Student Comprehension of Primary Literature is Aided by Companion Assignments Emphasizing Pattern Recognition and Information Literacy

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Abstract

Primary literature is our main mode of communication in the sciences. As such, it is important for our undergraduates in the discipline to learn how to read primary literature. Incorporating primary literature into undergraduate science courses is often difficult because students are unprepared to comprehend primary articles. Learning to read and evaluate primary literature can improve students' understanding of science and the scientific method, and develop the educational and life skill of evaluating whether assertions are supported by evidence. We integrated two areas of research (teaching students to use primary literature and pattern recognition in experts versus novices) to modify a curriculum used to teach information literacy and primary literature in an introductory biology course. The modifications taught students to recognize information by the communication patterns used in the literature, and despite literature's jargon. One section of this course used our modified curriculum while two control sections used the original curriculum. In all sections, students were asked to write a lab report citing a primary literature article pertinent to their laboratory experiment. We read each lab report and the article it cited, ranking the student's comprehension of the article and their ability to integrate the article into their laboratory report on a scale of 1 to 3 using rubrics. While citing a primary literature article was required of all students, more students using the modified curriculum cited primary articles in their laboratory reports (95% vs. 65% average in control sections). The comprehension of primary articles also appeared better, as cited articles were more likely to be correctly paraphrased by students with the modified curriculum (average score of 2.33 vs. 1.96), while there did not appear to be a difference between the groups' abilities to integrate the article into their report. This indicates that by incorporating pattern recognition assignments and information literacy instruction into the curriculum, teachers can significantly improve student comprehension of primary literature.

Introduction

Primary literature is one of the main modes of communication in the scientific community. It is the mode scientists use to compare and critique methods and share results. Given the prominence of primary literature in science, it is important for young researchers to be able to read primary literature and efficiently extract the important information. Undergraduate students find it difficult to read primary literature, possibly due to its style and jargon being very different from the textbooks they are accustomed to reading (Gehring & Eastman 2008). Common difficulties include: finding articles

pertinent to their research topic, understanding the articles, and integrating the findings in the article with their own findings in the classroom or laboratory (Gehring & Eastman 2008). Since students find primary literature so challenging, it is tempting to leave it out of our undergraduate curriculum in favor of more textbook material; however, this results in graduates who cannot comfortably read primary literature. Learning how to read primary literature gives students a better understanding of the scientific method (Brill & Yarden 2003) and learning how to critique primary literature improves their ability to assess many different types of information they will receive as adults, whether or not they become researchers.

It is not only a disservice to our undergraduate students to assume they cannot learn to read primary literature; it is also inaccurate. For example, two previous studies involving Indiana University biology students show that teaching undergraduates at upper and lower levels to read and use primary literature is possible under the right conditions. In one study that integrated information literacy principles, as defined by the Association of College and Research Libraries Information Literacy Standards for Higher Education (ACRL 2000), with course goals, the professors of an entry-level course designed and implemented an 8-week module called Science Seeker. The Science Seeker module led students from concepts in their textbook, gradually through the related literature, to a relevant primary article that they successfully summarized and presented to their peers (Petzold, et al. 2010). The second study focused on using information literacy standards as a guide for upper level students to develop research proposals by drawing parallels between the standards and the scientific process (Winterman 2009). In both cases, students' understanding of the nature and structure of science information resources was key to their success in synthesizing, writing, and presenting their ideas.

Students as young as high school can learn how to read and benefit from primary literature (Brill & Yarden 2003). Including primary literature in high school lessons results in the students achieving a higher level of understanding of the material; they ask more complex questions and show a deeper understanding of the content (Brill & Yarden 2003). Brill and Yarden (2003) found two keys to teaching high school students how to read and understand primary literature: first, the teacher must pre-select articles that are both pertinent to the content and relatively easy to read; second, the students need to be taught that the material in all primary literature articles follows a common pattern. In their case, Brill and Yarden (2003) compared the pattern of information in a primary literature article to the scientific method itself.

The need to teach pattern recognition to students is not a novel concept. Several studies have shown that it is the main difference between 'experts' and 'novices' (Bransford, et al. 2000). Experts in their field have an inherent understanding of the patterns their information occurs in, so they are able to extract pertinent information from a chart or article relatively easily by immediately recognizing which information is important and which information can be disregarded (Bransford, et al. 2000). For example, in one experiment, expert and novice circuit technicians were shown a circuit diagram for a couple seconds, then asked to reproduce the diagram from memory. The expert technicians, who had more experience with circuit diagrams, were able to reproduce the diagram more accurately because they recognized common patterns in the diagram (such as the pattern creating a capacitor; Bransford, et al. 2000). We hypothesize that our undergraduate students find it difficult to read primary literature articles, in part, because

they have not been taught the appropriate patterns to look for when reading the articles. Teaching these patterns may allow the students to find the patterns in the literature, mentally highlighting the important pieces of information and therefore improving their ability to summarize the article correctly.

Overview of Course

Introductory Biology Laboratory is a stand-alone laboratory course consisting of one 50-minute discussion and one 3-hour lab each week. It is taught in both the fall and spring semesters, with 16-17 sections and approximately 400 students each semester (20-25 students per section). These students are mainly sophomores (71% sophomores, 14% juniors, 12% seniors, 1% freshmen, 2% other). Most students are biology majors (56% biology majors, 35% other science majors, 9% non-science majors), and are planning to apply to medical, dental, or veterinary school (69%) or another medical profession (e.g., nurse or radiation technician; 9%) after graduation. Each section is taught by a graduate student Associate Instructor (AI, equivalent to a teaching assistant), who is responsible for leading discussion, setting up and running the lab, and grading the assignments. The curriculum is standardized: all sections have the same reading assignments, lab activities, and lab reports. Major assignments (such as the assignment introducing primary literature) are also uniform, though instructors are allowed to award 10% of the total grade at their discretion for unique assignments (such as quizzes or peer review assignments).

Primary Literature Assignment and Student Difficulties

The students are assigned one laboratory report for each of their five laboratory projects, and they are expected to cite a pertinent primary literature article in the last three reports. While they are working on their third laboratory report (on ultraviolet light and mutation rates), they spend one class period at the library, where a librarian teaches them how to use an appropriate journal literature index (in this case, Web of Science). The students are then given the Primary Literature Assignment, which presents them with a hypothesis related to ultraviolet light and mutation rates and asks them to find an article that either supports or refutes this hypothesis. They print the article and summarize it to complete the assignment.

Because of limited time and a lack of ongoing collaboration between professors, students, and librarians, single library instruction sessions (often referred to as "one-shots"), as they are usually designed and offered at IU, most often do not allow for teaching information skills beyond those associated with basic search techniques. While the library instruction session teaches the students how to search for pertinent primary literature, it does not teach them how to read or evaluate primary literature. As a result, most students tended to base their summary on parts of the abstract or introduction, without actually reading and fully understanding the whole article. Consequently, the AIs frequently found that the students were unable to accurately paraphrase these articles in their laboratory reports. In past years, our students have had the same difficulties Gehring and Eastman (2008) found with their students, including: 1) reading only the abstract of the article they cited, not the entire article; 2) citing information paraphrased in the introduction as if it were the topic of the article; and 3) using the same jargon used in the article without clearly understanding what they are saying. The optimal scenario is one where students learn information literacy skills, reading strategies, and writing skills as

an integrated step-by-step process instead of as discrete elements. Ideally, this would result in students being able to extract pertinent information from an article and paraphrase it correctly in their lab reports.

We tested whether a set of two library instruction sessions and two linked assignments would improve our students' ability to:

1. understand the content of primary literature articles (comprehension); and
2. integrate the information in their primary literature articles with their own findings in their laboratory experiment.

The first library instruction session and assignment introduced the students to the jargon associated with the study of ultraviolet light and mutagenesis by having them search for and read encyclopedia articles. The second session and assignment taught the students how to search for and identify relevant articles that were also easy to read and guided them through their first time reading primary literature by emphasizing the pattern in which important information is found in primary literature articles.

Methods

The standardized curriculum for this course allowed us to assess two control sections, which used the previous curriculum, and one experimental section, which used a new set of information literacy tutorials and assignments to help the students read primary literature. All three sections were held during the afternoon in the spring semester of 2010. Each section was taught by a different AI. Using two control sections allowed us to control for differences in teaching technique between the AI's.

Previous Primary Literature Tutorial and Assignment (Control Group)

Since the Primary Literature Assignment was a standardized assignment for the entire course, both control groups had identical one-shot library sessions and Primary Literature Assignments. During the library session, a librarian taught students how to use Web of Science to find primary literature articles. The students were then asked to find an article that discusses one of the two questions and hypotheses listed below:

Q1) Does short-wave UV irradiation have (either direct or indirect) mutagenic effects?
H1) It seems reasonable to predict that short-wave UV irradiation does have mutagenic effects and that greater exposure will result in more mutations so there should be a pattern of more yeast colonies with greater exposure to short-wave UV irradiation.

Q2) Does short-wave UV irradiation affect more than just the nucleic acids within living cells?
H2) Yes, short-wave UV irradiation causes damage to the proteins in living cells. Increased exposure to short-wave UV irradiation will cause a decrease in survivorship of yeast cells.

To complete the assignment (worth 5% of the total grade), the students needed to read the article, summarize it in one paragraph, and explain how the article was relevant to their in-class laboratory activity on ultraviolet light and mutagenesis. The students were not given any additional material or instruction on how to read primary literature, but they were allowed to ask the librarian and their AI questions while they were working.

New Primary Literature Tutorials and Assignments

(Experimental Group)

With the goal of improving the efficacy of the Primary Literature Assignment without significantly altering the grading structure, class schedule, or student workload, we divided the Primary Literature Assignment into two assignments, each worth 2.5% of the final grade. We then added a second library session and paired each session with one of the assignments. In the first library instruction session, we discussed the authority of different sources on the Internet and had the students compare articles from Wikipedia and two online encyclopedias available through the library's web site (AccessScience and Encyclopedia of Life Sciences). The students were then asked to find an encyclopedia article that answered the question "Does UV light/radiation have mutagenic effects?" Their Encyclopedia Assignment asked them to use the information in their article to answer the question. They were to paraphrase, not copy, the information in the article that answered the question. The goal of this assignment was to acquaint the students with the topic and the scientific jargon associated with the topic before they were asked to read a primary literature article.

In the second library instruction session, the students were shown how to search for primary articles using Web of Science. They were then asked to find a primary article addressing the question "Does UV light/radiation cause DNA mutagenesis?" Using this article, they completed a worksheet in class that asked for the main pieces of information from the article, including the following:

- What is the question that the authors are trying to address?
- Describe their hypothesis.
- Describe at least one experiment that they do to test this hypothesis. What is the logic of this experiment? (How will the experiment answer their question?)
- Describe the type of data they collect. (Is this collected in a lab or in the field? Is it qualitative or quantitative?)
- Summarize the conclusions that the authors make. Do you think they are correct?

The students answered the questions as they read the article. As this was an in-class activity, the students were able to ask for help if they had trouble reading the article or finding the required information. By completing the worksheet, the students distilled their articles into a small set of salient points that could be compared or contrasted to their own laboratory experiment. The goal of this assignment was to teach the students where principal pieces of information occur in the article by asking them to find this information in their first article. This changed their reading assignment from a solid block of text into a resource containing specific pieces of information in a specific pattern.

Assessment

We collected the third laboratory reports from students in the three sections who agreed to participate in the study. These were the laboratory reports completed immediately after the tutorials and assignments and covered the in-class laboratory experiment on exposure to ultraviolet light and mutation rate in yeast. First, one researcher determined whether the students cited a primary literature article in their lab report, as assigned. Then, this researcher assembled information from all of the laboratory reports into an Excel spreadsheet, including the bibliographical information about the primary article, any references in the lab report to the article, and the student's last name. This first researcher also determined how well the students connected the information in the article to the

results in their lab report ("integration") using a rubric (**Table 1**). An unaffiliated researcher assisting with the project, who did not know which section the different students belonged to, read each primary literature article and, using a rubric (**Table 2**) and the Excel spreadsheet determined whether the student correctly paraphrased the article (scored as "comprehension"). If a student cited more than one article in the report, the score was an average of the score for each article. This resulted in each student having one comprehension score and one integration score if they cited at least one article. The researchers used these scores to calculate the mean and standard error for the experimental group and combined control groups.

Results

While citing a primary article in the lab report was required for all students, fewer students in the two control groups cited an article in their lab reports compared to the experimental group. On average, only 65% of control group students cited an article while 95% of experimental group students cited an article. Students who did not cite an article were dropped from further analysis.

We did not find a difference in the students' ability to successfully integrate the articles into their lab reports (Wilcoxon Rank Sum test; $p = 0.606$).

Students in the experimental group were more likely to correctly summarize the paper they cited in their lab reports (i.e., higher comprehension). The average score for the experimental group was 2.33, while the average score for the control groups was 1.96. The control groups both had fewer good scores and more poor scores compared to the experimental group. A Wilcoxon Rank Sum test of the comprehension scores indicates slightly higher comprehension in the experimental group ($p = 0.091$). If the students in both groups who failed to cite an article in their report are given a comprehension score of 1, this difference becomes highly significant ($p = 0.001$).

Discussion

Our set of assignments (Encyclopedia Assignment and Primary Literature Assignment) improved our students' ability to read and understand primary articles cited in their lab reports. Students in the experimental group were more likely to cite an article in their lab report, which may indicate that the new curriculum made reading and understanding primary literature articles easier for the students. Among those students who cited a primary article, those in the experimental group were more accurate, indicating that they understood the main points of the article and did not just paraphrase the introduction. The difference between the experimental and control groups becomes more distinct if the students who failed to cite an article are given a comprehension score of one. Since 35% of the control group students failed to cite a primary literature article while only 5% (one student) in the experimental group failed to cite an article, the average comprehension score of the control groups drops farther than that of the experimental group, making the difference between the comprehension levels of the two groups even more distinct.

Our results show that including relatively simple assignments aimed at teaching students how to read primary literature can improve student comprehension of primary literature while taking up relatively little class time. In our course, the experimental tutorials and assignments took two 50-minute discussions instead of one, a reasonable increase in effort considering the potential for improved student learning. The benefits of this lesson would continue into additional courses as the same skills are used at all levels of biology

learning. This use of class time could be further reduced if the first tutorial were put online and the encyclopedia assignment done as homework. Future studies should try to determine how many of our assignments need to be done in the classroom to observe the same increase in comprehension.

Our second assignment adds to the increasing body of literature promoting the use of pattern-recognition in teaching students how to read primary literature (Brill and Yarden 2003; Gehring and Eastman 2008). Brill and Yarden (2003) used hand-picked articles that were easy to read and taught them using the scientific method as a pattern to teach high school students, while Gehring and Eastman (2008) used a set of one library tutorial, six linked assignments, and two laboratory reports to teach upper-level undergraduate students. Our study shows that lower-level undergraduate students can be taught how to read primary literature using significantly fewer assignments than Gehring and Eastman (2008) and without hand-picking the primary articles. One important key is to ask the students for specific pieces of information (e.g., the hypothesis) instead of asking the students to summarize the article. Our results support the argument that repeated use of a worksheet such as ours will train the students to look for the important pieces of information in an article and improve their ability to find this information quickly and easily (improved pattern recognition). Further studies should determine how many times a student must use the worksheet before they are able to accurately summarize an article without using the worksheet.

Since our modified curriculum did not improve the students' ability to connect information in the primary article with their laboratory exercise, additional modifications should be studied. It is possible that a relatively short worksheet completed after the laboratory exercise and Primary Literature Exercise but before the laboratory report could initiate in-class discussions on how the primary literature can be compared to the students' results.

The students in the experimental section did not achieve the level of fluency in the primary literature that we would like to expect from graduates of our program, especially those expecting to continue on to medical school. Our results show that introducing students to primary literature and teaching them discipline-appropriate information literacy skills in their sophomore year using a set of assignments similar to ours can improve their ability to read and understand primary literature. We selected the sophomore year because of the presence of an existing class suitable for modification; we expect the same curriculum would be suitable for introductory biology laboratories in the first year, when many schools already have library introduction sessions. It is possible that pairing our assignments in an early course and Gehring and Eastman's (2008) assignments in a later course will result in graduates that are truly comfortable reading and discussing primary literature. This could be tested using a paired set of required courses, where the earlier course is a prerequisite for the other.

Pattern recognition, which has been shown to be a skill used by experts in widely disparate fields (Bransford, et al. 2000), is an important tool that can substantially improve our students' ability to read and understand primary literature. Likewise, integrating information literacy principles enhances this process. Though more rigorous research should be done to determine the impact and effectiveness of combining these principles and methods, science teachers in all levels of education might consider incorporating pattern recognition and information literacy into their curriculum to teach

their students how to benefit from the primary literature.

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References

ACRL. 2000. *Information Literacy Competency Standards for Higher Education*. Chicago, IL: American Library Association. [Internet]. [Cited December 15, 2011]. Available from: http://www.ala.org/acrl/standards/informationliteracycompetency

Bransford, J.D. et al. (eds). 2000. *How People Learn*. National Academy Press, Washington, D.C.

Brill, G. & Yarden, A. 2003. Learning biology through research papers: a stimulus for question-asking by high-school students. *Cell Biol Education* 2:266-274

Gehring, K.M. & Eastman, D.A. 2008. Information fluency for undergraduate biology majors: applications of inquiry-based learning in a developmental biology course. *CBE - Life Sciences Education* 7:54-63.

Petzold, J., et al. 2010. Science Seeker: a new model for teaching information literacy to entry-level biology undergraduates. *Issues in Science and Technology Librarianship* 63 [Internet]. [Cited December 15, 2011]. Available from: http://www.istl.org/10-fall/refereed2.html

Winterman, B. 2009. Building better biology undergraduates through information literacy integration. *Issues in Science and Technology Librarianship* 58. [Internet]. [Cited December 15, 2011]. Available from: http://www.istl.org/09-summer/refereed1.html

Tables

Table 1: Rubric for scoring how well students integrated the information in their primary literature article with the methods or results from their laboratory exercise. Lab reports with poor integration cited a primary literature article but lacked any transition sentences comparing the article to the other material in their lab report.

Good (3)	Student specifically compares the methods and/or results in their primary literature article their own methods and/or results during the UV/mutagenesis lab.
Fair (2)	Student compares the general topic of the primary literature article to the general topic of their UV/mutagenesis lab.
Poor (1)	Student cites a primary literature article but does not compare this article to their UV/mutagenesis lab, nor do they connect the information in the article to other information in their lab report.

Table 2: Rubric for scoring how well students understood the primary literature article they cited (i.e., student comprehension). This assessment was based off their paraphrasing of the article in their lab reports.

Good (3)	All statements the student makes about the primary literature article are true.

Fair (2)	Student makes one of the following mistakes: • makes minor errors in paraphrasing the article; or • uses words or phrases from the article without showing that they clearly understand what they are saying.
Poor (1)	Student either • makes a statement about the article that is clearly false; • summarizes a statement from the introduction as if it were the conclusion of the article; or • copies phrases from the article instead of paraphrasing it.