Embedded reporters: Incorporating assessment into the core Biology curriculum for continuous, sustainable monitoring of student learning.

Abstract

We have recently introduced numerous changes in single sections of the core Biochemistry (Bio98) and Molecular Biology (Bio99) courses which have resulted in increased student learning and critical thinking compared to the traditionally taught sections. The purpose of this grant is to incorporate these changes into all sections of these classes, to develop a unified set of learning outcomes for all sections, and to design common assessments that can be used in these courses sustainably. Based on the data from these assessments, we can design specific interventions to maximally achieve our learning outcomes.

Introduction

The core Biochemistry (Bio98) and Molecular Biology (Bio99) courses lay the foundation for an understanding of the processes of life at the molecular level. They are also expected to serve as an introduction to the scientific thought process, and its application to furthering our understanding of biology through rigorous experimentation. With the exponential increase in the breadth of knowledge that students are required to know in these course, the challenge has been to balance knowledge transfer and critical thinking. The problem is further exacerbated by increases in class sizes and the decreases in the instructor:student ratio. One solution is to use a blended model, in which student responsibility for content acquisition is increased, so that class time can be spent on application of concepts and data analysis problems. By increasing the structure of the class, and including numerous formative assessments, we can ensure that students keep up with the required readings, and are better prepared for the in-depth class discussions. Our preliminary data indicated that implementation of some of these strategies in one section of Bio98 (Winter 2013) and Bio99 (Spring 2013) resulted in a marked improvement in both student learning, and higher order thinking. However, there were other differences between the classes (most notably, single instructor versus multiple instructors in each section), and we do not know what effect these had on student learning. Thus, we extended our increased structure model to all three sections of Bio98 and Bio99, and assessed learning gains in all sections, independent of the instructor(s) teaching the different sections. We designed these assessments to be part of the regular course, so that we can also rigorously assess future changes to these courses. The embedded assessments that we have developed are:

1. A set of iClicker questions that are administered in class and in weekly discussion sections that cover a variety of topics based on the learning goals for the class. In addition, the questions span different Bloom's levels (which correlate with different levels of higher order thinking), so that we can assess student performance at different thinking levels.
2. A set of pre-lecture, online quizzes that will be taken by students prior to each lecture. These consist of a variety of question types, including multiple choice, single word fill-in-the-blanks, rank ordering, sorting, etc.
3. A set of weekly homework assignments. These are more in-depth than the pre-lecture quizzes discussed above, and require students to apply and integrate concepts across all the topics covered in that week.
4. A multiple choice test that is administered in Week 9 discussion sections as a surprise quiz. This assessment tool also gives us an idea of learning retention, since it will be a surprise quiz, and students have not studied for it. In addition, it also helps us identify topics with weak learning gains. Finally, the assessment tool we developed for Bio99 also contained questions relevant to Bio98, so we can assess long-term retention of concepts, at least for Bio98.

Overall, the combination of these tools will allowed us to measure student learning of specific topics, learning at different Bloom's levels, learning of a specific topic at a specific Bloom's level, and also to track learning temporally, since we can compare performance for a specific topic using the iClickers with performance for the same topic in the surprise quiz and the final exam.

Results

This assessment took place during the 2012-14 academic years in the Bio98 and Bio99 courses. Study data was analyzed by course instructors, Dr. Brian Sato and Dr. Pavan Kadandale.

For all data presented below, the "High structure" section (HS) refers to the section of Bio98 taught by Dr. Kadandale, and the Bio99 section taught by Dr. Sato. The "Low structure" sections (LS) are the other two sections that were co-taught by different instructors.

Increasing structure increased student learning

Based on data collected in Winter and Spring 2013, we refined the structure of the existing Bio98 and Bio99 courses, and also adopted the increased structure format in all sections of Bio98 and Bio99. Using the embedded assessments, we saw an increase in student learning (Figure 1), not only in the HS sections (where we had improved the course structure), but also in the LS sections (where we had introduced the high structure format). This leads us to believe that increasing the

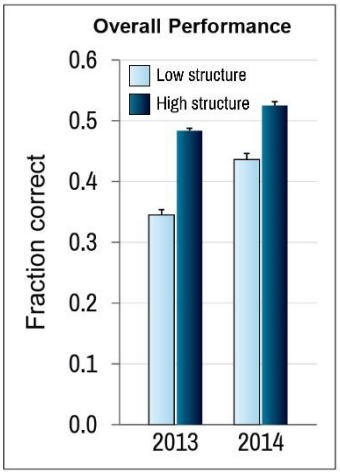

Figure 1: Increasing structure increases student learning, independent of instructor and class. Data shown is fraction correct on assessment for Bio98 and Bio99 combined.

course structure has a positive impact on student learning, irrespective to the instructors teaching the course.

Increased structure increased student performance at lower and higher Bloom's levels

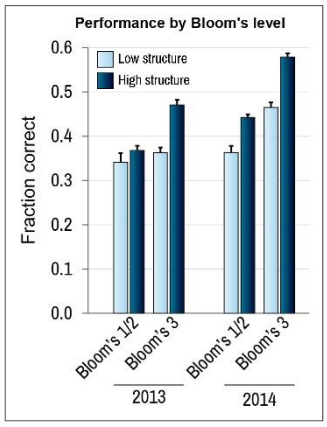

Figure 2: Increasing structure increases higher order thinking skills. Data shown is combined across Bio98 and Bio99.

Comparing student performance at lower Bloom's (1/2) and higher Bloom's (3), we see that the improvements we made to the courses increased student performance at both levels, across subjects (Figure 2). We did not measure performance at Bloom's higher than 3, since the embedded assessments which needed to be automatically graded could not have questions that we could reliably classify as higher Bloom's levels. What is particularly noteworthy is the improvements made in the "Application" level of Bloom's (level 3). One of the main reasons for our redesigning the courses was to improve student critical thinking skills, and one aspect of critical thinking is the ability to apply theoretical concepts. Based on our data, we conclude that the increased structure that we have introduced does improve student higher order thinking (at least at Bloom's level 3).

Long term effects of increased structure

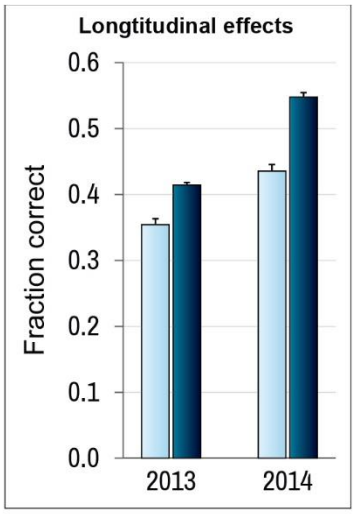

Figure 3: High structure classes have long term benefits for student learning. Pale blue bars represent performance of students in Bio99 who had taken a low structure section of Bio98, while the dark blue bars represent performance of students in Bio99 who had taken a high structure section of Bio98.

Students who took the different section of Bio98 would then disperse relatively randomly into the three sections of Bio99. Thus, each section of Bio99 consisted of a mix of students from the HS and LS sections of Bio98. This allowed us to compare the performance of students in all three sections of Bio99 based on which Bio98 section they had taken. If high structure classes had long term benefits, we would expect that irrespective of which Bio99 section they ultimately end up in, students from the HS section of Bio98 should outperform their classmates in that section of Bio99 who had come from the LS sections of Bio98. Indeed, we found that this was the case (Figure 3), leading us to conclude that high structure classes have positive, long-term impacts on student learning.

Future directions

Based on our data, it is clear that the increased structure format that we have developed for Bio98 and Bio99 has a positive impact on student learning. The various assessments that we have embedded in the redesigned courses provides us with valuable information that we are further analyzing to introduce the next round of improvements to our courses. Questions that we would still like to answer are whether specific topics require more attention, how we can further refine the implementation of the high structure model, and how we can further improve our existing assessment tools. However, the changes that we have made, and the assessments that we have developed thanks to this Assessment Grant have gone a long way in improving the Bio98 and Bio99 courses. Embedding these assessments into our courses means that we now have a way to check for the effectiveness of future interventions and changes to our courses.