Referencing Science: Teaching Undergraduates to Identify, Validate, and Utilize Peer-Reviewed Online Literature

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ABSTRACT Accessibility of online scientific literature continues to expand due to the advent of scholarly databases and search engines. Studies have shown that undergraduates favor using online scientific literature to address research questions, but they often do not have the skills to assess the validity of research articles. Undergraduates generally are deficient in information literacy. A partnership between a faculty member and librarian can often help overcome information literacy deficiencies. In this article, the development of a faculty–librarian partnership and online tutorials is explained. This partnership and the tutorials helped students identify peer-reviewed sources and assess their validity. Undergraduates taking a senior-level capstone plant sciences seminar over 5 years were surveyed regarding their understanding of peer-reviewed literature. Surveys were administered at the beginning of the course and again after they completed the tutorials. The responses given on the surveys suggest that students lacked a firm understanding of what constitutes peer-reviewed scientific literature until after meeting with the librarian and participating in the tutorials. Before development of the partnership, undergraduates had difficulty finding and effectively utilizing online scientific resources. Introducing assignments related to information literacy throughout the curriculum should help teach important scientific literacy skills. Faculty can collaborate with librarians to implement assignments similar to the ones described in this article.

articles

Scholarly research in the life sciences has traditionally centered on accessing peer-reviewed literature from hardcopy serials (Larivière et al., 2006) and citing this information in publications or presentations of scientific results. There are benefits to utilizing peer-reviewed scientific literature in undergraduate curricula (Scott and Simmons, 2006), but the trend for undergraduates is to eschew hardcopy serials in favor of online information in citing research (Oppenheim and Smith, 2001). In fact, surveys indicate that both students and professional scientists prefer utilizing online scientific literature (Leung, 1998; Bar Ilan and Fink, 2005). Likely contributing to this preference is the expanded accessibility of online literature (McDonald, 2007), deployment of Google Scholar, and the availability of a variety of searchable scientific literature databases (Kousha and Thelwall, 2007).

However, despite its ready accessibility, use of online literature presents problems in higher education science curricula. Unlike hardcopy serials, online literature may not be permanently available (Dellavalle et al., 2003; Goh and Ng, 2007), and students must somehow validate online research literature as being peer-reviewed for accuracy and scientific content. Experts in searching literature online remain focused on their task, efficiently use key words associated with their topic (MaKinster et al., 2002), and look for specific cues to determine accuracy and validity of content (Rieh, 2002; Wathen and Burkell, 2002). But undergraduates may not fully understand the scientific process (Jordan et al., 2006), let alone the peer-review process for scientific literature. Hence, for them, identifying and validating online peer-reviewed scientific literature can be daunting. A complicating factor is that undergraduates often lack the vocabulary and literacy to adequately address abstract scientific research problems (Scott and Simmons, 2006). Students generally lack effective online search skills (Tabatabai and Shore, 2005). Also, undergraduates in life sciences frequently exhibit rudimentary critical thinking skills, so they are reluctant to engage in accessing and critiquing peer-reviewed scientific literature (Jordan et al., 2006; Scott and Simmons, 2006). A preference of undergraduates to read scientific information oriented toward the layman may be key to the problem (Scott and Simmons,

Impact Statement

We established a faculty–librarian partnership and implemented tutorials designed to teach undergraduate students how to search for and validate online scientific literature. Results of student surveys demonstrated that they learned these skills. Because there is a preference for electronically available scientific information and its availability continues to expand, these students will be well-equipped with the skills to effectively interpret and apply the information as needed in their professional scientific careers.

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Abbreviations: NDSU, North Dakota State University.

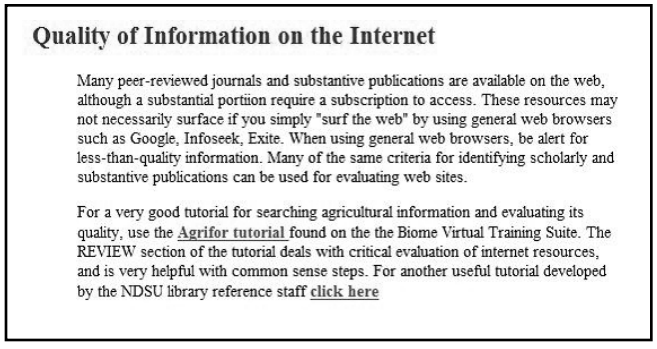
2006), and perhaps a consequence of this preference is the difficulty many students have in identifying peer-reviewed scientific information even before entering higher education (Wallace et al., 2000).

Senior Seminar is an undergraduate, upper-level capstone course in the Plant Sciences Department at North Dakota State University (NDSU). The education goals of this course are (1) to help students develop skills to identify and validate peer-reviewed scientific literature, (2) to help students develop skills to identify possible employment opportunities, and (3) to help students develop effective scientific oral presentation skills. Thus, the course instructor frequently encounters problems having undergraduates identify and utilize peer-reviewed online scientific literature. The objectives of this study were to develop a faculty–librarian partnership to help enhance the ability of undergraduates to identify and properly utilize online scientific literature, and to assess the success of this partnership using surveys of Senior Seminar students.

Methods

Faculty–Librarian Partnership Approach

A main requirement of students in Senior Seminar is to select a research topic and make a short 15-minute oral scientific presentation based on at least one peer-reviewed article relating to their selected topic. Recognizing that undergraduates prefer to conduct searches for scientific literature using the internet, a faculty–librarian partnership was developed to help Senior Seminar students identify, validate, and utilize online scientific literature. A NDSU library website, www.lib.ndsu.nodak.edu/research/subjects/ag/PLS491.php (verified 24 Oct. 2007) was established as a platform for tutorials on identifying and validating online peer-reviewed literature. Individual students can use the website, or as part of a class lesson the NDSU agricultural sciences librarian can use it to help students learn to validate and efficiently search for online scientific literature. One tutorial is based on the information provided at www.library.cornell.edu/olinuris/ref/research/skill20.html (verified 24 Oct. 2007). This tutorial illustrates the difference between peer-reviewed and other forms of literature, so students can validate the scientific nature of the online information they find. Other tutorials guide students in validating the scientific literature they find (Fig. 1) and in utilizing the internet to find appropriate scientific literature (Fig. 2).



Quality of Information on the Internet

Many peer-reviewed journals and substantive publications are available on the web, although a substantial portiion require a subscription to access. These resources may not necessarily surface if you simply "surf the web" by using general web browsers such as Google, Infoseek, Exite. When using general web browsers, be alert for less-than-quality information. Many of the same criteria for identifying scholarly and substantive publications can be used for evaluating web sites.

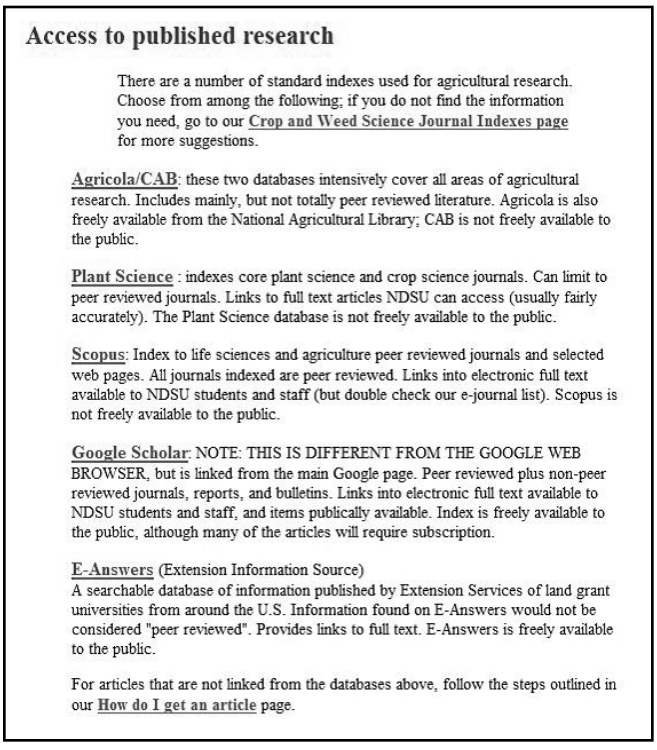
For a very good tutorial for searching agricultural information and evaluating its quality, use the Agrifor tutorial found on the the Biome Virtual Training Suite. The REVIEW section of the tutorial deals with critical evaluation of internet resources, and is very helpful with common sense steps. For another useful tutorial developed by the NDSU library reference staff click here

Fig. 1. Screen capture of a section of the NDSU library website (www.lib.ndsu.nodak.edu/research/subjects/ag/PLS491.php; verified 24 Oct. 2007) developed for Senior Seminar and intending to help undergraduates validate peer-reviewed scientific literature.

Student Surveys and Analyses of Data

Undergraduate students were surveyed to help assess the faculty–librarian partnership. Students surveyed were enrolled in Senior Seminar beginning in the fall semester 2001 and during the fall semesters of 2003 through 2006.

Before meeting with the agricultural sciences librarian and having a chance to utilize the library website tutorials, students were asked to participate in an anonymous pre-survey constructed to assess their knowledge of the peer-review process and to assess their understanding of what constitutes peer-reviewed scientific literature. The survey consisted of nine questions (Table 1), which remained unchanged throughout the study. After meeting with the agricultural sciences librarian and being able to use the library website tutorials, students were again asked to complete the same evaluation as a post-survey. Means for the number of student responses for each question were calculated over the 5-year survey, and a two-tailed *t*-test was used to compare pre-test and post-test means and to determine if responses were significantly different between the tests. A value of $p \leq 0.05$ was considered indicative of a significant difference between response means.



Access to published research

There are a number of standard indexes used for agricultural research. Choose from among the following; if you do not find the information you need, go to our Crop and Weed Science Journal Indexes page for more suggestions.

Agricola/CAB: these two databases intensively cover all areas of agricultural research. Includes mainly, but not totally peer reviewed literature. Agricola is also freely available from the National Agricultural Library; CAB is not freely available to the public.

Plant Science : indexes core plant science and crop science journals. Can limit to peer reviewed journals. Links to full text articles NDSU can access (usually fairly accurately). The Plant Science database is not freely available to the public.

Scopus: Index to life sciences and agriculture peer reviewed journals and selected web pages. All journals indexed are peer reviewed. Links into electronic full text available to NDSU students and staff (but double check our e-journal list). Scopus is not freely available to the public.

Google Scholar: NOTE: THIS IS DIFFERENT FROM THE GOOGLE WEB BROWSER, but is linked from the main Google page. Peer reviewed plus non-peer reviewed journals, reports, and bulletins. Links into electronic full text available to NDSU students and staff, and items publically available. Index is freely available to the public, although many of the articles will require subscription.

E-Answers (Extension Information Source)
A searchable database of information published by Extension Services of land grant universities from around the U.S. Information found on E-Answers would not be considered "peer reviewed". Provides links to full text. E-Answers is freely available to the public.

For articles that are not linked from the databases above, follow the steps outlined in our How do I get an article page.

Fig. 2. Screen capture of a section of the NDSU library website (www.lib.ndsu.nodak.edu/research/subjects/ag/PLS491.php; verified 24 Oct. 2007) developed for Senior Seminar and intending to help undergraduates search for appropriate peer-reviewed scientific literature.

Table 1. Pre- and post-survey offered to PLSC491 undergraduates in 2001, and 2003 to 2006.

	Question	Response
1.	Do you believe you know the difference between a scientific article that is "peer-reviewed" and one that is not?	a. Yes b. No
2.	Do you believe you know how to search for scientific "peer-reviewed" articles using the internet?	a. Yes b. No
3.	Have you ever prepared a written or oral scientific presentation?	a. Yes b. No
4.	What do you believe is the single most significant difference between making a scientific presentation and a speech or essay?	a. The scientific presentation is longer and more technical b. The organization of a scientific presentation is different c. The scientific presentation tells someone how to do something d. The scientific presentation summarizes prior research, experimental methods, and results
5.	Which one of the following do you think best describes a "peer-reviewed" scientific article?	a. An article that can only be published in printed form and not on the internet b. An article reviewed and published by scientists, all with the same level of education c. An article published after being analyzed by experts for scientific procedure d. An article reviewed for accuracy after publication
6.	Which one of the following do you think represents a "peer-reviewed" scientific journal	a. *Weed Science* b. *Successful Farmer* c. *NDSU Williston REC Annual Report* d. *Scientific American*
7.	What do you think AGRICOLA is?	a. An internet search engine, such as Lycos or Google, only for topics relating to agriculture b. An electronic database for agricultural literature c. An electronic dictionary of agricultural terms d. A popular magazine on agriculture
8.	Which of the following might best indicate that a scientific article is "peer-reviewed"	a. It is published on a university website b. It has research data c. It cites references in footnotes or a bibliography d. It covers a topic relating to agriculture
9.	What do you think is the single most important reason to base scientific presentations on "peer-reviewed" articles?	a. Because without them, presentations are not scientifically valid b. Because the articles should be scrutinized for scientific procedure and content c. Because scientific presentations should refer the audience to additional information d. Because scientific presentations should acknowledge the work of others

Table 2. Summary of results of pre- and post-surveys given to PLSC491 undergraduates, 2001 and 2003 to 2006.†

	Question	Response	Pre-survey			Post-survey			*t*-test
			N	Mean	Median	*N*	Mean	Median	*p* value
1.	Do you believe you know the difference between a scientific article that is "peer-reviewed" and one that is not?	a	47	9	9	88	18	14	0.01
		b	59	12	11	10	2	1	0.01
2.	Do you believe you know how to search for scientific "peer-reviewed" articles using the internet?	a	29	7	8	79	16	13	0.06
		b	61	15	16	20	4	2	0.09
3.	Have you ever prepared a written or oral scientific presentation?	a	65	13	10	62	12	10	0.91
		b	43	9	5	35	7	4	0.76
4.	What do you believe is the single most significant difference between making a scientific presentation and a speech or essay?	a	6	1	1	4	1	1	0.62
		b	8	2	1	6	1	1	0.62
		c	4	1	1	2	0	0	0.54
		d	89	18	14	88	18	18	0.92
5.	Which one of the following do you think best describes a "peer-reviewed" scientific article?	a	2	0	0	0	0	0	0.18
		b	29	6	6	15	3	3	0.05
		c	52	10	7	71	14	10	0.08
		d	19	4	3	15	3	3	0.75
6.	Which one of the following do you think represents a "peer-reviewed" scientific journal	a	24	5	5	43	9	9	0.05
		b	8	2	1	6	1	2	0.73
		c	50	10	11	16	3	3	0.01
		d	23	5	3	34	7	7	0.10
7.	What do you think AGRICOLA is?	a	18	4	4	18	4	3	1.00
		b	81 81	16	12	77	15	13	0.50
		c	7	1	1	3	1	1	0.10
		d	0	0	0	1	0	0	0.37
8.	Which of the following might best indicate that a scientific article is "peer-reviewed?	a	22	4	4	10	2	1	0.30
		b	30	6	6	49	10	7	0.35
		c	32	6	3	36	7	8	0.83
		d	22	4	1	8	2	0	0.18
9.	What do you think is the single most important reason to base scientific presentations on "peer- reviewed" articles?	a	27	5	4	20	4	4	0.34
		b	37	7	6	61	12	14	0.05
		c	17	3	3	9	2	1	0.28
		d	26	5	5	12	2	2	0.07

† N = total number of responses for each question item over five years; Mean = mean number of responses per year; Median = median of responses; t-test comparing pre and post-survey means, p value considered significant at $p \leq 0.05$.

Results and Discussion

Responses to the pre- and post-surveys were significantly different for items pertaining to Question 1 (Do you believe you know the difference between a scientific article that is "peer-reviewed" and one that is not?), Question 5 (Which of the following do you think best describes a "peer-reviewed" scientific article?), Question 6 (Which one of the following do you think represents a "peer-reviewed" scientific journal?), and Question 9 (What do you think is the single most important reason to base scientific presentations on "peer-reviewed" articles?) (Table 2).

Most students responded "yes" to Question 1 after meeting with the NDSU agricultural sciences librarian and following their participation in the tutorials to identify and validate peer-reviewed online scientific literature (Table 2). Many Senior Seminar students lacked a basic understanding of what constitutes a peer-reviewed article before participating in the tutorials. For example, the majority of students on the pre-survey thought a peer-reviewed article was "an article reviewed and published by scientists, all with the same level of education" (Table 2, Question 5). Furthermore, many students on the pre-survey identified an article that was not peer-reviewed as being peer-reviewed, presumably because its title indicated it was developed from research conducted at NDSU or perhaps because it had "science" in its title (Table 2, Question 6).

It is very difficult to illustrate to students the importance of basing scientific presentations on peer-reviewed scientific literature, particularly because of a propensity to use the internet to find easy answers to problems (Wallace et al., 2000). Thus, it is important to note that after students used the NDSU Library website tutorials, a significant number of Senior Seminar students shifted their thinking and indicated presentations should be based on peer-reviewed articles mainly "because the articles should be scrutinized for scientific procedure and content" (Table 2, Question 9).

Interestingly, the majority of students responded that they had previously prepared a written or oral scientific presentation, and responses were similar from the pre-survey to the post-survey (Table 2, Question 3). This might indicate a false sense of confidence by students who thought they already had made a scientific presentation, when in fact their responses to other questions indicate the opposite. Student responses to Question 2 between the pre- and post-survey were statistically similar, but many students on the post-survey did respond "yes" to "Do you believe you know how to search for scientific 'peer-reviewed' articles using the internet?" A low number of students answered "yes" for Question 2 on both the pre- and post-survey in only one year (data not shown). Otherwise, the responses for this question would likely have been significantly different as indicated by the *t*-test.

Common sense dictates that students know what they are looking for before initiating a literature search. However, survey results indicate that many Senior Seminar undergraduates did not have a good initial understanding of what constitutes peer-reviewed scientific literature prior to their participation in tutorials. Guilford (2001) recognized the fact that undergraduates struggle with understanding the peer-review process as it relates to scientific literature. However, peer-reviewed scientific literature remains an integral part of the scientific process (Mulligan, 2005), despite the transition from hardcopy to electronic accessibility. Also, the benefits of teaching the peer-review process to undergraduates have been underscored by several attempts to engage students in practicing peer-review (Lightfoot, 1998; Pall, 2000). Clearly, it is important to teach the process and to have students use peer-reviewed literature as part of assignments, but an initial problem lies in having students first understand what constitutes peer-reviewed literature.

Aside from teaching students how to conduct effective online searches for scientific literature, the faculty–librarian partnership led to Senior Seminar students having a better understanding of what constitutes peer-reviewed scientific literature. Once Senior Seminar undergraduates had a good understanding of what they were seeking, they became more confident in their ability to search for and find the required peer-reviewed literature for the course. Similar results were achieved by DebBurman (2002) when an emphasis was placed on use of peer-reviewed literature as part of a sophomore-level cell biology course, and similar faculty–librarian partnerships have been used before to enhance online student literacy skills (Donaldson, 2000).

On course evaluations, several Senior Seminar students commented on the need to initiate an understanding of the utilization of peer-reviewed literature in lower-level courses. Results of Senior Seminar surveys also suggest that making this change would likely help students attain important science literacy skills even earlier in their undergraduate curricula.

Conclusions

Most Senior Seminar undergraduates enrolled for the survey period did not have a good initial understanding of what constitutes peer-reviewed scientific literature. Consequently, even though students favor using online resources, they often find identifying and accessing valid scientific literature difficult. Thus, Senior Seminar students benefited from accessing a NDSU Library website and participating in tutorials designed to help them identify, validate, and utilize online peer-reviewed scientific literature. Design of the library website and development of the learning session resulted from a successful partnership established between the authors, a NDSU plant sciences faculty member, and the NDSU agricultural sciences librarian.

Due to the importance of peer-reviewed literature to the scientific process and the unique problems faced by students attempting to access literature online, Senior Seminar students likely would benefit from being exposed to this teaching approach at an earlier stage of their undergraduate careers. It seems students will benefit most from a continued emphasis on teaching how to effectively identify, validate, and utilize online peer-reviewed literature. Efforts to use a faculty–librarian partnership approach to accomplish this in lower-level plant sciences courses might also be beneficial. Since there is a trend favoring use of online scientific literature, introducing peer-reviewed literature into

the curriculum might help improve student understanding of the literature and increase the utilization of this literature in future courses.

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