

## An online tutorial for helping nonscience majors read primary research literature in biology

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**Gillen, Christopher M., Jasmine Vaughan, and Bethany R. Lye.** An online tutorial for helping nonscience majors read primary research literature in biology. *Adv Physiol Educ* 28: 95–99, 2004; 10.1152/advan.00044.2003.—Using primary literature is an effective tool for promoting active learning and critical thinking in science classes. However, it can be challenging to use primary literature in large classes and in classes for nonscience majors. We describe the development and implementation of an online tutorial for helping nonscience majors learn to read primary literature in biology. The tutorial includes content about the scientific process and the structure of scientific papers and provides opportunities for students to practice reading primary literature. We describe the use of the tutorial in Biology of Exercise, a course for nonscience majors. Students used the tutorial outside of class to learn the basic principles involved in reading scientific papers, enabling class sessions to focus on active-learning activities and substantive class discussions.

active learning; critical thinking

READING PRIMARY LITERATURE is an important component of undergraduate education in biology. Employers in many fields and faculty in graduate schools expect students to effectively read research articles. Furthermore, reading primary literature serves as an important instructional tool. When reading research articles, students begin to learn actively and think critically as participants in the investigative process of science (10, 21). Primary literature is widely used in upper-level courses for science majors, and its use has been well described recently (8, 10, 13, 21). Primary literature is used less often in general education courses and courses for nonscience majors, even though several authors have convincingly described effective uses of primary literature in these courses (1, 2, 27).

There are several reasons for using primary literature in courses aimed at the nonscience major. When science is presented only as a body of inarguable facts rather than as an ongoing process, students, especially nonscience majors, may become disinterested and discouraged. Learner-centered, inquiry-based activities can overcome these problems by engaging students as active participants in the learning process (14, 19). The primary literature is a cost-effective and widely available tool for promoting inquiry-based learning of science (1). Research articles are specific, concrete examples of the scientific process and illustrate how scientific knowledge is generated (27). Because research articles often deal with areas of disagreement or controversy, students who read them can be encouraged to develop their own interpretations and criticisms of the work. In this way, students move from being passive recipients of scientific facts to active participants in a scientific discussion.

It may seem surprising that nonscience majors are capable of reading the biological literature and of approaching it with a critical stance. Admittedly, the structure, content, and technical language in many primary articles are challenging for the nonspecialist. Some have argued that the ideal media for these students are secondary sources such as magazines, as the students are most likely to get scientific information from these resources in their adult life (6, 11). However, in some ways, nonscience majors are well prepared to read primary material. In humanities disciplines, even at the introductory level, primary material often comprises a large portion of the assigned reading. In college introductory classes, students routinely read difficult primary writings, for example, those of Shakespeare and Kant. Nonscience majors may have substantial experience struggling with difficult primary texts and thus may be familiar with the process of critical analysis of texts. Experiences reading primary literature in other disciplines could help nonscience majors approach the scientific literature with a critical mindset when it is first presented to them. However, despite having experience with critically reading texts in humanities disciplines, nonscience majors may fail to apply these skills to primary biology literature without prompting, possibly because they perceive science to be factual, objective, and free of interpretation.

Although nonscience majors are capable of reading primary literature and will benefit from the experience, there are substantial challenges for instructors who wish to use primary literature with nonscience majors. First, teaching students to read primary literature is time consuming and thus competes with other important course goals. Also, there is a relative lack of instructional materials for helping students to read primary literature. This stands in contrast to excellent guides for finding primary literature and for writing scientific papers (12, 18). Finally, reading primary literature requires practice, so instructional materials that encourage students to actively practice reading literature will be most effective.

We have developed an online tutorial intended to support the use of primary literature in biology courses for nonscience majors. The tutorial models the process of critically reading scientific research and includes opportunities for students to practice this process. This report describes the rationale, implementation, and qualitative assessment of the tutorial used in the Biology of Exercise course at Kenyon College, Gambier, Ohio.

### METHODS

**Personnel.** The role of each author in this project is as follows. C. Gillen is an animal physiologist and the course instructor of Biology of Exercise. J. Vaughan is a librarian with an interest in information literacy. In the integrated department of Library and Information Services (17) at Kenyon College, librarian and technology consultants

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(LTCs) are assigned as liaisons to faculty departments, supporting both computing and library needs. As LTC to Biology, J. Vaughan worked closely for several years with C. Gillen to support the information literacy aspects of the Biology of Exercise course, culminating in the development of the online tutorial described here. B. Lye '03, an undergraduate Biology and English major, provided feedback and edited the tutorial.

Collaboration between a faculty member and librarian on critical reading has a pedagogical rationale. Information literacy requires an integration of library skills and the ability to think critically about sources (5, 22). These tasks are increasingly interconnected because online databases often allow users to access full text articles immediately after finding them in a search. Although library instruction sessions are associated with many undergraduate biology courses, these sessions rarely focus on the structure of a scientific article or how to read articles critically (20). We anticipated that the collaboration between a faculty member and librarian would lead to instructional materials that better integrate the tasks of finding and assessing research articles.

*The course.* Biology of Exercise is a one-semester course designed specifically for nonscience majors. Some students take the class because of their interest in exercise and athletics; others enroll to help fulfill the college's natural sciences diversification requirement. The course was first taught in 1999 and is taught in alternating years to ~60 students in a traditional lecture hall classroom. The course emphasizes the scientific process and critical thinking, using examples from exercise, nutrition, and athletics. We believe that an emphasis on critical thinking and the scientific process, rather than an approach emphasizing factual detail, is appropriate for the students who enroll in Biology of Exercise. Most of these students will not need a comprehensive knowledge of modern biology in their adult lives. However, they probably will need to assess the credibility of scientific information in the context of health, environmental, or even investment decisions during and after college life.

*Biology of Exercise course project.* Our approach to using the primary literature in Biology of Exercise is similar to that described by Woodhull-McNeal (27). Students in her nonscience majors' course Physiology of Human Movement developed their own research questions and used the primary literature and laboratory experiments as investigative tools. In Biology of Exercise, the objective of the major assignment is to teach students to think critically about scientific information. In this multiphase assignment, students pose a question in exercise biology and write a short background paper based on secondary sources. Next, they carefully critique a primary research article. Finally, they write a position paper that uses one or more primary sources to argue a particular position on their topic. The full assignment and deadlines are online (3). The assignment requires students to effectively use library resources, to understand complicated biological principles, and to critically read primary articles relevant to their question. Despite the significant amount of work required to complete the assignment, many students are motivated to invest time and effort because they choose a topic of personal interest. For example, recent student projects have explored the safety of the dietary supplement ephedrine, the effectiveness of the Atkins diet, and the benefits of sports beverages. Early in the class, students understand that they will need to independently read primary literature to accomplish their project; thus they are motivated to learn the needed skills. Despite their motivation, many students have difficulties finding and critically evaluating primary literature articles without support from an instructor.

*Development of an online tutorial.* Because of the challenge students experience in finding and critically evaluating primary literature articles, we have developed instructional approaches and materials to help students in these tasks. The first time that Biology of Exercise was taught, we developed Web pages to help students find appropriate

primary sources. Additionally, a bibliographic instruction presentation was made to the class by the LTC. Topics in the presentation included distinguishing between popular and scholarly sources, identifying reference sources in the online catalog, finding primary sources in online periodical databases, evaluating online information, and appropriately citing online information. After this instruction, most of the students were able to find primary research articles relevant to their topic using Medline and other online databases.

Although in-class instruction sessions were effective in teaching students how to find primary literature, we found them less useful in teaching students how to read literature. The first time that Biology of Exercise was taught, several class periods were devoted to teaching students how to read the scientific literature. These sessions included a lecture describing the scientific process and the format of scientific papers, followed by a class period in which we analyzed a section of a paper. It was observed that many students still had significant difficulty in reading and understanding the primary literature despite these class sessions devoted to teaching these skills.

In addition to specific knowledge and strategies, students need examples and practice when learning to read the literature (2, 21). Biology educators have noted that students often need to have paper reading skills "modeled" (13). We hypothesized that an online tutorial might be more effective than traditional classroom activities in teaching paper reading skills, especially in a large class. Tutorials can deliver both the specific knowledge and the practice required to help students read the scientific literature effectively. Two additional advantages of the tutorial are that each student must engage the material directly rather than passively listening to a class discussion, and much of the basic information delivery occurs outside of class time, freeing class periods for higher-level discussion and analysis. With funding from an Andrew W. Mellon grant to the Five Colleges of Ohio, we developed a tutorial and implemented it in the Biology of Exercise course during a recent semester.

The tutorial (4) has four lessons that explore 1) the overall structure of a paper and the 2) Introduction, 3) Methods, and 4) Results sections. Sample screenshots from *lesson 2* are shown in Fig. 1. Sections in each lesson follow a progression of modeling, practice, and application. The first section of each lesson includes instructional content and examples that model how to read a scientific paper. For example, in the Introduction lesson, we provide information about scientific theories and hypotheses and an example of how scientific theories change over time. The example discusses "athletes' heart," an enlargement of the heart seen in many athletes, and describes how the understanding of this phenomenon has changed over time (26). The second section of each lesson encourages readers to reflect on the lesson's content by asking questions about a specific scenario. In the Introduction lesson, readers are asked to speculate about how scientists' understanding of the enlarged heart of athletes would influence the development of hypotheses. In the next session of each lesson, students take a multiple-choice quiz that asks them to analyze a section of a scientific paper. Students receive immediate feedback and can thus instantly identify lesson concepts that remain unclear. In the Introduction lesson, students are asked to read the introduction of a scientific paper (23) and answer questions about the major theoretical framework and specific hypothesis. The final section of each lesson is a homework assignment that requires short answers to questions about a different scientific paper. In the Introduction lesson, students answer questions about a paper describing the use of exercise as a countermeasure to the negative aspects of microgravity during space flight (24).

After completing the lesson, students have had three chances to practice paper reading skills: the reflection, the multiple-choice quiz, and the homework assignment. Activities are ordered in increasing difficulty so that students are asked to assume greater independence and critical thinking as they progress through a lesson. This tutorial

**Reading the Literature Homepage**

**Lesson 2: Introduction**

Page 1  
Page 2  
Reflection  
Quiz Yourself  
1 | 2 | 3 | 4  
Homework

**The Introduction section.**

**3 main questions are usually addressed in the introduction:**

- What is the major theory that frames the work being done?
- What research question is under investigation?
- What specific hypothesis (or hypotheses) is being tested?

To understand how these questions relate to each other, let's look at a classic diagram describing the production of scientific knowledge.

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graph TD
    Theory[Theory] -- Deduction --> CumulativeEvidence[Cumulative Evidence]
    CumulativeEvidence -- Induction --> Theory
  
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**Reading the Literature Homepage**

**Lesson 2: Introduction**

Page 1  
Page 2  
Reflection  
Quiz Yourself  
1 | 2 | 3 | 4  
Homework

**Quiz Yourself: Question 1**

The following question refers to the **introduction section** of the paper:

Mark A. Tarnopolsky, Carol Zawada, Lindsay B. Richmond, Sherry Carter, Jane Shearer, Terry Graham, and Stuart M. Phillips. Gender differences in carbohydrate loading are related to energy intake. *J Appl Physiol* 91: 225-230, 2001.

**Select the best answer to this question by checking the appropriate box.**

1. What major theory frames the work being done in this paper?

☐ There are gender differences in how human metabolism responds to endurance exercise.

☐ There are some important nutritional recommendations for athletes.

☐ Athletes use hexokinase and glycogen during exercise.

☐ Women do not efficiently carbo load because they eat less than men.

**Reading the Literature Homepage**

**Lesson 2: Homework**

Now, let's look at a different paper. The homework questions below refer to the **introduction section** of the following research paper.

Donald E. Watenpaugh, Richard E. Ballard, Suzanne M. Schneider, Stuart M. C. Lee, Andrew C. Ertl, Jacqueline M. William, Wanda L. Boda, Karen J. Hutchinson, and Alan R. Hargens. Supine lower body negative pressure exercise during bed rest maintains upright exercise capacity. *J Appl Physiol* 89: 218-227, 2000.

<http://jap.physiology.org/cgi/reprint/89/1/218.pdf>

Please answer the questions in the space provided, then print out this page and hand it in to your instructor.

1. What major theory frames the work being done?

2. What prior work supports the theoretical framework described in this paper?

design is based on other successful tutorials. For example, Leach (9) described a library instruction tutorial in which each lesson builds progressively in complexity: users are first shown how to accomplish a task, then they are led through the task, and finally they are asked to accomplish the task without help. To maximize the effectiveness of the Web-based format, we used appropriate images, adopted a conversational tone, and used succinct text.

Other authors have noted the importance of selecting appropriate primary literature for use in classes. For example, Muench (13) describes choosing papers with great care for her senior seminar in Evolutionary Biology. In our tutorial, we have carefully selected examples and research articles that are accessible to the nonscience major. For example, we used a paper on gender difference in sports nutrition for some of the tutorial's homework assignments (23). This paper covers a topic that engaged many of the students and created some controversy. Students were motivated to make critical analyses and to engage in spirited class discussion.

**Student involvement in the project.** We sought student feedback at several stages in the development of the tutorial, both during and after the web design stage. Students influenced aspects of the tutorial design, including navigation structure and aesthetics. A Kenyon College undergraduate edited each lesson, wrote portions of the Methods lesson, and contributed to this manuscript. This student also edited the tutorial text to be more accessible to students and identified concepts (such as "placebo" and "control group") that many students find challenging.

## RESULTS

**Classroom observations.** We implemented the tutorial in the Biology of Exercise course during a recent semester. Each Monday class meeting was devoted to examining the process of science and the primary literature of biology (Fig. 2). Students were assigned to read a lesson from the tutorial and to turn in the homework assignment for four separate class meetings. Other Monday class meetings were devoted to discussing aspects of the scientific literature without a supporting tutorial lesson. When a tutorial lesson was assigned, we began class with a discussion of the homework and then moved to another example intended to reinforce the principles of the lesson. For example, after we discussed the tutorial lesson on Methods, students were given a Methods section of another primary scientific paper. They worked in small groups to determine the experimental design and draw a timeline for the experiment.

Our experiences suggest that the tutorial greatly improved the relevant portions of the course compared with previous years. After using the tutorial, students came to class with a basic understanding of the material, and class time was spent answering student questions and completing active-learning exercises rather than introducing basic concepts. There was a tangible difference in the quality of class sessions supported by the online tutorial compared with the same sessions in previous years when the tutorial had not been used. When students were prepared by the online tutorial, our discussions moved directly toward critical analysis of papers and scientific information. We had time to perform active-learning exercises, providing an additional opportunity for students to practice critical reading

Fig. 1. Screen shots from the tutorial lesson about the Introduction section of a paper. *Top*: contents page. *Middle*: multiple-choice quiz. *Bottom*: homework. The full tutorial is at [http://biology.kenyon.edu/Bio\\_InfoLit/index.html](http://biology.kenyon.edu/Bio_InfoLit/index.html)



Fig. 2. Class sessions focusing on reading and analyzing primary literature during Biology of Exercise.

| Week | Topic   | Homework          | In-class active exercise  |
|------|---|-------------------|---|
| 2    | Introduction to the scientific process.                   | None              | Delayed onset muscle soreness (DOMS). Students propose different hypotheses for the development of DOMS and design experiments to test the hypotheses (7).          |
| 3    | Structure of a scientific paper and how scientists read.  | Tutorial lesson 1 | Athlete's heart. Students brainstorm about the factors, both scientific and social, that may have contributed to a different understanding of athlete's heart (26). |
| 4    | Literature searches. (This class was led by a librarian). | None              | Creatine sulfate. Students generate keywords and search strategies to find information of the benefits and risks of creatine sulfate supplementation.               |
| 5    | Introduction section: Hypotheses and theories.            | Tutorial Lesson 2 | Gender differences. Students develop hypotheses to explain differences in the trends of running world records in men compared to women (25).                        |
| 7    | Methods section and experimental design.                  | Tutorial Lesson 3 | Diagram methods. Students read a methods section and draw a timeline that illustrates the experimental procedure.   |
| 8    | Steps in the research process.                            | None              | Dietary supplements. Students brainstorm all of the steps in a research project that examines the efficacy of a dietary supplement.                                 |
| 10   | Results section and analysis of data.                     | Tutorial Lesson 4 | Drawing a graph. Students are presented with a set of data and construct graphs based on the data.  |

of papers. These observations support our hypothesis that the online tutorial enables more efficient use of class time.

**Feedback from students.** Anonymous written course evaluations at the middle and end of the semester asked students the following question: "How challenging is the material in this class?" Approximately 50 of the 60 enrolled students responded to each of the evaluations. Several students noted that the science content of the course was very challenging. However, students did not recognize the tutorial, the in-class sessions covering the process of science, or the Monday homework assignments as too challenging. In fact, several students even remarked that these parts of the course were not challenging enough. Although we plan to respond to this issue in future semesters, we find it interesting that nonscience majors claim no difficulties in completing assignments requiring them to read primary literature. Supporting these student comments, a review of answers to the homework questions indicated that students were able to complete the assignments successfully and generally understood the content of each lesson.

We also assessed the effectiveness of the online tutorial by carefully examining the students' project assignments. These assignments required students to read, interpret, and critique a scientific article (3). Nearly all of the students in the class (91%) accurately described a primary scientific article in their projects, and many students (41%) successfully critiqued a primary research article in detail. These observations support the hypothesis that, when provided with appropriate learning materials and classroom sessions, nonscience majors can readily learn to read, analyze, and apply the primary literature of biology.

**Integration with library instruction.** We found that the collaboration between a faculty member and a librarian led to effective pedagogical approaches and instructional materials. The bibliographic session was more effective because students were already familiar with the basic structure of a paper. Students were therefore better prepared to understand the intricacies of search strategies, and there was more time to answer student questions. Also, students chose better papers for their course projects than in previous years. This may have been because they were able to begin to make critical assessments of the articles during the search process.

## DISCUSSION

**How to find time for the primary literature.** Reading primary literature is an excellent tool for promoting critical thinking about science. However, faculty may be hesitant to include primary literature because it takes a large amount of class time to explain the structure of articles and appropriate methods for reading and evaluating the content that could otherwise be spent covering biology content. However, the apparent trade-off between teaching critical thinking and content may be misleading. Nelson (15, 16) argues that, when critical thinking is stressed, students are more enthusiastic, work harder, and even learn more basic content. Nelson also argues that students need appropriate support when they are asked to think critically.

We find that completing lessons in an online tutorial, followed by classroom sessions that include discussion and active learning exercise, is an effective and time-efficient means of

supporting the development of critical thinking about scientific papers. Because students use the tutorial outside of the classroom, we are able to use class time for discussion and active-learning exercises. Furthermore, students are held accountable for the content through the multiple-choice portions of the tutorial that enable students to immediately test their knowledge of the material and because printed homework sections of the tutorial are collected. Working on the tutorial outside of class allows students to review and consolidate difficult material and may be a useful “reality check” for students who think they already know the material. Because it is online, students can access the tutorial and review it in greater detail at any point throughout the semester. This availability is particularly beneficial for students desiring to review sections of the tutorial as they work on the final stages of the course project.

**Conclusion and future work.** Two conclusions arise from our work. First, we find that that college nonscience majors are capable of critically reading primary literature in biology, an observation that is consistent with the work of other college instructors (2, 27). Second, we find that an online tutorial is an effective mechanism for overcoming some of the practical difficulties of using primary literature in courses for nonmajors. The tutorial enables us to use class time efficiently, and gives students an opportunity to practice reading primary literature.

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