Development of a year-long, research-based laboratory integrated within core genetics and cellular & molecular biology courses

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Abstract

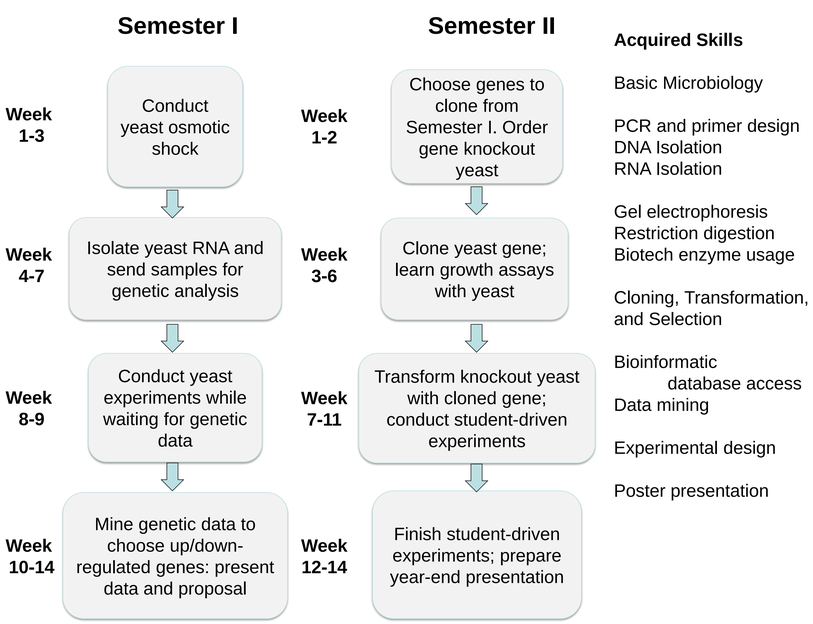
This study details the assessment of a novel year-long, research-based major core laboratory curriculum completed by biology majors at Pace and LaSalle Universities during the 2013-2014 academic year. In the first semester, students conducted and analyzed microarray data to study the effects of osmotic stress on the yeast transcriptome. Students generated hypotheses on the roles of various affected genes. The following semester, students cloned candidate genes, designed and conducted cell-based functional assays using knockout yeast and overexpression studies to test their original hypotheses. We hypothesized that the year-long program would enhance the students' biological literacy skills and their aptitude and appreciation for the process and practice of science. To assess this, we administered two validated concept inventories (CI) in a pre- and post-test format. We compared student performance on the CI to the course grades the students earned. Next, the students took the ETS Major Field Test in Biology (MFT). The scores earned on the MFT were compared between students that had and had not taken the year-long program. Finally, the students participated in the CURE survey to help us determine the students' perceptions of the impact of the program on their interest/aptitude for research. The CI/course grade analysis showed that the "weaker" students in the first semester made the greatest gains on the CI. They also performed just as well as the "stronger" students on the assignments in the second semester (n=16). The MFT results indicated that the difference between the molecular biology/molecular genetics assessment indicator (AI) score approached significance (p=0.0556, U=13.5, n=9) where the students that took the year-long program performed better. Of the 22 questions about science on the CURE survey, the students indicated increased, statistically significant attitudes on 16 questions. These findings suggest that the program had several positive impacts on the students and we are hopeful that these observations will be strengthened upon inclusion of our 2014-2015 data.

Introduction

The emergence of new disciplines within biology, such as genomics, bioinformatics, and systems biology, signal the transformation of biology into a dynamic, interdisciplinary science. In response, national calls have been made to similarly transform undergraduate biology education to increase interest and appropriately prepare students for successful careers in biology. A conserved feature of recommended reforms is an emphasis on active, inquiry-based learning to highlight the process and practice of science (*Vision and Change: A Call to Action in Undergraduate Biology Education,* 2011). As such, the goal of our year-long laboratory based program is to:

Implement a laboratory curriculum that emphasizes experimental design and scientific communication to enhance the students' biological literacy and practice within the discipline.

Laboratory Curriculum



Hypothesis

We hypothesized that the year-long program would enhance the students' biological literacy skills and their aptitude and appreciation for the process and practice of science

Outcomes/Assessment Tools (Aligned with *Vision and Change; VC*)

	Student Grades[1]	Pre-/Post-Concept Inventory Performance[2]	ETS Major Field Test in Biology Content Area + Assessment Indicator Scores	Classroom Undergraduate Research Experience (CURE) Survey[3]
Outcome 1: Develop a strong foundation in the following core concepts associated with biological literacy:				
a. Structure and Function (VC Core Concept 2)	X	X	X	
b. Information flow from gene to protein (*VCC* Concept 3)	X	X	X	
c. Pathways of energy transformations (*VCC* Concept 4)	X	X	X	
Outcome 2: Become proficient in following biological core competencies and disciplinary practices:				
a. Realize the steps involved in the process of science (*VCC* Competency 1)	X			X
b. Develop quantitative reasoning skills to interrogate large data sets (*VCC* Competency 2)	X		X	X
c. Appreciate the interdisciplinary nature of science by navigating biological data repositories (*VCC* Competency 4)	X			X
d. Communicate and collaborate with other scientists (*VCC* Competency 5)	X			X
Outcome 3: Enhance the students' interest and enthusiasm for scientific research.				
Enhance the students' interest and enthusiasm for scientific research				X

[1] Student grades evaluated included: Critiques of the primary literature, Laboratory notebooks, Final papers, Final presentations, final laboratory grades, final course grades.
[2] Genetics Concept Assessment (Smith, MK *et* al., 2008) and Introductory Molecular and Cell Biology Assessment (Shi J *et* al., 2010)
[3] CURE Survey (Lopatto, D *et* al., 2008)

Results: Pace University I

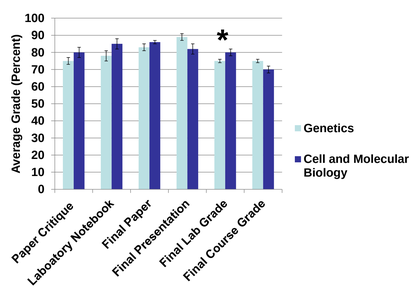


Figure 1. Pace student grades on assignments in the year-long, research-based course. Data represents the percent grades from the 26 students that enrolled in both Genetics (Semester I) and Cell and Molecular Biology (Semester II). Using a Wilcoxon signed rank test, we determined that the Cell and Molecular Biology final laboratory grades were significantly higher than the Genetics final laboratory grades (p=0.028, Z=244, n=25).

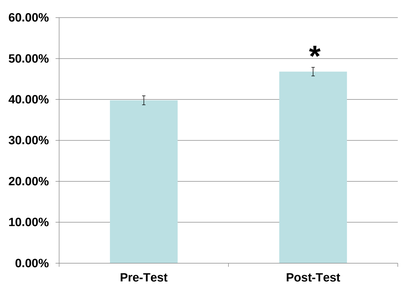


Figure 2. Pace student performance on the pre-/post-test. In total, there were 47 questions on each test. The pre-test was given to the students to complete by the second week of the Fall 2013 semester and the post-test was given to the students to complete by the 12th week of the Spring 2014 semester. 16 students took both the pre- and post-tests and the average percent results from their responses on the tests are represented. Using a Wilcoxon signed rank test to compare the pre- and post-test grades and determined that the post-test grades were significantly greater than the pre-test grades (p=0.011, Z=709.5, n=47).

We considered the *difference* between pre-/post-test grades and how these differences were correlated with pre-/post-test grades and with course grades. A two-tailed Spearman's rank order correlation analyses (alpha = 0.05) demonstrated that the difference was significantly negatively correlated with the total pre-test grade (p=0.049, rho= -0.500, n=16) and with the final laboratory grade (p=0.009, rho= -0.633, n=16) for Genetics. This suggests that the "weaker" students in Genetics made the greatest gains on the pre-/post-tests AND they performed just as well as the "stronger" students in the Cell and Molecular Biology laboratory.

Results: Pace University II

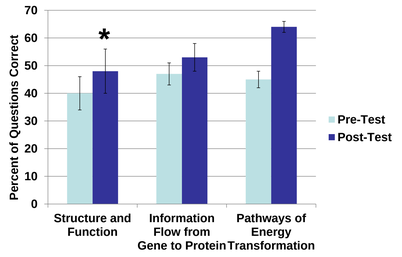
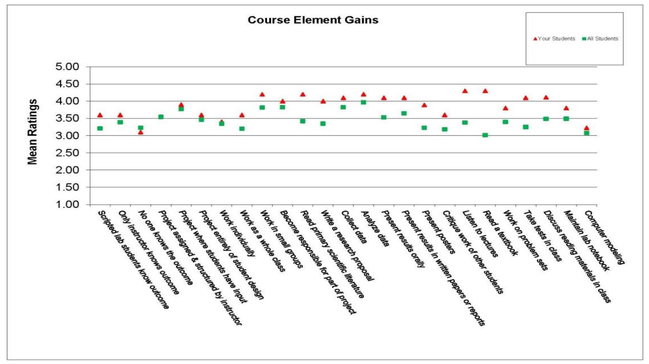
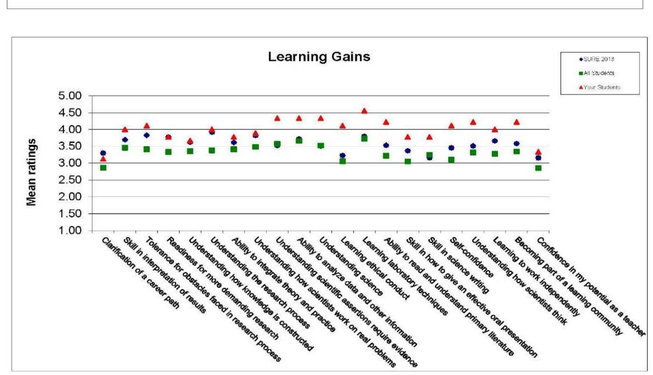


Figure 3. Comparison of Pace student performance on the pre- and post-tests based upon core concepts. The questions on the pre-/post-test were re-categorized by assigning outcomes to them based upon the outcomes determined for the year-long laboratory program. We determined that 13 questions were related to Outcome 1a, 27 questions were related to Outcome 1b, and 7 questions were related to Outcome 1c. 16 students took both the pre- and post-tests and the average percent results from their responses on the tests are represented. Using a Wilcoxon signed rank tests to compare pre- and post-test grades we determined that, for Outcome 1a, students performed significantly better on the post-test (p=0.009, Z==2.621, n=13).





Figures 4A (top) and 4B (bottom). Student responses to CURE survey.

Additional Findings

- Students in the Biology major at Pace University are required to take the Educational Testing Service Major Field Test in Biology (MFT) the semester following their participation in this one year laboratory program. In comparing student performance on the MFT for the first cohort enrolled in our study to student performance on the exam prior to the start of the one-year, laboratory curriculum (2005-2011), we determined that the study cohort scores on the molecular biology/molecular genetics assessment area approached significance (Mann-Whitney U test; p=0.0556, U=13.5, n=9).
- LaSalle University did not enroll enough students in their year 1 courses in order for us to perform rigorous statistical analyses. In most cases, the trends in the data as the year progressed were positive and similar to those described for Pace University.

Conclusions and Future Directions

- The results obtained thus far suggest that the year-long laboratory, research based laboratory curriculum does indeed enhance the students' biological literacy skills and their aptitude and appreciation for the process and practice of science – especially the "weaker" students.
- This study was limited by the fact that we could not tease out the impact of the lecture component of the course on the assessment data. We have addressed this in our year 2 study by including pre-/post-course assessments that focus on experimental design and data interpretation.
- Microarray analysis is costly. Therefore, for the second year of our course, we switched to next-generation sequencing analyses – which turned out to be more cost effective.

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