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Integrating authentic, inquiry-based lab activities in a large GE biology course to enhance student understanding and attitudes towards the process of science. (Faculty Learning Community on Large-Lecture General Education, 2012)

I. Project background

Biology 156, Plant Biology, is a large lecture (140-150 students) course with accompanying lab sections (typically six sections of 24-25 students). The students enrolled in the course are typically pursuing majors outside the STEM disciplines, and apprehensive about the subject matter. A major problem that I perceived with this course is that the laboratory sections were designed to supplement, as opposed to reinforce, the content covered during lectures. In addition, the lab consisted primarily of “cookbook” style activities that failed to expose students to the creativity and genuine sense of discovery associated with authentic research experiences. Related, but separate, challenges with this course included students’ often poor performance on examinations and the lecture-centric format of course content delivery.

This project’s main objective was to restructure and align the lecture and lab sections of this course so that students could better develop an understanding of the process of science. Specifically, the aim was to develop students’ competency in several key content areas and improve their self confidence as scientifically engaged citizens so that they could successfully complete a culminating independent research project that required them to make observations and ask questions based on their observations, evaluate evidence to form conclusions, and critically evaluate the conclusions drawn by others based on available evidence. Through this culminating research activity and its associated content, I also hoped to increase students’ appreciation of the role of plants in their daily lives, and the links between plant biodiversity, cultural integrity, the environment, and human health.

II. Project elements

To address the essential problems of this course, my project focused on re-designing the course laboratory and accompanying laboratory manual to: (1) reinforce knowledge and attitudes presented in the lecture section of the course; (2) provide a succinct source of content appropriate for the course and thus free up time and resources for increased active learning during lecture periods; (3) engage students in the scientific process through a scaffolded research project that built from understanding evolutionary diversity and interpreting phylogenetic tree diagrams to identifying fruits and vegetables to formulating original research questions based on available class data. These three elements of the project are discussed in more detail below.

1. The laboratory manual and course lectures and associated lecture activities were aligned so that each week’s lecture content was reinforced by the readings and activities in the lab manual. The course was reorganized around a limited number of key content areas, specifically: 1. photosynthesis and its role in the history of life on Earth; 2. plant growth and organization; 3.
plant reproduction and life cycle; 4. inheritance; 5. plant evolution and interpreting phylogenetic trees; 6. plant secondary chemicals and their influence on human health; 7. food environments and human health; 8. agriculture; and 9. gardens and horticulture.

2. The ten-week format of this course constrains the breadth of content areas it can effectively cover. For this reason, selecting an appropriate and affordable textbook for the course is challenging, as most quality general plant biology texts for non-majors are far too comprehensive, and thus expensive. In the past, very few students actually purchased the textbook, even when a custom version (with some irrelevant chapters removed) was adopted for the course. All students in the course must purchase a (relatively inexpensive) lab manual, however, since it contains worksheets and other materials that are turned in for credit during the lab sections. With this dynamic in mind, I decided to eliminate a required textbook for the course, and instead supplemented the lab manual with extra content, including more explanatory text within actual lab activities as well as separate readings to clarify more conceptually complex topics covered in the lecture (e.g., evolutionary trees, phylogenetic diversity, and photosynthesis).

3. The final four laboratory activities were designed to provide a culminating authentic research experience related to the issues of phylogenetic diversity, plant secondary chemistry, and food justice. After learning about the health benefits of diverse plant secondary chemicals like antioxidants, students were introduced to the topic of phylogenetic diversity and learned to assess phylogenetic diversity using common fruits and vegetables (during previous years teaching this course, it became clear that many of the students were unfamiliar with even the most seemingly prosaic fruits and vegetables). Students were then tasked with surveying all the fresh fruits and vegetables available at the produce-selling store closest to their residence. During the next lab, all students entered their fruit and vegetable survey data and store/locality information into a class database, and I generated a phylogenetic tree representing the evolutionary relationships of each store’s available fruits and vegetables, along with a metric that expressed the individual stores’ overall evolutionary diversity of available fruits and vegetables. The entire class data set was then provided to the students, and one lab section was devoted to developing original research questions that could be addressed with the data available in the class data set. This approach to conducting research using existing data is becoming increasingly common in the current age of genomic data, where the focus has shifted from obtaining data to answering original questions using existing data. Students were explicitly reminded that this approach to scientific research mirrored the actual process of inquiry currently utilized by many scientists.

III. Project outcomes
Qualitatively, the changes to course content and structure that were implemented through this project seemed to have a positive effect on the course overall. Attendance during lectures was much higher throughout the quarter than in previous years teaching the course, and students were more inclined to ask questions or contribute their ideas during class discussions.

To assess any changes in student attitudes towards science, I administered entrance and exit surveys using a modified version of an established tool, the Views About Science Survey (VASS; Halloun, 1997; Halloun & Hestenes, 1998; Halloun 2001). The 14-question scantron survey (IRB 12-12X, exempt) was administered during the first full week of lecture (Sept. 27, 2012) and during the final week of lecture (Dec. 29, 2012).

The VASS instrument differs from a typical Likert scale in that it requests that students identify their position with respect to two contrasting alternatives. For example, a question might be posed as:

My science course covers:
(1) abstract themes.
(2) practical themes.

The student would then decide to what degree they agreed with alternative (1) versus alternative (2) using the following scale:

A. My science course covers mostly abstract themes and rarely any practical themes.
B. My science course covers more abstract themes than practical themes.
C. My science course covers as much abstract themes as practical themes.
D. My science course covers more practical themes than abstract themes.
E. My science course covers mostly practical themes and rarely any abstract themes.

At entrance, 104 surveys were completed and 98 surveys were completed at exit. Of the 14 questions in the survey, 12 were selected for further analysis (one question, related to when students studied course materials, was deemed inappropriate; the other question was not related to science attitudes and was only inserted to test for the consistency of responses). For each survey, I calculated number of student responses (A – E) for each of the 12 questions. For each survey, the number of responses to each question was divided by the total number of surveys.
completed to produce a standardized percentage for comparison between the two surveys. For some questions, A (alternative 1) represented the most desirable attitude, whereas E (alternative 2) was most desirable for other questions. I first standardized all the questions (reversed answers A and E, B and D) so that all the question responses reflected a consistent scale from most to least desirable (A = best; B = second-best; C = neutral; D = second-worst; E=worst). Next, I compared number of responses from each category, A-E, between the entrance and exit surveys using two-tailed paired t-tests, to determine whether number of responses to each category significantly increased or decreased between the two surveys.

In this analysis, two response categories showed significant shifts between the entrance and exit surveys. The number of student responses in the most desirable attitude category, A, significantly increased between the two surveys (p = 0.0025), and the number of responses in the neutral category, C, significantly decreased between the entrance and exit surveys (p = 0.018). Numbers of responses in the second-best and two undesirable attitude categories did not change significantly between the two surveys.

To assess the impact of the course changes on student mastery of course content, I compared student’s answers to questions on the final exam from a previous year’s course to student’s answers from the current year’s modified course. Ten questions were selected from the two years’ tests that all addressed the same course learning outcomes: Evaluate the connection between plant secondary chemicals, food, and human health; predict the health effects of cultural assimilation and loss of traditional dietary practices. The number of learning outcomes for comparison was restricted to those that were covered in both years’ final exams, since only final exams were available for comparison from the previous course. Numbers of correct responses to each question were compiled from both years’ exams, and each number of correct responses was divided by the total number of students taking the exam in a given year to produce a percentage correct responses for comparison between years. A two-tailed t-test was then performed to compare each year’s correct responses, indicating a significant increase in the percentage of correct responses to questions under the modified course design compared to the previous year’s course (p = 0.031).

IV. Project summary

Overall, the results of this project were encouraging, as my own anecdotal evidence and the survey data both suggest that the modifications to Biology 156 improved student performance and attitudes towards science. I plan to use the feedback and evidence from this year to further improve this course in the future. For example, with more time I hope to expand upon some of the topics I cover in more depth in the lab manual, particularly plant growth and organization and plant reproduction, as these content areas remain difficult for students to master. I also plan to apply for a short-term visitor grant through the National Evolutionary Synthesis Center, with the intent of leveraging the expertise of its informatics staff to develop a more seamless web interface that pipelines the analyses required for the fruit and vegetable diversity project. Hopefully, with such an
interface in place, it will be possible to implement this culminating research project across multiple offerings of this and other courses and increase student awareness of the connections between evolutionary diversity, environmental justice, and their own health.
Literature Cited:

