Assessment of student understanding of primary literature in Bio Sci lab courses and methods to enhance this learning – Brian Sato, Pavan Kadandale Final Report

Abstract

The ability to read and critically analyze primary literature is a key learning outcome for our department's majors. While the use of scientific papers is common in many Biological Sciences lecture and lab courses, many students find this aspect of the curriculum difficult to master. This assessment program is geared towards determining the degree to which undergraduates in biology lab courses are capable of understanding primary literature and whether variables including previous research experience, study method utilized, or open versus closed note testing, among others, affect performance on a paper related exam.

Introduction

Over 90% of fourth year Biological Sciences majors claim that scientific literature has been incorporated into at least one of their previous courses. Despite this, it is clear from classroom discussions and talking to students in office hours, that this skill is poorly developed. This is not surprising, as there is little in the means of formal training that currently exists to teach students how to read papers. Accordingly, many students approach a scientific paper similarly to how they approach a textbook, and while this allows for the memorization of a handful of key facts, little is accomplished in terms of higher order analysis.

To improve on our students' abilities to read scientific literature, we have incorporated papers as a major component of the upper division laboratory curriculum in the Molecular Biology and Biochemistry (MB&B) department. These labs include Bio Sci M114L (Biochemistry lab), M116L (Molecular Biology lab) and M118L (Microbiology lab), which are offered at least three academic quarters per year with course enrollments ranging from 40 to 160 students per quarter. The following system has been established in each course:

- Three paper are assigned during the quarter, the first two are discussed as a class and comprehension of the third is measured through a paper quiz
- Two methods to approach the papers are introduced:
    1. Students answer 4 questions regarding each figure
        (a) Why was this experiment performed?
        (b) How was this experiment performed?
        (c) What were the results of the experiment?
        (d) What conclusion is drawn from these results?
    2. Students write summary paragraphs regarding each figure

Assessment of student learning and critical thinking abilities occurs through the paper quiz, administered at the end of the quarter. The paper quiz contains questions from all Bloom's levels, requiring students to recall basic facts from the paper, draw conclusions from figures, and speculate on the outcome if various alterations were made to the experimental methods. Student performance is then compared across a variety of parameters related to student background and test taking conditions. In this way, we are able to measure our students' abilities and then determine how to increase proficiency in this task for future Bio Sci majors.

Results

This assessment took place during the 2013-14 academic year in the courses mentioned above. Study data was analyzed by course instructors, Dr. Brian Sato and Dr. Pavan Kadandale, with the assistance of two Bio Sci undergraduate readers, Yama Latif and Paige Murata.

Student Performance by Bloom's Level

Exam scores were analyzed both in terms of overall test performance as well as by sorting questions by Bloom's level. Bloom's Taxonomy characterizes the different types of learning students can demonstrate. Bloom's levels 1 and 2 correspond to questions that involve recall of information, while higher order Bloom's questions require students to synthesize novel conclusions based on presented material. Not surprisingly, student performance was highest on the recall questions (Figure 1). This is likely due to the fact that these are the types of questions they have become accustomed to from early education through most of their undergraduate career. While instructors want to see critical thinking from their students, exams often contain primarily memorization-based questions. This result highlights the fact that classroom assessments need to correlate with the established learning outcomes.

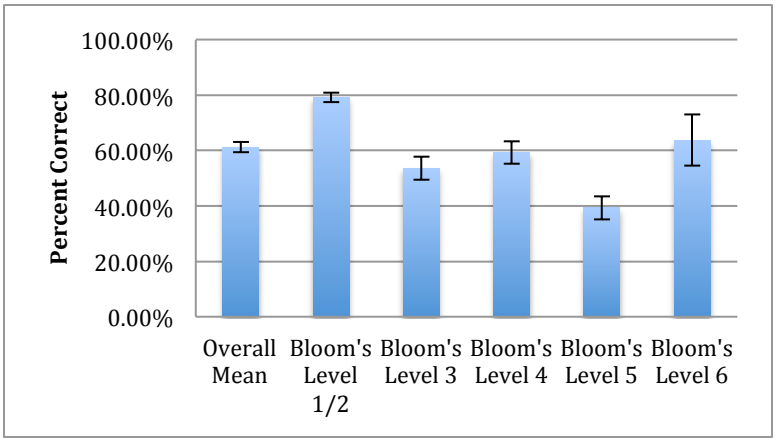

Figure 1. Average scores on the paper quiz and on questions separated by Bloom's level. The above numbers represent data from all 9 courses included in the assessment. The standard error of the mean is indicated.

Open versus Closed-Note Testing

Since in-depth analysis of a paper requires students to think beyond the presented text, we wanted to determine whether having that text during the paper quiz was an advantage. We set up two distinct parameters for this assessment:

1. In each course, half of the class was allowed to have the paper with them during the quiz, while the other half was not. This was decided randomly and students were split based on lab section.
2. The Bio Sci M114L and M118L courses took non-paper quiz exams in a closed-note fashion. This is in contrast to the Bio Sci M116L course, where all of the exams were open note. We hypothesized that students who consistently took exams open note would be negatively impacted when reverting back to a closed note testing setting.

Overall, student perception was skewed towards the idea that the open-note takers would have an advantage. When asked, "What section will have the higher mean?", 53% of respondents answered open note, 11% responded closed note and 36% believed that there would be no difference. This was despite the fact that when presenting the open versus closed

scenarios, we ensured students that the quiz would measure understanding and not memorization, and that having the paper would provide no significant advantage.

From Figure 2, it is clear that taking the exam with the paper did not increase student performance. In addition, there was no difference for any of the Bloom's levels (data not shown) in the open versus closed note scenarios. There was also no significance whether or not students had taken other exams throughout the quarter open or closed note. Student performance on the paper quiz was the same in the M116L courses, despite the fact that they had become accustomed to taking open note exams.

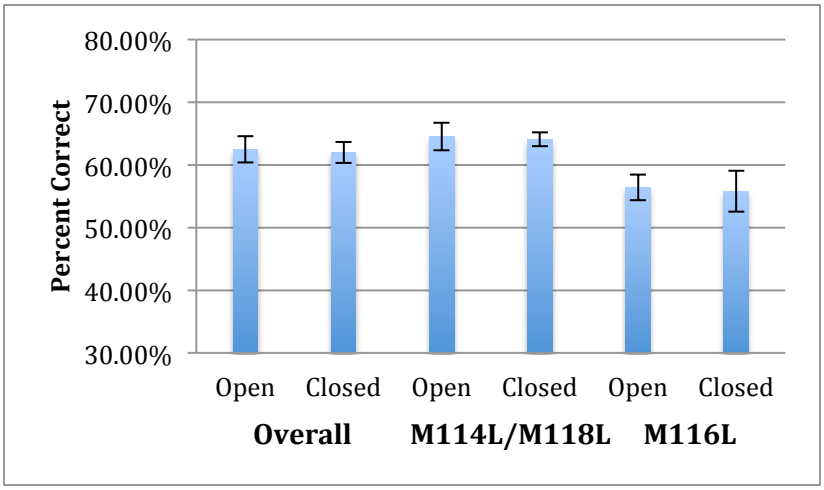

Figure 2. Average scores on the paper quiz sorted by open versus closed note testing. Students in each class were assigned either open or closed note testing conditions. In M114L and M118L, all other exams were closed note. In M116L, all other exams were open note. All differences are statistically insignificant as measured by t-test with a p value > 0.8. The standard error of the mean is indicated.

Study Method

Students were free to prepare for the paper quiz in any manner. They were encouraged to use the two methods introduced earlier in the quarter (four questions or summary paragraphs for each figure), but could also decide to study in their own way. To determine whether either of the prescribed methods resulted in increased comprehension of the paper, students self-reported their means of study.

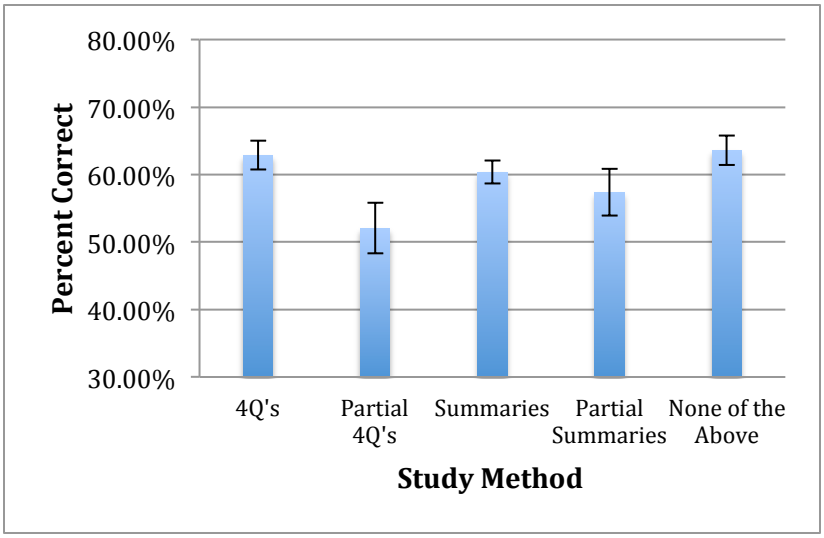

Figure 3. Average scores on the paper quiz sorted by study method. Students self-reported whether they prepared by using the 4 question method for each figure, wrote summary paragraphs for each figure, or neither. There was also a fraction of students who used the two prescribed study methods for only a fraction of the figures (partial). The decreases in the partial conditions are statistically significant compared to "none of the above" as measured by t-test with a p value < 0.05. The standard error of the mean is indicated.

As can be seen in Figure 3, using either of the prescribed study methods did not provide an advantage compared to students who studied in their own manner. There was though, a statistically significant decrease in quiz scores for students who only partially used either study method. These students may have been disorganized in their study, implying that a lack of a concrete plan to tackle the paper resulted in decreased comprehension. It also may illustrate the need to examine a paper as a whole, as each article is a complete story, and concentrating on one or two figures will not translate to a comprehensive understanding.

Overall Course Grade

The ability to successfully read and analyze a scientific paper requires skills that are also used for evaluation of data and scientific writing, both of which are also assessed in our laboratory courses. We speculated that students who perform highly on the paper quiz will also tend to perform well in the courses overall. From Figure 4, it can be seen that there is a strong correlation between overall grade and the ability to comprehend a scientific paper, despite the fact that the paper quiz is worth only 10% of the final grade. Further analysis needs to be performed to determine whether the skills used for paper reading are the main cause of this trend, or whether it is a matter of better students performing well on all assignments.

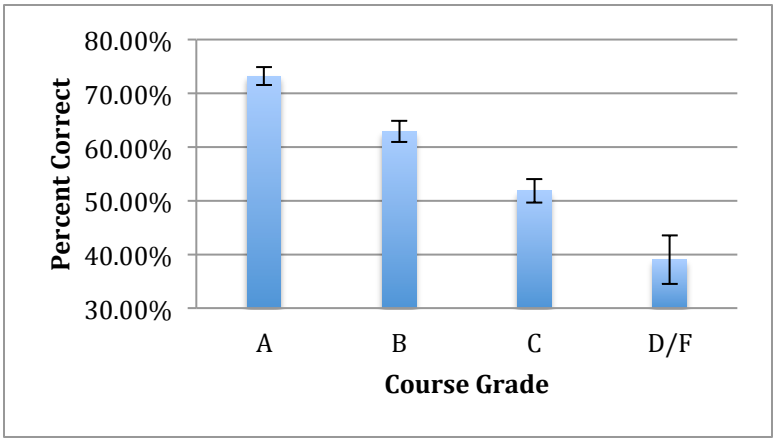

Figure 4. Average scores on the paper quiz sorted by overall course grade. Student paper quiz scores are displayed based on the final grade earned in each course. The results are statistically significant as measured with a one-way ANOVA test with a p value < 0.0001. The standard error of the mean is indicated.

Independent Research Experience

Nearly 2/3 of Bio Sci majors are involved in independent research at some point during their undergraduate career. While the quality of these experiences varies for each, we would expect that more exposure to the scientific method should produce an increased familiarity with and ability to read primary literature. We asked students to self-report their research experience, either in basic research that would be related to the molecular biology, biochemistry or microbiology topics discussed in the lab courses, or medical research, which is somewhat less connected. Students with a basic research background earned scores that were statistically higher than students with medical research or no past research experience (Figure 5). This confirms the value of student involvement in research projects, and that despite the lack of standardized assessments for independent research programs, students on average are benefiting from the experience.

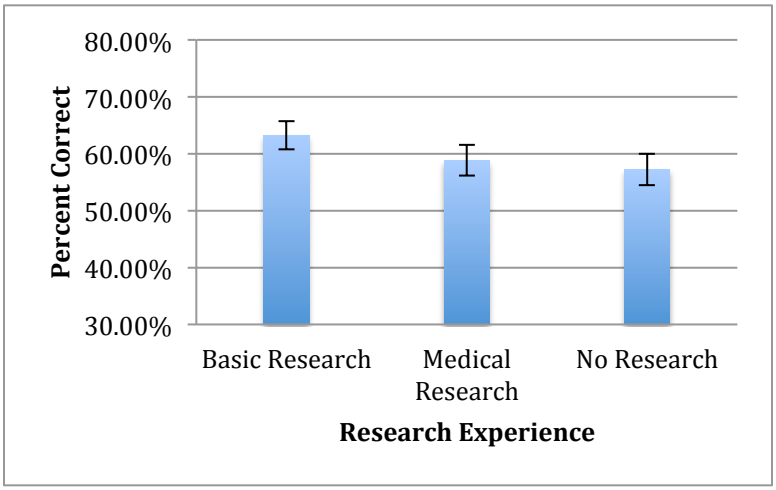

Figure 5. Average scores on the paper quiz sorted by independent research experience. Student paper quiz scores are displayed based on student self-reporting of their previous research experience (at least 1 year). Students who have basic research experience performed statistically higher than students with medical research or no research experience as measured by t-test with a p value < 0.05. The standard error of the mean is indicated.

Students Enrolled in Multiple MB&B Lab Courses

While the study techniques we proposed did not result in higher paper quiz scores, we wondered whether the increased focus on primary literature in the lab courses improved the students' abilities to read papers. To examine this, we separated students in the winter and spring courses by those who had or had not taken Bio Sci M114L, M116L or M118L in a previous quarter. Figure 6 shows that students who had enrolled in an MB&B lab in a prior quarter did perform higher on the paper quiz compared to their peers who had not (Figure 6). This illustrates the importance of spending class time to walk students through papers, rather than assuming they can perform this analysis on their own. Like many academic tasks, the ability to critically read primary literature can only be built through practice and repetition, but this must be a guided process. Without the proper foundation, students cannot be expected to understand what to focus on in a novel activity.

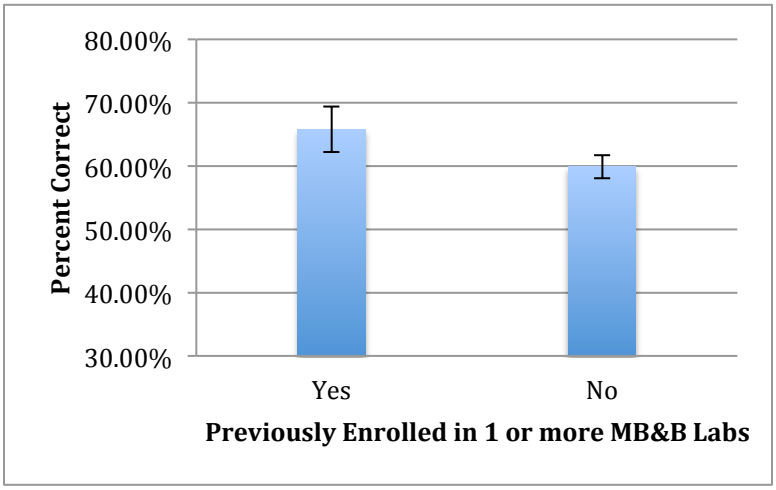

Figure 6. Average scores on the paper quiz sorted by those who have previously taken an MB&B lab course. Student paper quiz scores are displayed based on student self-reporting of their previous research experience (at least 1 year). Students who have basic research experience performed statistically higher than students with medical research or no research experience as measured with a t-test with a p value < 0.05.

Future Directions

Based on this yearlong assessment, it is clear that there is value to training students how to acquire knowledge from the published literature. Merely describing a significant finding in lecture can often obscure the connection between this information and the scientific method. We will continue to include a similar multi-paper system in future lab courses and hope to expand these to other courses both within the department and the School of Biological Sciences as a whole. As most upper division classes spend at least some time on primary literature, such benefits will not be restricted to a single course.

While we were able to demonstrate an increase in primary literature comprehension in our lab classes, such positive attributes may be limited in scope since most students taking lab courses are in their 4th or 5th years. Thus, it may be too late to have an impact on the majority of the upper division courses these students will enroll in. To solve this problem, Dr. Sato and Dr. Kadandale have formed a new course, Bio Sci M126 (Primary Literature in Molecular Biology and Biochemistry), starting in the fall quarter 2013. This course will focus entirely on reading papers and is geared towards students who have just completed the lower division biology core curriculum after their 2nd year. We will conduct an additional assessment with these students to determine learning gains based off of practices used in the class and follow their progress longitudinally to ascertain whether students who successfully complete our course perform better in their upper division classes.