Getting Undergraduates to Critically Read and Discuss Primary Literature

Cultivating Students' Analytical Abilities in an Advanced Cell Biology Course

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Many undergraduates have limited experience reading scientific primary literature, although the ability to read and evaluate this form of information is crucial for their success in graduate school, medical school, or in the scientific work force.

For those students who do gain exposure to primary literature, their early encounters can often be bewildering and humbling. When reading articles on cellular and molecular biology, students confront a highly technical language that is quite different from what they have experienced in textbooks and popular reviews. They are often unsure how to approach reading these articles, let alone how to understand the information contained in them. I have found that when instructors provide undergraduates with guidelines indicating the points they should be looking for, not only are they capable of dissecting an original research article and comprehending the information held in it, but they can find this an extremely satisfying endeavor.

I recently offered an advanced cell biology course that had as its overall design the critical reading and examination of primary literature. The single most important aspect to getting students to engage in an active and meaningful discussion of journal articles was to get them to critically analyze each article *prior* to starting our dialogue. This was accomplished by providing students with guidelines for critically reading articles and requiring them to turn in a written critique of the article on the first day of discussion. The following is a description of the methods that I use to cultivate undergraduates' ability to read primary literature as part of a course that covers selected topics in cell biology through the review of current journal articles.

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COURSE STRUCTURE

Prior to enrolling in this course, students were required to have successfully completed cell biology, genetics, and physiology classes. These courses are required of all biology majors at our institution. The cell biology and genetics classes provide essential background information for students to understand advanced topics in cell biology. I chose to include physiology as a prerequisite because students in this course gain some exposure to primary literature and engage in a great deal of scientific writing.

On the first day of class, we arranged the seats in a circle so that all 16 students and the instructor could see each other. To facilitate the creation of a friendly and relaxed atmosphere from the very first meeting, I introduced all of the students, indicating their professional goals upon graduation and a few of their personal interests. I emphasized that the course would mainly involve discussion and described how their performance would be evaluated. I stressed that a

significant portion (*i.e.*, 25 percent) of their course grade would be based upon class participation and that the remainder of their grade would be determined by the quality of their written reviews of the articles that we would analyze (described below). This gave students a chance to drop the course if they felt uncomfortable with the format, although no student did. I also distributed copies of the first article and the guidelines outlining how the students should approach reading and writing about the article (**Figure 1**). I handed out each subsequent article two weeks before its discussion. Lastly, I made it very clear that I expected the students to review and/or seek background information independently prior to reading each article.

As one of the goals of the course was for students to learn about selected topics in cell biology, I wanted them to become aware of the "hot" areas of research in that field, especially since the majority of students had plans to attend graduate school in cellular and molecular biology, genetics, or biochemistry. Thus, when choosing the course topics, I examined programs of several different professional meetings on cellular and molecular biology and studied current issues of cell biology journals. Frequently, I selected several articles on a particular topic and then let the students decide which specific article to read and discuss so that they were involved in the process of article selection.

In addition, I strongly recommended that the students purchase *Molecular Biology of the Cell* by Alberts *et al.* (1994) or a similar graduate level cell biology textbook and read sections that were pertinent to the material covered in each article. I also gave the students a list of potential sources (*Cell*, *Annual Review of Cell and Developmental Biology*, *Advances in Cell Biology*, *Annual Review of Biochemistry*, and *Annual Review of Genetics*) of review articles, although I frequently provided reviews that would be useful for the comprehension of complex cellular processes.

The next three meetings in the course were devoted to covering methods that are extensively used to study cells and were utilized by the authors of nearly every article that we discussed. We examined this information in an informal lecture in which students were encouraged to actively participate. This not only provided the students with very important background information, but it also gave them time to read and review the first article. For subsequent articles, we explored additional, related methods in the class period just before our initial discussion of the article.

We usually completed the discussion of an article in three 80-minute periods. This schedule permitted us to analyze each article in-depth and to cover a sufficient number of journal articles during the semester. (The average length of the articles was 12 pages.) On the opening day of discussion, our dialogue centered on why the authors of our first article conducted their study. For background information, we turned to *Molecular and Cellular Biology* and related review articles, as well as details that the students and instructor gleaned from other sources. We then proceeded through the paper figure by figure, discussing the experimentation in each, the results that were obtained, and the authors' interpretation of these results. I encouraged the students to consider whether the authors' interpretations and conclusions were reasonable or if they felt that alternative explanations existed.

The article discussions concluded with a deliberation of how the study enhanced our understanding of cells and what studies should be done next to further this line of research. The students' written reviews of the articles should have addressed all of these points, and therefore each student was able to make meaningful contributions to our discussion.

Throughout the course, I encouraged students to ask questions both inside and outside of the classroom. I did not call on an individual to either answer questions or make comments unless I knew that the student could address a specific point. I tried to foster an atmosphere of trust so that the students felt comfortable to speak up when they did not understand a particular aspect of an article.

One advantage to the three-day discussion format was that some of the less confident students had opportunities to hear that nearly everyone had problems understanding some part of an article and they felt more at ease indicating this on the second or third day of discussion. Initially, the students would address their comments and questions to me, although I invited other students to answer these queries and respond to these remarks. Eventually the students directed their observations and questions to the entire group and we worked together to resolve points of confusion. In this environment of student-driven discourse, I tried to act more as a moderator and facilitator than as the leader of the discussion. However, I did make sure that essential points in each article were raised and that no one or two students dominated the exchange.

One unexpected but desirable outcome of the open atmosphere was that our discussions took unforeseen, student-driven directions. While I did try to limit the amount of time spent on these diversions, several valuable points were brought up regarding how science is done. Some of these topics were as follows: How are decisions made regarding authorship on articles? How expensive is it to carry out cellular and molecular research? Where do scientists get money to carry out their research? How competitive is it to obtain funding? How much time does it take to acquire the data that is presented in the articles we read? What does "data not shown" really mean? How was the

statistical evaluation of data carried out? I felt that it was important to spend time on these points because it enabled the students to gain valuable insight into the professional life of scientists, as well as how cellular and molecular biologists go about their work. Such information is not always shared with students, but should be if they are considering careers involving research.

GRADING METHODS

I determined the students' grades based on class participation and the quality of their written reviews. They received a separate grade for each of the eight articles we discussed. Class participation accounted for 25 percent of their grade and was decided by the instructor. I recorded the extent and quality of participation by each of the students immediately following each class meeting so that I could more objectively assign a grade. Because the group of students in this course was highly motivated and readily engaged in discussion, most of the grades were quite high.

The students' written reviews accounted for 75 percent of their grade. These reviews were due the first day that we discussed an article. My rationale for having the students turn in their reviews *prior* to discussing the article was to ensure that they made a *sincere* and *genuine* effort to comprehend the articles, allowing them to fully participate in the discussions. Most of the students (approximately 80 percent) participated every day.

The degree of participation by any given student varied from meeting to meeting, although five of the 16 students made considerable contributions on a daily basis. At the students' request, on one occasion I did not require a written review for an article; the students agreed to have their entire grade for that article based solely on class participation. The discussion of this particular article lagged and I had to pry information out of many of the students. While I believe that all of the students had sincere intentions to critically read the article, it was clear that only a few had. As a result, several students stated on the course evaluation that written assignments should *always* be required.

In their written reviews, I asked the students to address all of the points in the guidelines (**Figure 1**). I encouraged them to approach the "methods" and "results" sections of papers simultaneously by separately evaluating each of the figures in an article, asking what the purpose was of the experiment, what techniques the authors used, whether these techniques were appropriate to answer the question at hand, what results were obtained, and whether the results supported the authors' hypothesis.

At the beginning of the course, the

Figure 1. Guidelines for Preparation of Written Article Reviews

The following are guidelines to assist you in reading and writing reviews of the journal articles that we will be discussing in this course. Please note that you should feel free to work with others to prepare your reviews. However, the review that you turn in must be in your own words. A high degree of identity between article reviews will not be acceptable and will result in a failing grade for those reviews in question. The review of an article will be due on the first day that we discuss that particular journal article. I suggest that you make two copies of each of your review; one to be handed in and graded and the second to have at your disposal in class during discussion. Your review must address the following:

1. Why was the study done? Summarize the relevant background information to demonstrate that you understand why the study was done. Explain the investigators' working hypothesis and the predictions that the investigators made based upon that hypothesis.

2. What techniques/experimental procedures were used to collect results? Why were the techniques used valid for the type of information the investigators wanted to collect?

3. How was the study done? For each of the figures and tables that include experimental results, describe the experimental design. What were the controls that were used? What was the purpose of using each of these controls? Are there any other controls that would have been useful to include?

4. What results did the investigators collect? For each of the figures and tables that include experimental results, describe the results that were collected. What do these results suggest? Do they support the investigators' hypothesis? Why or why not?

5. For informational diagrams, explain why the diagram was included in the article. What does the diagram demonstrate? How does it enhance the reader's understanding of the article.

6. What conclusions did the investigators reach based upon their data? Are there viable alternative interpretations of their data? How do these new data influence and relate to the literature in this field? In other words, how does this study fit into the "big picture" of cell biology?

7. Please do not feel that you are limited to only addressing the above points.

students were anxious about writing these reviews without necessarily understanding all that was in the article. I had to stress to them that their grade would be based on their demonstrated effort to comprehend the material, and not whether their understanding was correct. I also asked the students to include their own interpretations of the material in their reviews. I reassured them that the detailed discussion of the article would clarify misconceptions and the synergism of the group exchange would enhance each person's comprehension level. Indeed, aspects of an article that were unclear often drove the class discussion. Only after the students had written reviews of the first few articles did they begin to feel comfortable with this method of evaluation. While the students did indicate that the preparation of these reviews was extremely time consuming, they also felt that it really forced them to closely examine the articles and prepared them for discussion.

Figure 2. Student Evaluation of Course using the IDEA Form Survey[a]

Summary Profile	All Courses[b]	Similar Courses
Overall Evaluation (progress on relevant goals[c])	97	95
Improved Attitude toward Field	98	92
Would Like to Take Instructor Again	98	96

[a] The results represent the responses of all 16 students enrolled in the course.

[b] "All courses" refers to all courses in the IDEA Form national database. "Similar courses" compares survey results to those courses in a national database with similar class size and student motivational level. Numbers represent percentile ranking.

[c] The relevant goals for this course included 1) learning how cell biologists go about gaining new knowledge; 2) developing skills, aptitude, and points of view needed by the cell biologists; and 3) improving oral and written expression.

Student Response to the Course

The students evaluated the course near the end of the semester, both by answering open-ended questions and a standardized evaluation form (IDEA Form Survey, Center for Faculty Evaluation and Development, Kansas State University). The results of these evaluations were very positive. Figure 2 shows a summary profile of the student responses on the IDEA Form survey. Overall, the students liked the format of the course and felt that their critical reading, writing, and analytical skills improved due to their experience in the course. They also felt that the written article reviews turned in before the discussion were essential to helping them read and critique primary literature.

Several students indicated to me that the course helped them tremendously with their undergraduate research. Not only did they feel that they became better readers of primary literature, but they felt that their ability to design their own experiments and interpret their own data improved. Some of the students used research methods that were employed by the authors of the articles we read. Often, the course helped students understand these methods more fully and to gain exposure to different applications of these techniques.

The format of the course allowed students to work cooperatively, both inside and outside of the classroom. Important points and valid criticisms were raised in the class that clearly came from out-of-class discussions among students. Thus, these out-of-class meetings were useful, productive, and enhanced our in-class dialogue. The course was also designed so that students could contribute their own unique knowledge of the topic. For example, one of the articles that we discussed dealt with cancer biology. Two of the students in the course had previously worked with cancer patients at a local hospital and were able to make insightful comments based upon their experiences, strengthening our overall understanding of the article.

An extremely important outcome of the course was that the students gained confidence not only in analyzing primary literature, but also in their ability to reason, research, and apply knowledge. Our discussions revealed that all of the students, and occasionally the instructor, had difficulties comprehending certain aspects of an article. The students who were less confident in their abilities could readily see that reading journal articles was not just difficult for them; it was a challenge even for those with more research experience and/or an advanced degree.

Many of the students became more self-assured as they acquired the experience and knowledge to understand state-of-the-art research in cellular and molecular biology, as well as to recognize limitations to certain methods, how and whether data were analyzed correctly, and whether the overall design of an experiment was satisfactory. The students expressed a tremendous amount of personal satisfaction in these accomplishments.

Reference

Alberts, B., D. Bray, J. Lewis, M. Raff, K. Roberts, and J.D. Watson. 1994. *Molecular Biology of the Cell*. 3rd ed. New York: Garland Publishing, Inc.