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The Effect of Peer Review on Information Literacy Outcomes in a Chemical Literature Course

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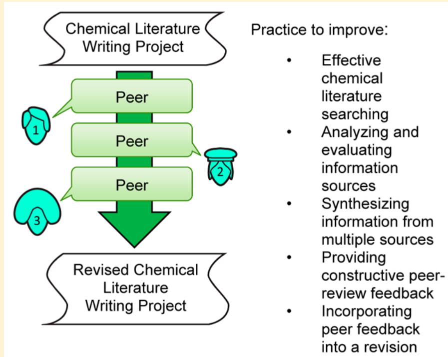
Supporting Information

ABSTRACT: This article describes the use of peer review in a writing project involving upper-level chemistry students in a chemical literature course, with the goal of improving student performance in meeting information literacy outcomes. Students were asked to find articles on a topic of their choice over the course of a semester and assemble the results into a brief paper, which was anonymously peer-reviewed by their classmates and then revised. The papers and the reviews were evaluated using a rubric based on ACRL information literacy competency standards for science, engineering, and technology students. Significant improvements relating to seven standards-based outcomes were observed ($p < 0.02$), corresponding to specific reviewer criticisms in up to 43% of student papers.



KEYWORDS: *Upper-Division Undergraduate, Curriculum, Communication/Writing, Collaborative/Cooperative Learning, Constructivism, Undergraduate Research*

INTRODUCTION

Can chemistry students give each other the feedback necessary to build information literacy skills? Do they have the skills to critically engage with other students' work? Given the opportunity, what do they deem worthy of comment? This study details a class project in a chemical literature course in which upper-level students in an ACS-certified chemistry program wrote brief, literature-focused papers and reviewed their peers' submissions.

Information literacy, the ability to "recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information",[1] is one of the key factors in lifelong learning and is implicit in American Chemical Society (ACS) certification standards regarding chemical literature skills, communication skills, and problem-solving skills.[2] The Accreditation Board for Engineering and Technology (ABET) also recognizes the importance of information literacy in its accreditation criteria.[3,4] Standards for information literacy have been developed by several different groups, including the American Library Association's American Association of School Librarians (AASL) and Association of College & Research Libraries (ACRL) units[5,6] and the Chemistry Division of the Special Library Association (SLA) working in conjunction with ACS's Chemical Information Division.[7] This study applies the ACRL standards, specifically the outcomes for science, engineering, and technology students developed by ACRL's Science & Technology Section (STS).[8]

Peer review has been shown to be an effective pedagogical tool for encouraging learning and improving performance on papers and projects across STEM and non-STEM disciplines.[9−11] Student peer review has been used in chemistry curricula, often using the Calibrated Peer Review (CPR) software,[12] to develop student proficiency in writing lab reports,[13−15] general technical writing,[16−19] and even chemical identification.[20] In the CPR process, the software guides students through the peer review of a preselected, pregraded paper in order to build their skills and model proper reviewing technique, and then assigns them papers written by their peers. While this project followed the general outline of Calibrated Peer Review, the authors chose not to use the specific piece of software, in favor of a more flexible manual approach.

In previous discussions of student peer review of writing assignments, emphasis has generally been placed on the quality of writing and the correctness of the answers to objective questions. Only one study discussed the impact of CPR on information literacy, in the context of an upper-level seminar course.[21] In that course, the students wrote short essays (300−500 words) comparing nontechnical review papers on energy security and assessed each other's papers both quantitatively and qualitatively. The assignment was analyzed looking for the use of specific quotes or data in assessing the review papers, the relevance of those quotes or data, and whether or not the students suggested alternate sources of information.

This paper, based on work done with a chemical literature course at a large Midwestern public university, will focus on upper-level chemistry students, detail the semester-long research paper project, discuss the feedback reviewers shared

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Table 1. Average Scores and Standard Deviations for Student Papers

Criterion	ACRL/STS Outcome[8]	Midterm Score[a]	Final Score[a]	p-value[b]
Does the student clearly define a focused information need?	1.1(a)	2.62 (0.84)	2.83 (0.80)	0.0131
Does the student state a hypothesis or thesis statement?	1.1(c)	1.92 (0.86)	2.25 (0.97)	0.0010
Do the student's conclusions follow from the analyses of the cited articles?	3.4(c)	1.58 (0.87)	1.93 (0.81)	0.0006
Does the student make connections between the questions raised in the introduction and the answers presented in the conclusion?	3.4(g)	1.75 (0.89)	2.30 (0.78)	0.0003
Does the student present an answer to the research question?	3.6(a)	1.43 (1.01)	1.75 (1.03)	0.0016
Does the student identify any drawbacks or limitations in the various search tools?	2.4(a)	0.55 (0.90)	0.85 (0.99)	0.0154
How well-written is the paper?	4.6(d)	2.10 (0.88)	2.50 (0.84)	0.0001

[a]Maximum possible score for each criterion is 4. Standard deviations in parentheses. [b]p-values calculated using a paired t test. N = 30.

with their fellow students, examine the effects of the reviews on revised papers, and suggest approaches to incorporating this approach into other courses.

■ METHODS

Course Overview

The class, titled "Chemical Literature", provides a broad overview of the chemical literature, from a top-down look at the scholarly publishing landscape to chemical patents to practical experience with SciFinder and other databases relevant to chemistry. It is taught by a member of the library faculty and fulfils the chemical literature requirement necessary for an ACS-certified chemistry degree. Students enrolled in the class are generally, although not exclusively, juniors and seniors pursuing that specific degree plan.

Demographics

The participants in this study (N = 30) were all enrolled in the aforementioned chemical literature course during the Spring semester of the 2014−2015 school year. The majority of the students (83%) were pursuing ACS chemistry degrees. Of the remaining students, 7% were chemical engineering students, 7% were pursuing non-ACS chemistry degrees, and 3% were studying neuroscience. In terms of class level, 33% of the students were juniors and 67% were seniors. International students made up 43% of the class, and the gender split was 33% female and 67% male.

Design

As part of their regular homework assignments, students chose a chemistry-related topic of their choice and used various electronic resources (Google Scholar, Web of Science, SciFinder, and Reaxys) to find articles and other relevant documents on topics of their choice. Their topic choices ranged from theoretical chemistry to the environment to healthcare, and many students chose to focus on topics related to their undergraduate research projects in campus laboratories. They were instructed to formulate search strategies for their topic, using the specific features of each database, then select documents of interest and cite them in proper ACS format. The students read the documents they found, summarized them, and assessed them for relevance, clarity, authority, validity, and timeliness.

For their midterm paper, the students took their search strategies, summaries, and analyses and combined them into a brief paper. They were expected to write an introduction covering necessary background and motivation, a methods section explaining their search strategies and their approaches to each resource, and a conclusion reflecting on both their topic and the process of searching for scholarly information. Finally, they wrote an abstract, in the style of the abstract for a review paper. The midterms were graded by the course instructor and the teaching assistant based on expected information competencies for upper-level science and engineering students.[22] The project requirements and grading rubric are included as Supporting Information.

Students were then given a lecture, an in-class activity, and a homework assignment related to the academic peer review process. The in-class activity was a group review of a farcical paper about a compound that improves frogs' jumping abilities.[23] Students were asked to evaluate the article using a series of prompts that asked students to assess the article on the basis of clarity, relevance, and accuracy and to thoroughly interrogate the author's methodology. The homework assignment involved reviewing a draft of a published chemistry research paper by applying the same criteria. Specific prompts were worded to reflect the type of text the students were tasked with evaluating.

The midterm papers were deidentified and each student was randomly assigned three of their peers' papers to review. The instructions were broad; while students were asked to address a few specific topics (methodology, writing quality, etc.) and to focus on constructive criticism, the students were able to interpret them as they saw fit. The anonymous reviews were then aggregated and forwarded to the reviewees. The students revised their midterm papers, incorporating the criticism they had received, and submitted the revisions as their final papers. In addition, students were also given minimal feedback on their midterm by the course instructor or teaching assistant, mainly focused on minor grammatical or organizational corrections. Three students also met with the course instructor individually, outside of class, to clarify their understanding of the project's expectations. This project received IRB approval before the information literacy aspects of students' work were examined.

Data Analysis

An information literacy rubric (see Supporting Information) was developed using the ACRL STS information literacy standards and outcomes,[8] creating a list of 33 criteria which could be assessed in the context of this project. Each paper was scored on a four point scale in each category. A score of four indicated that the criterion was present and well done, while a score of one indicated that student work was incomplete regarding addressing that criterion. A score of zero was assigned when the criterion was not addressed. The authors discussed definitions and exemplars for each category and each possible score prior to analyzing any of the student papers. Each author then scored all of the student midterms and finals separately. The scores assigned by each author were averaged to assign an overall score for each category for each student. Of the 33

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criteria initially assessed, seven showed differences between the midterm paper and the final paper, warranting further analysis (Table 1). Paired *t* tests comparing the students' midterm and final scores for these seven criteria were conducted to investigate improvements in performance.

In addition to analyzing the student midterms and finals, the feedback from the peer review that each student was given was also examined. Using the same categories created for the information literacy rubric, the authors analyzed each student's peer reviews for the presence of feedback addressing each category. The category was marked as present in the review if either author identified it as present. The comparison of the number of students who showed improvement on their final in a specific category to the number of students who received feedback in that category was used as a measure of the impact of the peer review process.

■ RESULTS AND DISCUSSION

To examine differences between the midterm and final student papers, scores for each of the seven categories were compared using paired *t* tests (Table 1). Overall, students performed moderately well on the midterm in regards to clearly defining a focused information need and composing a well written paper. For example, a student doing crystallography research whose topic focused on crystallography education wrote "Specifically, I was motivated to choose this topic by a desire to learn about the different approaches to teaching crystallography as well as need [sic] to have basic knowledge about the state of the field." The midterm instructions specifically asked students to address what motivated them to choose their topic, what they knew about it before starting their research, and why their topic might be of interest to others. Those areas, along with the nature of the assignment, may have helped students clearly define their information need on their first submission of their paper. While the extent of each student's writing experience is not known, institutional requirements make it likely that these upper-level students had, at minimum, some college writing experience in previous courses. This background could have contributed to their defining an information need and to the overall quality of their writing. However, the final papers showed statistically significant improvement in both of these criteria.

Even though students performed reasonably well defining their information needs, they included a complete hypothesis or thesis statement less often. One of the few who did, a student whose topic was the cesium effect, wrote "What certainly is mystery [sic] pertaining to this subject is what actually drives the reaction, because no record to date has actually been able to fully explain the causes behind it, although many different theories have been created." Many students either did not include a thesis statement at all or had an incomplete one on their midterm. This showed statistically significant improvement for the final papers, with most students writing at least a moderately well-stated thesis statement (Table 1).

When examining the conclusions of the student papers, the midterms were somewhat incomplete, but the final papers showed statistically significant improvement in this area (Table 1). Even though students were prompted to discuss what they had learned about their topic, many students did not specifically address that in the conclusions section of their midterms. As a result, when they were scored on whether their conclusions followed from their analyses of the articles, the scores were low. In addition, several students drew conclusions about their topic that were not supported by the research articles that they reviewed in their paper. For example, one student concluded that "Ayurvedic medicine and treatments can not only be used to treat patients by alleviating their pain, but also make people healthier as a whole by having the ability to boost body functions," while the articles they reviewed did not support such a broad claim. These types of unsupported conclusions also contributed to low scores in this area. In the final papers, more students included a satisfactory summary of their topic in their conclusions. Additionally, the students who had drawn unsupported conclusions did include some statements that more accurately reflected the conclusions of their summarized and analyzed articles. For example, the student who researched Ayurvedic medicine wrote in the final paper "I learned that not all of the treatments in Ayurveda can be blindly trusted, as some research has showed that the prescriptions for some medicine can result in toxicity from the prescribed dosage." However, this student also repeated the previously quoted statement without alteration, so unsupported claims were still present.

While a focused information need and thesis statement were adequately presented most of the time, students were less effective in connecting their introductions to their conclusions and in answering the research questions they had posed (Table 1). For their midterms, many students only wrote short summaries of the research articles they had read without relating that content to the questions they had presented in their introductions. In their final papers, they at least moderately connected their conclusions to their introductions, as shown by the statistically significant improvement to an average above two. There was also statistically significant improvement in presenting an answer to the research question, albeit still below an adequate level. This may partially be due to many students presenting very broad questions about their topic that would be difficult to answer from reviewing 12 to 15 research articles. However, most students did not discuss this issue and simply did not address their research questions in their conclusions.

As part of their conclusions, students were prompted to address what they learned about the scholarly literature and about conducting research. While they were not explicitly told to include drawbacks or limitations of the various search tools they had used, it was expected that students would have some comparison of the search tools. As shown in Table 1, it is clear that the majority of students did not include this comparison on either the midterm or the final, although there was some statistically significant improvement. On the midterm, the few discussions of the different search tools were made by students who had difficulty either using or finding information about their topic in one or more of the tools. For example, one student wrote "Reaxys had literally no information relating to my topic. Web of Science had the same exact information as SciFinder and Google Scholar, so it was useless when it came time for me to search through it. One thing I definitely took away from conducting this research was how specified some databases are." On the final, more students included a comparison, such as a student who did not include it at all on the midterm writing "Different searching database has [sic] its own benefit. For my topic, I would prefer using SciFinder, since this one give [sic] me the detailed information I need. The Web of Science gave me mostly about human based articles [sic]. It was more like an application of gold nanoparticle rather than syntheses itself [sic]" in the final

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paper. While their discussion was incomplete, it did address differences between search tools on a very basic level that was not present in their midterm. It is unlikely that students failed to have an opinion on the relative merits of each resource, as all four were discussed and used in class. Students also completed additional homework assignments using all four resources. The lack of comparison of the search tools may have been due to the prompts being too broad, so it may be beneficial to be more specific in the future.

In addition to analyzing student midterms and finals, it was also of interest to examine the feedback that students received from the peer review process. While the quality of the peer reviews varied, all but five of the 30 students received constructive feedback beyond minor grammatical or organizational corrections from at least one reviewer. An example of constructive feedback provided by a student was "This paper does need proofread [sic] for grammatical errors and such. Also the conclusion needs to answer what you would have done differently... Also in the second citation of Reaxys the summary paragraph mentioned the high cost of the transesterfication step. However, nothing about the cost was mentioned. Also the research done mentions a lot about the transesterfication step used for algae biodiesel production, yet the abstract, intro, no conclusion [sic] mention anything about this." Each student was reviewed by three of their peers, and thus could receive from zero to three constructive reviews. As the majority of students received constructive feedback, a significant correlation between quality of feedback and improvement in grade between the midterm and the final could not be determined. Regardless of the number of constructive reviews received, there were students who performed worse on the final, who received the same grade, and who improved. This excludes the students who received no constructive feedback, none of whom performed worse on the final. These results suggest that some students did not use the feedback they were given to improve their paper, which may mask any significant correlation between quality of feedback and paper improvement.

The majority of students received feedback on needing to clearly define a focused information need, ensuring conclusions follow from analyses of the cited articles, and on writing quality (Table 2). Many students also received feedback related to presenting a hypothesis or thesis statement and connecting the introduction and conclusion, with few students getting feedback on presenting an answer to the research question or identifying limitations of the search tools. Few students commented on including drawbacks, possibly because they were not aware it should be included based on the broad prompts in the assignment. It is interesting to note that even though students were not specifically prompted to provide feedback on these specific areas, they were present in the peer reviews, indicating that the peer review in-class and homework activities may have influenced student feedback as well.

Even though all students were given feedback from their peers, not all of them acted upon it (Table 2). In general, about half of the students who received feedback related to each criterion showed improvement in that area on their final, with the exception of presenting an answer to the research question and identifying drawbacks or limitations of the search tools. Far fewer students addressed these two criteria, although the number of reviewers commenting in those categories was correspondingly small. While only about half of the students who received feedback in a specific area incorporated their feedback to show improvement in their final paper, it is possible that more students incorporated their feedback in less observable ways. Students who performed well on the midterm paper did not have much room for improvement and other students may have attempted to include their feedback in their revisions but did not show significant improvement, causing an underestimate of the students who used their feedback. It is encouraging that the peer review process as implemented in this study did help students improve their papers, as indicated by the data in Tables 1 and 2.

Table 2. Impact of Peer Reviews

Criterion	Feedback Present[a]	Feedback Impact[b]
A focused information need is clearly defined	56.67%	26.67%
A hypothesis or thesis statement is present	20.00%	13.33%
Conclusions follow from the analyses of the cited articles	60.00%	33.33%
Connections between the introduction and the conclusion are made	23.33%	13.33%
An answer to the research question is presented	10.00%	3.33%
Drawbacks or limitations in the various search tools are identified	3.33%	0.00%
The paper is well written	76.67%	43.33%

[a]Percentage of students who received peer reviews that addressed the criterion. [b]Percentage of students who received feedback addressing the criterion and scored higher on their final than on their midterm in that category. $N = 30$.

CONCLUSION

Peer review, in addition to its established role in improving the quality of chemistry students' writing, improves information literacy outcomes. Students are able to critically engage with a text and suggest structural, stylistic, and conceptual improvements. The process can give instructors insight into what students find worthy of comment and criticism when evaluating their peers' writing. It is also possible to gauge the effect of this criticism in observing how well students follow through on their reviews. This project could serve as an additional template when considering the use or assessment of a peer review activity.

One issue that needs to be addressed in future iterations of this project is the degree of calibration and guidance. Even when given significant latitude in how to approach criticism, students tended to follow the specific critical prompts given in class and in the peer review homework. It may be possible to clarify student expectations through additional calibration exercises or additional, more specific prompts.

There is also a difficulty in distinguishing between improvements directly attributable to the peer reviews and improvements attributable to simple iteration and revision. The increase in the number of students clearly defining an information need is encouraging, but it could be the result of self-criticism rather than peer criticism. One option to help clarify this issue is to have students explain the changes they have made and the corresponding motivations. If students were asked to write a brief response to their criticism and explain their reasoning, it may be possible to more accurately separate the effect of the peer review from that of other inputs. This may also address the lack of follow-through on the criticism, in cases where students made superficial fixes instead of more substantive revisions.

Although the authors chose to use a literature-focused research paper as the vehicle for the peer review exercise, the

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design could be implemented with other types of writing and research projects. Similarly, the design of this project does not depend on any specific set of databases. Instructors at institutions without access to particular databases could substitute whichever chemistry literature resources they normally use when working with undergraduates. Finally, while the authors used a more ad hoc method for coordinating the distribution of reviews, automated systems such as Calibrated Peer Review would work equally well, and might be preferable in larger classroom settings.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00413.

Midterm project assignment (PDF, DOCX)
Final project assignment (PDF, DOC)
Grading rubric (PDF, DOC)
Information literacy rubric (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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