft. I didn't know of any science based databases before this class. I figured I'd just look through the list of databases, in alphabetical order, until I found one that sounded science related.

> I find most of my articles using SciFinder (since its chemistry major heaven). However, after the class, I used ScienceDirect to find some of my articles that SciFinder didn't have.

> When I first started researching topics I used Google Scholar as my primary database and was not very successful. I found the listed science databases SciFinder, ScienceDirect, and Scopus to be the most helpful in regards to collecting primary research articles.

These findings show that library instruction, along with the online research guide, was their first exposure to science research databases for many students. Without this implicit librarian-led instruction, the students would not have had the tools necessary to complete their writing assignments. We expected that by combining library instruction with the semester-long writing project that used library resources, students would continue to improve their confidence in information literacy even after the library instruction. To identify this change, we conducted surveys of student confidence in literacy skills at the beginning and end of the semester. Here, we measured the overall effects of both library and course instruction. Approximately 70% of students reported an increased confidence in finding primary research articles (Table 4). Presumably, this confidence meant students felt positive about their ability to locate journal articles using the databases they learned in class.

Combined, these indirect and direct results support that the majority of students increased both their confidence in finding scientific literature and their ability in using discipline-specific databases. Additionally, we used the post-course survey to assess which course tools or activities helped increase their ability to find articles. Students could choose from a list of all lessons in the course, including those that may not have been relevant to information literacy (Appendix D). The top five activities that contributed to confidence in finding primary literature using databases were the following: Database instruction with the science librarian (80%), Primary Research vs. Review articles Venn Diagram (78.5%), writing the review throughout the semester (74.6%), the Annotated References assignment (73%), and the online Science Research Writing Guide (67.7%). Activities that clearly did not relate to finding primary research articles, such as games to teach writing style (26.2%), were not common choices for students. However, these choices do reveal some baseline confusion with which activities supported these skills. In these questions, most students were able to identify relevant tasks with the appropriate skill, providing additional support that these pedagogical tools and activities supported semester-long growth in information literacy.

Student identification and evaluation of resource types

After a student finds a relevant article in a database, the student must then determine if the article will be appropriate for their research. This critical evaluation of the literature is an essential step and standard in scientific information literacy. We have seen that many

Table 4. Changes in student confidence from a pre- and post-course Likert scale question: *I know how to find primary research articles, published in academic journals, on any topic.*

	Sophomores		Juniors		Seniors		Total	
Change	*N*	%	*N*	%	*N*	%	*N*	%
Increased	48	73.85	30	69.77	14	63.64	92	70.76
No changes	13	20	12	27.91	7	31.81	32	24.62
Decreased	4	6.15	1	2.32	1	4.55	6	4.62
N total	65		43		22		130	

students experience difficulty distinguishing between primary and secondary scientific literature and students prefer secondary content. This may be because primary literature is more difficult to understand, but also because there can be an extreme variation in discipline formats within the sciences. For example, a research paper in theoretical physics may be structured differently than a medical case study or even a standard hypothesis-driven study. Additionally, the journal publication may change the format of an article. Therefore, students need to learn what makes an article 'primary' as opposed to memorizing a format to designate an article as primary. To this end, students learned the structure and content of scientific articles through several activity-based lessons so that they could relate the process of science to published communications through authentic texts. This included a lesson where students compared articles from different scientific journals to create a Venn Diagram of primary vs. secondary literature and compare structure and content. They also identified the steps of the scientific method and then applied these steps to the structure of primary research. This could be used to help them navigate through a research article. For example, they learned that the introduction of an article mirrored the literature review step of the scientific method and that the end of an introduction always indicates the gap in the field, followed by the objective or hypothesis of the primary study. This example would help emphasize that the citations in the introduction of a primary research article cannot be cited, but rather they can be used to mine additional resources in the databases. Instead, the only part of the introduction that is primary to an article is the objective of the study. They also applied the scientific method while judging other science writing works, such as grants and poster presentations. These conversations allowed students to discuss the fluidity of the scientific method, and how the presentation of this method might differ from the actual practice. Together, these lessons were meant to increase information literacy at higher levels so that they could both identify research articles and develop a deeper cognitive understanding of how scientists communicate data.

To objectively assess how students' understanding of these articles changed throughout the writing process, students were asked to define a primary research article and a secondary article in the pre- and post-course surveys (Table 5). In the pre-course survey, approximately 57% of students defined a primary research article as an article written by an author who performed an original set of experiments and while only one-fifth of students defined a review article as a secondary source that summarized multiple primary research articles. Most students either declined to define a review in the pre-survey because they did not know, or defined a review as an article that summarized only one research study. By the end of the semester, most students could define a primary research article or review correctly. Interestingly, the definitions for primary research evolved, reflecting course lessons. In the pre-survey, only eight students (6.15%) both correctly defined a primary research article and included a reference to the article's structure (e.g. Materials and

Table 5. Student ability to correctly define a primary research article or a review in pre- and post-course surveys.

	Pre-survey		Post-survey	
Definition	*N*	%	*N*	%
Primary research article	74	56.92	128	98.46
Review article	27	20.77	111	85.38

Methods, Results, Conclusions) or the scientific method. In the post-survey, 51 students (39.23%) used language indicative of a primary research article's structure and/or the scientific method in their definition without being prompted to do so.

At the end of the semester, 80% of students reported an increased confidence in identifying primary research articles (Table 6). Because this course served students from multiple disciplines at various stages of their undergraduate careers, we divided these data based on year to reveal any differences. We hypothesized that seniors may have a higher initial confidence due to their experiences in other courses and may not change or increase their confidence over a semester. However, there was only a small difference among the years, suggesting that the majority of students did not have a high level of experience in primary literature prior to the course, regardless of year. Interestingly, a small number of students reported a decrease in confidence over the semester (Table 6).

On several assignments, students labeled all the articles they identified as secondary. This encouraged them to constantly be cognisant of the difference and allowed the instructor to directly measure whether or not students could identify research types. This offered a genuine view into how students identified resources they found in databases and objective evidence of this challenge. We completed singular reference checks for the Annotated References, Draft I, and the Final Review assignments (Table 7). These data represented at least one instance of incorrect identification on an assignment per student. Some students had multiple instances of incorrect identification within a reference list, but this was not tallied for this data set. For most students, the reference list on the Annotated References, Draft I, and Final Review was for the same topic. The reference list grew longer as the semester progressed, and often changed based on instructor and peer feedback. The high number of students with an incorrect identification on Draft I likely indicates that many of these students did not apply that feedback to change errors on the Annotated References, but did apply feedback by the Final Review and avoided mistakes on new references. Therefore, over 89% of students correctly identified primary and secondary articles within their discipline by the Final Review (Table 7). In addition to course-aggregated

Table 6. Changes in student confidence in a pre- and post-course Likert scale question: *I know how to distinguish primary research articles from secondary articles.*

	Sophomores		Juniors		Seniors		Total	
Change	*N*	%	*N*	%	*N*	%	*N*	%
Increased	51	78.46	36	83.72	18	81.82	105	80.77
No change	10	15.38	7	16.28	3	13.64	20	15.38
Decreased	4	6.15	0	0	1	4.55	5	3.85
N total	65		43		22		130	

Table 7. Number of students ($N = 130$) that correctly distinguished primary research from secondary science articles on individual assignments.

Assignment	Percentage of students with correct identification
Annotated references	70.77
Draft I	77.69
Final review	89.23
Anonymous peer review of draft II	98.46
News article	98.46

data, we also find that, individually, students' identification skills progressed through this semester-long process. Of the 38 students that made an incorrect identification on the Annotated References assignment, only 7 made an incorrect identification by the Final Review. There were nine students who did not make incorrect identifications on the Annotated References, but did make a mistake on Draft 1. However, all of these students made correct identifications by the Final Review. Most often, students misidentified a review as primary research, rather than the opposite.

There were also two opportunities to test students' abilities to distinguish literature types outside the semester-long process of writing their own reviews. First, students completed the Anonymous Peer Review of Draft II. Within the Anonymous Peer Review, the students picked one primary article from a peer's paper and verified it as primary. This tested their ability to identify primary literature in another discipline. In their verifications, students as peer reviewers had to explain how they knew it was a primary research article. This allowed us to assess not only their ability to identify an article as primary or secondary, but to evaluate their justification. Examples of justification included language that reflected the article's primary structure or content, such as the methods section, or an example of original data from the article. Only two peer reviewers (Table 7) incorrectly identified or supported the article from the author's paper. This supports that most students were comfortable using an article's structure to identify it as primary, even if they were not scientists within the same discipline. The last writing assignment of the semester, the News Article, required students to choose one primary research article on a new topic. Here, 128 out of 130 students correctly chose a primary research article (Table 7).

Finally, the pre- and post-course surveys also asked students to identify which resources they would use for data when writing a scientific article. Interestingly, there was a decrease in the number of students that would use a book, website, magazine, or newspaper as a resource for data (Figure 2). Because the databases that the students used did not identify many of these resources, this might indicate that fewer students saw these as the best resources for their paper as the semester progressed and therefore favored more authentic science texts.

Student use of resources in writing

Once students have identified resources, they next must use them ethically, which represents a higher information literacy standard (Association of College and Research Libraries, 2006). While students' ability to identify primary research articles improved over the semester in several assessments, we noticed a continuous challenge to students when they used these references, despite course activities that addressed proper use. For example, some students incorrectly used a primary research article for content that is secondary to the source, such as cited background information from the introduction. During the reference check of Draft I and the Final Review, at least one reference would be checked for two items: (1) was the article identified correctly as review or primary research (Table 7)? (2) If the article was correctly identified as primary research, was it used correctly and paraphrased for research reflecting original content from the scientific method (e.g. hypothesis, methods, data, and conclusions)? Failure on either item resulted in a failure in that rubric category, regardless of the mistake. From a grading perspective, this represented a student's ability to complete learning goals that increased in difficulty.

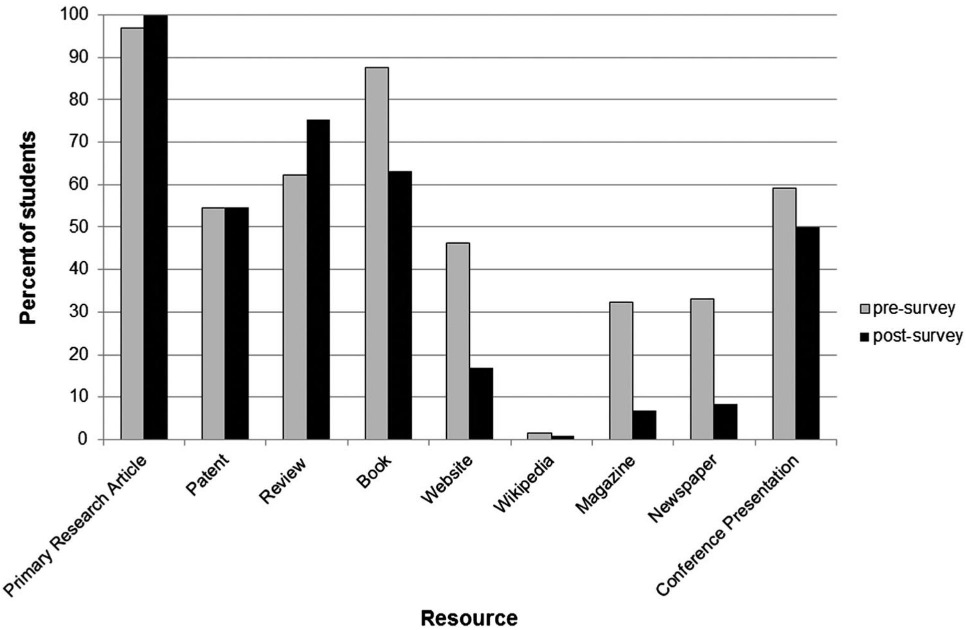

Figure 2. Students indicated which resources they would use for data. In pre- and post-course surveys, students ($N = 130$) were asked which resources they would use for data when writing a scientific article. Students could choose more than one option from the following list: Primary research article, Patent, Review, Book, Website, Wikipedia, Magazine, Newspaper, or Conference Presentation.

First, they had to find research articles on their topic and identify them. Next, they had to use these articles correctly. Twenty-four students (18.46%) incorrectly used a primary research article in Draft I and 21 students (16.15%) incorrectly used a primary research article in the Final Review. In totaling failures of the first (Table 7) and second steps of the reference check, 40% and 26.9% of students failed the reference check on Draft I and the Final Review, respectively. This aggregated course data may also mask some of the individual progress. Yet, we do believe it is likely reflective of collective progress. To support this, we found that of the 24 students who incorrectly used a primary research article in Draft I, only three of these students repeated this error in a different reference on the Final Review. Instead, the majority of reference check failures on the Final Review were from different students.

Because the misuse checks were singular, there were likely more students with this problem than identified by the reference check, which may explain mistakes on later drafts. Furthermore, an analysis of the reference check in the Final Review was more difficult, as this also identified that some students were using these resources partially correctly for results, but sometimes taking cited content from the discussion of primary research articles as well. Also, some students were misinterpreting results from an article or lacking citations on sentences that did not represent general knowledge. A deeper analysis of student use of secondary literature (reviews) revealed that some students might use these sources for specific data from original research, rather than general information. This would also be an inappropriate use of a reference. We have not quantified the types of mistakes from these reference checks due to their singular and likely underrecognized nature. However, in Figure 3, we describe our observations of student use of both primary and secondary literature. This includes both instances from submitted, written assignments, as well as informal classroom feedback and lesson content. For example, our rubrics could not identify if a student used a reference to resource-mine additional references but these discussions were part of individual consultations during the writing process. While conducting a thorough study of resource use is clearly needed, it is further complicated by the diversity in students' topics and disciplines and the instructors' own field expertise. Instead, a larger, coded study may help to reveal trends in the future. Here, we propose that instructors use our observations to aid conversations on the ethical, appropriate use of resources and citations in science writing as part of information literacy and the writing process.

Limitations

There were several limitations to the current study. First, while we could see that student confidence levels and abilities increased over a semester, we had no base level assessment of specific information or scientific literacy skills to compare them to. Instead, we chose to use their actual assessments as direct, objective, and authentic evidence of their learning during the writing process. In addition, it would have been unethical to teach sections of the course differently and remove lessons on finding, evaluating, and using articles, as this would have left some students unequipped for their assignments. Our results also reflect students in different science programs and in varying years of study. However, we feel this supports the application of our results to different science disciplines. Due to the singular nature of the reference check, we have also acknowledged that our study likely did not uncover all instances of inappropriate identification and use of research articles. It is also possible that some students may have repeated an error type due to a lack in revisions or attention to feedback.

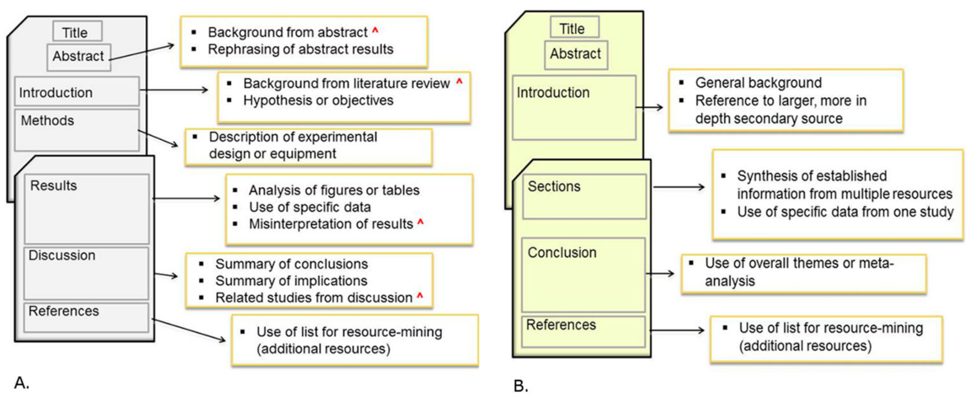

Figure 3. Student approaches to scientific content from primary or secondary articles. (A) When students wrote literature reviews, they used primary research articles both correctly and incorrectly for original research, as well as a source of additional references to read (resource-mining). ^ denotes inappropriate use of a primary article for secondary information during a reference check. (B) When students used review articles (secondary sources) in their own writing, they used both general and specific content. Some of the specific information could also have been an inappropriate use, where the best practice would have been to cite the original study.

Discussion and future directions

In this case study, we embedded a science librarian into a professional undergraduate science writing course and evaluated the semester-long effects of this integration on information literacy. We also aimed to understand the challenges students encountered when interacting with scientific articles. To meet this end, the class combined the library and writing instruction with the process of scientific publishing in peer-reviewed journals. We present both indirect evidence supporting increases in student confidence, as well as objective, direct evidence of learning through surveys and assignments. In creating a class that covers writing and publishing, students gain both an appreciation for peer-reviewed resources as well as knowledge of this writing process (Guilford, 2001). In our study, we found direct evidence that our students favored the use of peer-reviewed sources over websites at the end the semester, and that they use discipline-specific databases to find these resources. Importantly, our data support the additional value of integrated library instruction within a writing course to improve information literacy through a semester-long research assignment through our analysis of students' resource identification and uses.

Through library instruction and course activities and assessments, our course met current *Information Literacy Standards for Science and Technology* to improve information and science literacy student outcomes (Association of College and Research Libraries, 2006). Instruction that meets these standards is a valuable way to systematically address information literacy in a course, program, or curriculum (Aydelott, 2007). Table 8 compares these literacy standards to the course instruction and assignments outlined in the present study.

Information literacy standards 1–3

The first three of the five information literacy standards for science and technology are determining an information need, finding resources, and then evaluating those resources within a defined context (Association of College and Research Libraries, 2006). Examining the nature and extent of information that is needed may seem apparent as a logical first step; however, we have found that many students have difficulty choosing a topic and narrowing it down to a manageable research statement or question for their review assignments. The aim is to identify a scientific research topic of interest and list related subtopics. Through the use of keyword and controlled vocabulary searching, library instruction teaches students both the appropriate science databases and the use of these databases. Building upon this, the students consulted with their course instructor as well as their peers to propose a well-developed research topic. Our research indicates that most students had low confidence and ability in finding and evaluating peer-reviewed resources before library instruction.

Our discussions with disciplinary faculty indicate that they expect students to have experience using resources germane to their areas of study to find scientific information. However, without direct instruction, they have no opportunity to learn effective research strategies for their own disciplines. A study of biomedical science students found that students prefer to use Google, yet these students are unable to find primary research articles and evidence-based citations for their assignments (Kingsley et al., 2011). In our study,

Table 8. Information literacy standards mapped to course instruction and assignments.

Information literacy standards for science and technology	Course instruction and assignments
1. Determines the nature and extent of the information needed	a. Topic choice b. Annotated references criteria c. Review assignment criteria, that is, minimum number of articles d. Primary research vs. review literature Venn Diagram
2. Acquires needed information effectively and efficiently	a. Library sessions – determine keywords, develop search strategies based on topic; determine appropriate databases b. Science writing research guide (online)– research databases and tutorials
3. Critically evaluates procured information and its sources, and as a result, decides whether or not to modify the initial query and/or seek additional sources and whether to develop a new research process	a. Library sessions; revised search strategies b. Peer review with classmates c. Consultation with instructor d. Determines whether article is primary research or a review e. Drafts and revisions for assignments
4. Understands the economic, ethical, legal, and social issues surrounding the use of information and its technologies. Uses information effectively, ethically, and legally to accomplish a specific purpose	a. Draft/assignment criteria b. Review article format c. Annotated references - citations in ACS style d. Paraphrasing and plagiarism lesson e. Science writing research guide – citation information, ACS Style guide
5. Understands that information literacy is an ongoing process and an important component of lifelong learning and recognizes the need to keep current regarding new developments in her or his field	a. Library sessions – creating alerts in databases b. Science writing research guide – RSS science news feeds, newly published research from University faculty c. Review article assignment d. Primary research in the news

most students had little experience with science database instruction lessons prior to our course. Many reported using Google or Google Scholar for their assignments. We found that library instruction and the Science Writing Research Guide website, together, increased students' abilities to choose and use databases appropriate for their discipline. This supports previous research that both library integration and a course guide may be a way to continuously support students throughout a course (Thompson & Blankinship, 2015). Furthermore, this research guide could also be a way to provide continuous instruction throughout a curriculum, as information literacy could evolve over time (Ferrer-Vinent & Carello, 2011). Effective long-term information literacy, or fluency, likely needs reinforcement (Aydelott, 2007).

Interestingly, some students in our study noted little change to a decrease in confidence in these skills by the end of the semester. This decreased confidence in writing skills is likely caused by students' realisation that these skills are more difficult than they had anticipated or that they needed reinforcement. McLaren (2014) found a similar result in overconfidence, suggesting that '… students are accustomed to being required to focus on their writing only in their English language courses and not in their individual disciplines'. Combined with our data, this supports that students need continuous practice in writing and information literacy skills in their science courses, as they may become over-confident in their abilities without direct instruction and practice in their own disciplines.

Our study also uncovered challenges to student learning in information and science literacy. Higher-order skills in scientific and information literacy, such as critiquing and evaluating literature, may be more difficult to achieve and require continuous application (Krontiris-Litowitz, 2013). Here, we analysed students' progress in article identification through task-scaffolded writing assignments. We believe that this is also a previously unrecognized higher-order skill, above determining a need for information or finding reference. Identifying article type is a step in literature evaluation. We reveal that this skill is a challenge to students, and confirm that students need time and multiple assignments to improve.

Information literacy standard 4

Compared to finding and identifying articles, the ethical use of research articles is an even higher skill. This is also representative of the fourth information literacy standard for science and technology: the ability to understand the economic, ethical, legal, and social issues surrounding the use of information and its technologies; and use information effectively, ethically, and legally to accomplish a specific purpose (Table 8) (Association of College and Research Libraries, 2006). When writing, students should examine the authenticity and reliability of the information along with its usefulness to their research and assignments. However, they also need to appropriately cite the articles they use to complete their assignments. Outcomes that support the ethical standards of information literacy include properly quoting, paraphrasing, and citing scientific research articles and communicating the information they have synthesised into a final product.

To address the ethical concerns of information literacy, our course design included lessons on plagiarism, article structure and content, and appropriately citing an author's work. Still, some students used content from the literature review of a primary research articles' introduction in their Final Review. This may be due to the difficult nature of primary research articles. While the end of an introduction of a scientific primary research article does include the authors' original objectives, the majority of the introduction is, in essence, a secondary source. Students might prefer to use secondary sources, or cite secondary content of scientific primary literature, because they find secondary literature easier to read and understand (Baram-Tsabari & Yarden, 2005). Our results both support this finding and call for the continual need for students to learn and use the discourse of primary research articles as authentic texts (Ford, 2009). It is also important that they properly attribute original research to an author. To accomplish this, instructors should incorporate lessons on article types and content, as well as the steps and fluidity of the scientific method and process, into their science literacy courses. In the classroom, students should compare and contrast research articles from multiple journals to investigate common themes in structure and content. However, this is also an important activity so that they can understand the purpose of primary research articles to convey unpublished data, regardless of differences in a journal's structure. Our results indicate that some students misuse texts, and part of this reason may be that they feel more comfortable with secondary content and therefore prefer to cite this. Multiple courses, at all levels within a curriculum, should use primary literature to encourage student exposure and confidence in identifying and using these texts. Additionally, instructors should recognize that authentic texts also include documents such as poster presentations and grant proposals. These can also be used in discussion of information and science literacy.

Discussions on how science as a process is organized in writing can help students understand what content is ethical to use and how they should use it, regardless of the text. While many instructors monitor plagiarism via software tools, we propose that instructors should also monitor reference use in writing assignments, either as part of a rubric or a peer review assignment. In the classroom, students could mark the purpose of each section of primary research articles and then discuss the possible and ethical uses of each section. For example, the introduction of a primary research article can be used to mine additional, helpful resources, but a student cannot cite information from this section of a primary research article because it is not original to the authors' hypothesis and experiments. Understanding the purpose of article parts could also help students in writing their own research articles.

Difficulties in citation use are not unprecedented, but they are understudied, especially in the sciences. The Citation Project is currently investigating how students use citations (Jamieson, 2013). Jamieson (2013) suggests that we need to pedagogically address the evidence that students often do not use their resources properly and may not know how to appropriately interact with these texts. When reading articles, students uniquely highlight content, suggesting a level of uncertainty that improves as a student becomes more comfortable with the literature (Gallo & Rinaldo, 2012). Novice writers also use citations differently than expert writers (Mansourizadeh & Ahmad, 2011), indicating that novice writers, such as students, need to learn conventions of citations in their discipline in conjunction with writing practices. While our course instruction did emphasize citation practices, ethical challenges in student citations still existed. Together with our data, these studies support the need for further investigation into resource use in the sciences, perhaps over several courses. We need to understand the reasons for these errors, as well as the types, before we can examine effective pedagogical solutions.

Information literacy standard 5

We did not directly assess student outcomes related to the understanding of the ongoing process of information literacy and recognising the need to keep current, or the fifth standard of information literacy (Table 8). However, this necessary and transferable concept was addressed during library instruction sessions where students learned how to identify current faculty publications and create and manage alerts, or notifications, about new, relevant research articles. The Science Writing Research guide also links to news feeds on current developments in science, and class lessons and the News Article assignment emphasize currency and the awareness of cutting edge discoveries. Currency is also part of the larger context of *Scholarship as a Conversation* as new information and scientific evidence is made available.

To embrace information and science literacy as higher-level threshold concepts, we must couple database instruction using science research tools, such as SciFinder, ScienceDirect, and Scopus, with richer instruction on properly using that information for a specific purpose, such as a semester-long writing assignment. The new framework recently adopted by ACRL addresses *Research as Inquiry*, *Information Creation as a Process*, and *Scholarship as a Conversation* (Association of College and Research

Libraries, 2016). This generates further opportunities for connecting information literacy to more effective pedagogical strategies in science reading, writing, and publication. Overall, our research clearly underlines a need for science faculty and librarians to address citations and resource use as a part of information literacy in the sciences. This emphasis on all levels of information literacy should be part of writing instruction and assignments.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Kristin M. Klucevsek http://orcid.org/0000-0001-6462-4099
Allison B. Brungard http://orcid.org/0000-0002-0811-5318

References

Association of College and Research Libraries. (2006). *Information literacy standards for science and technology*. Retrieved from http://www.ala.org/acrl/standards/infolitscitech

Association of College and Research Libraries. (2015). *Framework for information literacy for higher education*. Association of College & Research Libraries (ACRL). Retrieved from http://www.ala.org/acrl/standards/ilframework

Aydelott, K. (2007). Using the ACRL information literacy competency standards for science and engineering/technology to develop a modular critical-thinking-based information literacy tutorial. *Science & Technology Libraries*, *27*(4), 19–42.

Baram-Tsabari, A., & Yarden, A. (2005). Text genre as a factor in the formation of scientific literacy. *Journal of Research in Science Teaching*, *42*(4), 403–428. doi:10.1002/tea.20063

Bromme, R., Scharrer, L., Stadtler, M., Hömberg, J., & Torspecken, R. (2015). Is it believable when it's scientific? How scientific discourse style influences laypeople's resolution of conflicts. *Journal of Research in Science Teaching*, *52*(1), 36–57. doi:10.1002/tea.21172

Brownell, S. E., Price, J. V., & Steinman, L. (2013). A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. *AJP: Advances in Physiology Education*, *37*, 70–79. doi:10.1152/advan.00138.2012

Burgoyne, M. B., & Chuppa-Cornell, K. (2015). Beyond embedded: Creating an online-learning community integrating information literacy and composition courses. *The Journal of Academic Librarianship*, *41*(4), 416–421. doi:10.1016/j.acalib.2015.05.005

Coil, D., Wenderoth, M. P., Cunningham, M., & Dirks, C. (2010). Teaching the process of science: Faculty perceptions and an effective methodology. *Cell Biology Education*, *9*(4), 524–535. doi:10.1187/cbe.10-01-0005

Ferrer-Vinent, I. J., & Carello, C. A. (2008). Embedded library instruction in a first-year biology laboratory course. *Science & Technology Libraries*, *28*(4), 325–351.

Ferrer-Vinent, I. J., & Carello, C. A. (2011). The lasting value of an embedded, first-year, biology library instruction program. *Science & Technology Libraries*, *30*(3), 254–266. doi:10.1080/0194262X.2011.592789

Ford, D. J. (2009). Promises and challenges for the use of adapted primary literature in science curricula: Commentary. *Research in Science Education*, *39*(3), 385–390. doi:10.1007/s11165-008-9115-8

Gallo, M., & Rinaldo, V. (2012). Towards a mastery understanding of critical reading in biology: The use of highlighting by students to assess their value judgment of the importance of primary literature. *Journal of Microbiology & Biology Education : JMBE*, *13*(2), 142–149. doi:10.1128/jmbe.v13i2.493

Gonyo, C. P., & Cantwell, B. (2015). Faculty perceptions of students in life and physical science research labs. *Innovative Higher Education*, *40*(4), 317–329. doi:10.1007/s10755-014-9315-2

Guilford, W. H. (2001). Teaching peer review and the process of scientific writing. *Advances in Physiology Education*, *25*(3), 167–175.

Haines, L. L., Light, J., O'Malley, D., & Delwiche, F. A. (2010). Information-seeking behavior of basic science researchers: Implications for library services. *Journal of the Medical Library Association: JMLA*, *98*(1), 73–81.

Jacob, N., & Heisel, A. P. (2008). A faculty-librarian partnership for investigative learning in the introductory biology laboratory. *Journal of College Science Teaching*, *37*(4), 54–59..

Jamieson, S. (2013). Reading and Engaging Sources: What Students' Use of Sources Reveals About Advanced Reading Skills. *Across the Disciplines*, *10*(4). Retrieved from http://wac.colostate.edu/atd/reading/jamieson.cfm.

Kingsley, K., Galbraith, G. M., Herring, M., Stowers, E., Stewart, T., & Kingsley, K. V. (2011). Why not just Google it? An assessment of information literacy skills in a biomedical science curriculum. *BMC Medical Education*, *11*, 17. Retrieved from http://bmcmededuc.biomedcentral.com/articles/10.1186/1472-6920-11-17. doi:10.1186/1472-6920-11-17.

Kozeracki, C. A., Carey, M. F., Colicelli, J., & Levis-Fitzgerald, M. (2006). An intensive primary-literature-based teaching program directly benefits undergraduate science majors and facilitates their transition to doctoral programs. *Cell Biology Education*, *5*(4), 340–347. doi:10.1187/cbe.06-02-0144

Krontiris-Litowitz, J. (2013). Using primary literature to teach science literacy to introductory biology students. *Journal of Microbiology & Biology Education*, *14*(1), 66–77.

Mansourizadeh, K., & Ahmad, U. K. (2011). Citation practices among non-native expert and novice scientific writers. *Journal of English for Academic Purposes*, *10*(3), 152–161. doi:10.1016/j.jeap.2011.03.004

Mc Goldrick, N. B., Marzec, B., Scully, P. N., & Draper, S. M. (2013). Implementing a multidisciplinary program for developing learning, communication, and team-working skills in second-year undergraduate chemistry students. *Journal of Chemical Education*, *90*(3), 338–344. doi:10.1021/ed200643g

McLaren, I. A. M. (2014). Contexts of engagement: Towards developing a model for implementing and evaluating a writing across the curriculum programme in the sciences. *Assessing Writing*, *22*, 18–32. doi:10.1016/j.asw.2014.03.005

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academy Press.

National Research Council. (2014). *Literacy for science: Exploring the intersection of the next generation science standards*. Washington, DC: National Academy Press.

Phillips, L. M., & Norris, S. P. (2009). Bridging the gap between the language of science and the language of school science through the use of adapted primary literature. *Research in Science Education*, *39*(3), 313–319. doi:10.1007/s11165-008-9111-z

Porter, J. A., Wolbach, K. C., Purzycki, C. B., Bowman, L. A., Agbada, E., & Mostrom, A. M. (2010). Integration of information and scientific literacy: Promoting literacy in undergraduates. *CBE-Life Sciences Education*, *9*(4), 536–542.

Pritchard, P. A. (2010). The embedded science librarian: Partner in curriculum design and delivery. *Journal of Library Administration*, *50*(4), 373–396.

Shah, J., Shah, A., & Pietrobon, R. (2009). Scientific writing of novice researchers: What difficulties and encouragements do they encounter? *Academic Medicine*, *84*(4), 511–516.

Thompson, L., & Blankinship, L. A. (2015). Teaching information literacy skills to sophomore-level biology majors. *Journal of Microbiology & Biology Education*, *16*(1), 29–33. doi:10.1128/jmbe.v16i1.818