VIRTUAL LABS FOR GE BIOLOGY

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ABSTRACT

We redesigned a GE biology course by using existing web-based software to replace traditional wet labs. The course was BIOL 155 (Animal Biology), one of only three life science courses with laboratory required by all Cal State LA students to satisfy Block B1 of the general education requirements. Two new modes of lab instruction were compared to the traditional offering: (1) all labs online with a "drop-by" help center and (2) a hybrid "flipped lab" model with two tracks of online and in-person labs alternating every week. In the first mode, all labs were offered online and students were required to perform a series of experiments that demonstrated scientific concepts and, in some cases, design and carry out their own experiments to test a scientific hypothesis. In the second mode, labs were “flipped” so that students met with an instructor biweekly who guided them through the more conceptually challenging tasks of experimental design and data interpretation, and in off-weeks when labs did not meet students collaborated in groups on the more routine tasks of data collection and presentation. Both modes included a face-to-face lecture. Engaging inquiry-based exercises were developed around each online activity where students were provided background information, guided though a series of basic experiments, encouraged to design their own experiments, and required to produce a simple scientific report that is delivered electronically. A rubric was designed so that graduate assistants could grade reports. The course offerings with online labs were piloted during the 2013/14 academic year. An evaluator was employed for assessment. Formative assessment involved the use of surveys to track students’ attitudes and performance. Summative assessment involved a comparison of student performance for the online, hybrid and traditional modes.

COURSE REDESIGN OVERVIEW

Motivation

General education (GE) laboratory courses represent a bottleneck for students’ progress to graduation. As part of their general education requirements, every CSU student must complete a science course with a laboratory. At Cal Sate LA, a life science course with a laboratory activity is required of every student. For practical reasons, the enrollment in each lab section must be limited in size (20-24 students) and each must be staffed by an instructor or graduate teaching assistant. Lab sections must be taught in specialized facilities which are limited in number and availability. Moreover, many GE students struggle with science classes and so the rates of repeatable grades are often high. Based on our experience using virtual labs as a supplement to traditional wet labs for science majors, we felt that virtual labs could address both the facility and pedagogical bottlenecks faced by GE students.

GE biology courses are a challenge for non-science majors, who often view science as a static body of facts. Labs are intended to involve students in science, but there is no room for error, and so most wet labs are “cook-book” activities. The lack of engagement and opportunity for creativity may be one reason why some students perform poorly in these courses. One of the advantages of virtual labs is that they provide risk-free environment for students to explore scientific concepts in inquiry-based fashion. Using virtual labs students can formulate hypotheses and carry out experiments where mistakes are of no consequence, since modified experiments can be redesigned with little additional effort. This mode of learning by doing is one the main reasons virtual labs were designed for science majors. Thus virtual labs can provide a hands-on opportunity for GE students to “achieve an understanding and appreciation of scientific principles and the scientific method” as specified in CSU Executive Order No. 10652011—General Education Breadth Requirements.

Another advantage of virtual labs of virtual labs is that they can be used to address the limitations imposed by the high resource demands of wet labs. The use virtual labs can remove some of the barriers to enrollments, such as the availability of laboratory space and instructors, allowing more students to be served.

Our goal in this course redesign project was to explore the potential of virtual labs to address to increase the opportunities for inquiry-based learning and active engagement with the scientific method, while at the same time increasing enrollments in a general education biology course with a laboratory component.

Course Redesign Strategy

We redesigned a GE biology course by using existing web-based software to replace traditional wet labs. Two new modes of lab instruction were compared to the traditional offering: (1) all labs online with a "drop-by" help center and (2) a hybrid "flipped lab" model with two tracks of online and in-person labs alternating every week. Both modes included a face-to-face lecture. Engaging inquiry-based exercises were developed around each online activity where students were provided background information, guided though a series of basic experiments, encouraged to design their own experiments, and required to produce a simple scientific report that was delivered electronically. A rubric was designed so that graduate assistants can grade reports. The course offerings with online labs was piloted during the 2013/14 academic year. The course offerings with online labs were piloted during the 2013/14 academic year. Formative assessment involved the tracking of students’ attitudes and performance. Summative assessment compared student performance for the online, hybrid and traditional modes.

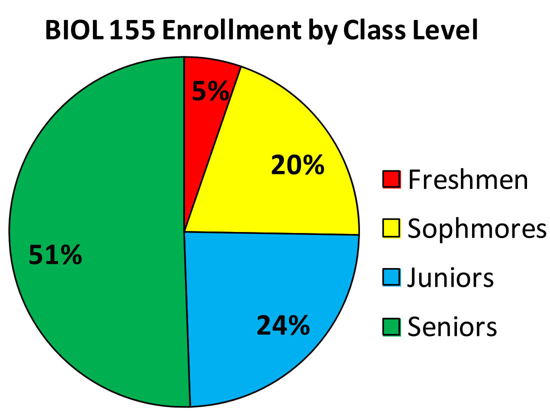
Expected Benefits

The current project can benefit students in two ways. First, by providing an opportunity to actively engage in the conduct of science (formulating hypotheses, designing and carrying out experiments, analyzing and interpreting results), student will gain a deeper understanding of science as a process for investigating the natural world. It is our hope that students will become more engaged in the course subject and this will result in a reduction of the number of repeatable grades, reducing the pedagogical bottleneck encountered in GE science classes. Secondly, by reducing the high demands for facilities and instructional staff that are a part of the traditional GE course science course with a laboratory component, we hope to address directly the facility and resource bottlenecks that can delay students' progress to graduation.

COURSE AND STUDENT BACKGROUND

We are redesigning a non-majors general education course at Cal State LA called Animal Biology (BIOL 155). This four unit quarter-based course appears in Block B1 of the GE requirements. It is one of only three courses that satisfy the GE requirement for a life science course with a laboratory component. Since most science majors require a majors biology course as part of their programs, BIOL 155 is usually taken by non-science majors. There are no prerequisites for the course. It is normally taught with two 75 minute lectures and one 150 minute laboratory session per week. The Department of Biological Sciences at Cal State LA usually offer this course 2-3 times per year with 6-8 lab sections of 24 students each (144-192 students total). The lecture is always offered in a large lecture hall and the lab sections are offered in a specialized laboratory facility devoted to this course. The lecture is taught by a tenure/tenure track or part-time faculty members and the eight lab sections are most often staffed by graduate teaching assistants, when available. Part-time faculty often teach a few of the lab sections.

Because of the bottleneck that this course represents, students often are delayed in taking this course until their junior or senior years. The chart below shows the distribution of students who enrolled in BIOL 155 from Fall 2012 through Spring 2013 (N = 455). The majority of students complete this course late in their academic career.



In the laboratory portion of the course student conduct exercises as outlined in a laboratory manual delivered through the bookstore or as handouts available online. Most of these exercises require the completion of a laboratory exercise that is turned in at the end of the lab period. For example, in the exercise on digestions, students follow instructions to combine egg white (protein), canned milk (fat), and potato (starch) with various enzymes or distilled water (control) and observe what happens. Students work in groups. They answer questions and turn their answer sheets for grading. Students are also required to submit one longer laboratory report in the format of a scientific paper with drafts due over the course of the quarter. Students generally do not have the opportunity to formulate hypotheses and design experiments on their own. A sample syllabus from Winter Quarter 2011 is included below.

LEARNING OUTCOMES AND REDESIGN ACTIVITIES

Student Learning Outcomes

The student learning outcomes (SLOs) for the redesigned course are essentially unchanged from what has been used before. The methods used for achieving these outcomes are changed for the laboratory portion of the course. The SLOs require that a student be able to

- demonstrate an understanding of and be able to apply the steps in the scientific method while conducting an experiment;
- demonstrate an understanding of the differences between Biology and the other natural sciences and will be able to give a definition of a living organism;
- demonstrate an understanding of the hierarchical nature of animal bodies and will be able to
- define, identify and give functions for the major cellular organelles;
    - give a definition of a cell;
    - define, identify and give functions for the major animal tissues;
    - identify the tissues found in major organs;
    - define, identify and give functions for the major organ systems found in animals;
- define homeostasis and give examples of negative feedback loops operative in animals;
- demonstrate an understanding of the basic structure and function of representative organ systems found in animals;
- demonstrate a knowledge of the great diversity and adaptation in design of these systems across the animal kingdom;
- demonstrate an understanding of the basic steps in animal development, including gamete formation using meiosis;
- demonstrate an understanding of the basic concepts of genetic inheritance including the structure and function of DNA, RNA and proteins;
- demonstrate an understanding of the basic concepts of evolution including
    - the concept of natural selection,
    - the definition of a species,
    - evidence for natural selection and evolution;
- demonstrate an understanding of the great diversity within the animal kingdom, particularly within the context of evolution;
- demonstrate knowledge of the conventions of scientific writing by preparing a report of the findings from an experiment.

In particular, it is the first SLO that the redesign addresses.

Two Redesign Models

We are comparing the efficacy of two different curriculum models with each other and to the traditional course with all wet labs. The lecture portions of all the course use the same syllabus and PowerPoint slides. The two new models employing virtual labs are described below.

Model 1. All Labs Offered Online.

In this model all labs are offered online. Nine virtual labs were employed, one for each week of the academic quarter excluding the first week when labs traditionally do not meet. For all nine labs students were provided with a handout, delivered through Moodle, with an introduction on how to use the activity and step-by-step instructions that led students though a series of experiments or activities designed around important concepts from the course. As the students completed the guided experiments, they were given multiple choice questions that they had to answer in Moodle.

For three of the nine labs, students were give an additional assignment where a problem was posed and then students had to propose a formal hypothesis, design experiments to test the hypothesis, carry out the experiments, analyze the results, and present all of this information in the format of a brief scientific report. A report template was provided with instructions for each of the following sections: introduction, experimental design, results, discussion and conclusions. A grading rubric was provided to the students to guide them in the writing of their reports.

Model 2. Hybrid Flipped Lab.

In this model students met in the physical laboratory every other week. On days they met in the laboratory, students worked on group exercises under the guidance of a laboratory instructor. During the weeks when they were not meeting, each student worked on individual assignments. The class was divided into two tracks. Students in track A met in the laboratory on even weeks of the quarter and worked on individual assignments on odd weeks. Students in track B met in the laboratory on odd weeks of the quarter and worked on individual assignments on even weeks. This process is illustrated below:

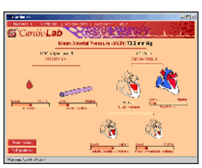
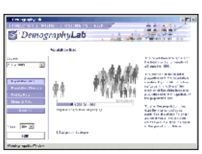
WEEK	TRACK A	TRACK B
1	Intro to virtual lab	No lab
2	Individual online exercises	Intro to virtual lab
3	Group report in lab	Individual online exercises
4	Individual online exercises	Group report in lab
5	Group report in lab	Individual online exercises
6	Individual online exercises	Group report in lab
7	Group report in lab	Individual online exercises
8	Individual online exercises	Group report in lab
9	Group report in lab	Individual online exercises
10	No lab	Group report in lab

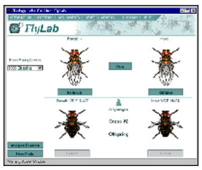
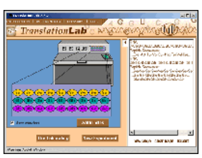
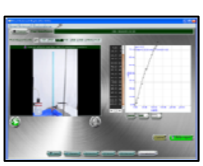
Lab instructors would alternate meeting in person with students from Tracks A and B. Thus, the same number of instructors could accommodate twice as many students, which addressed the bottleneck issue.

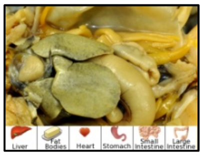
On the in-person meeting, the lab instructor explained the organization of the labs and introduced the first virtual lab activity. The following week each student worked on a set of step-by-step instructions that led them though a series of experiments or activities designed around important concepts from the course. (These were similar to the all online exercises.) As the students completed the guided experiments, they were given multiple choice questions that they had to answer in Moodle. When they came together in the next in-person meeting, students would discuss on their answers to the online exercises and were given a second attempt to answer them in Moodle. The highest grade on the two attempts was used. Additionally, students had to work together to formulate hypotheses, design and carry out experiments to test their hypotheses, organize their results, and submit a report in the format of a scientific paper. The lab instructor would also introduce the next activity. This pattern of individual online activities followed by in-person group work was repeated until the end of the quarter.

Online Labs Being Employed

Nine virtual labs were employed during the Fall 2013 and Winter 2014 quarters for the sections where all the laboratories were online. Six of thee were from the suite of 12 applets that make up Biology Labs OnLine. These virtual labs simulate real experimental situations such as the genetics of inheritance or evolution. Student can vary several inputs to design a large variety of experiments. Tabular and graphical outputs are provided as well as the ability to transfer and export data their experimental data. Three of the virtual labs were part of a suite of activities available commercially form SmartScience Labs. This product provides videos of real experiments that the students can view and pause to collect data. Videos of experiments conducted under different conditions are provided. The software has integrated introductory information. The table below describes the virtual labs that were employed.

Activity	Topics	Usage
Biology Labs On-Line:		
 ***CardioLab***	Students explore the concept of homeostasis using arterial blood pressure as an example. The interaction of variables related to heart rate, vessel radius, blood viscosity, and stroke volume can be studied by direct manipulation, or indirectly through interventions, such as hemorrhage, exercise, dehydration, shock, intravenous infusion, epinephrine, and foxglove. Nerve impulses can be monitored under the experimental conditions. Realistic case studies such as hypertension and congestive heart failure are also available for investigation.	F13, W14
 ***DemographyLab***	Students investigate how differences in population size, age-structure, and age-specific fertility and mortality rates affect human population growth. This lab can be used to investigate phenomena such as exponential growth, stable age structure, zero population growth, and demographic momentum.	F13, W14

 ***EvolutionLab***	Students investigate the process of adaptation by natural selection by manipulating various parameters of a bird species, such as initial mean beak size, variability, heritability, and population size, and various parameters of the environment such as precipitation and island size. This lab can be used to investigate evolutionary principles such as directional, disruptive and balancing selection, the dependence of natural selection on the variability and heritability of a trait, founder effects, genetic drift, and extinction.	F13, W14, Sp14
 ***FlyLab***	Students learn the principles of genetic inheritance by designing matings between female and male fruit flies carrying one or more genetic mutations. This lab can be used to demonstrate genetic principles such as dominant versus recessive traits, independent assortment, sex-linked inheritance, linkage and chromosome maps, and modifications to Mendelian ratios caused by lethal mutations and epistasis.	F13, W14, Sp14
 ***PopEcoLab***	Students investigate principles of population ecology by manipulating various attributes of three bird species: two competing sparrows and a hawk predator. Users can vary initial population numbers, clutch size, life span, competition coefficients, predation rates and resource availability. This lab can be used to investigate ecological principles such as carrying capacity, extinction, overpopulation, competitive coexistence, competitive exclusion, predator-prey cycles, and predator-mediated coexistence.	F13, W14, Sp14
 ***TranslationLab***	Students create simple RNA sequences and then translate these in a virtual "in vitro" cell-free system. From the proteins produced by the translation mix, students determine the characteristics of the genetic code and assign codons to amino acids. This lab was modeled after some of the original experiments used to determine the genetic code.	F13, W14, Sp14
Smart Science Labs:		
 ***Animal Behavior***	Students observe the behavior of animals (small isopods) in different situations to determine how these particular animals respond to their environment. Students can may investigate their response to light and dark, wet and dry, pH, and other factors. They can compare the behavior with controls in which the environment is uniform. All experiments are videos of real trials involving live animals.	F13, W14
 ***Enzymes***	Students investigate the effect of pH on enzyme reactions. The experiments involve the enzyme catalase which catalyzes the decomposition of hydrogen peroxide into water and oxygen. Students measure the amount of oxygen generated when catalase is mixed with hydrogen peroxide. They graph the volume of O_2 against time. The videos are of real experiments for different pH values. Students can explore how the rate of reaction changes as a function of pH.	F13, W14

 ***Frog Dissection***	Students observe videos of a frog dissection and learn to identify different organs and their functions.	F13, W14

Four labs were used in Spring 2014 for the hybrid flipped lab model. These labs were chosen because they offer much flexibility in terms of designing experiments. As part of their group activities, students were required to formulate hypotheses and design and carry out experiments to test their hypotheses.

Assessment Activities

There were two sources of assessment data for this project. (1) Course grades were tabulated for every offering of the course, and (2) student surveys were administered at the beginning and end of each quarter. The surveys were designed to address the following topics:

- attitudes about the study of biology;
- knowledge of the nature of science;
- knowledge of the process of evolution;
- ability to design and carry out experiments.

Evolution was chosen for the knowledge topic because it is covered in the laboratory portions of the courses which use traditional wet labs, all online labs, and hybrid flipped labs. The pre- and post-course surveys were conducted using Moodle and bonus points were offered to students who completed these surveys. The post-course surveys also included a few questions on their major, why the student was taking the course, and how the student accessed the labs. The post-survey also provided students with an opportunity to comment on what they like and disliked about the laboratory portion of the course.

The survey items were adapted from instruments that were developed and tested previously and published in the literature. The questions on attitudes were selected from the BioCLASS: Colorado Learning Attitudes about Science Survey (Semsar, Knight, Birol, & Smith 2011). Questions regarding the nature of science were obtained from the Measure of Acceptance of the Theory of Evolution (Rutledge & Sadler 2007). Questions on the knowledge of evolution were taken from the Natural Selection Concept Inventory (Anderson, Fisher, & Norman 2002). Questions dealing with experimental design were adapted from the Biological Concepts Instrument (Klymkowsky, Underwood, & Garvin-Doxas 2010).

Project Assessment was conducted by Dr. Ji Son from the Department of Psychology at CSULA. She was reponsible for the development and implementation of the pre- and post-class surveys and the analyses of the results.

Project Timeline

Below is a summary timeline of the project activities.

Activities	Su 13			F 3			W 14			Sp 14		
	J	A	S	O	N	D	J	F	M	A	M	J
Preparation of lab handouts	X	X	X									
Preparation of grading rubrics		X	X									
Hiring and training GAs		X	X					X	X			
Teaching with all online labs				X	X	X	X	X	X			
Teaching with wet labs							X	X	X			
Teaching with hybrid flipped labs										X	X	X
Formative assessment				X	X	X	X	X	X	X	X	X
Summative assessment												X

Cal State LA is on the quarter system. Spring classes do not end until mid-June.

ACCESSIBILITY, AFFORDABILITY, AND DIVERSITY

Most of the course materials are accessible to students. Handouts were developed using standard commercial software programs such as Microsoft Word and Adobe Acrobat for which accessibility features are available. The Smart Science online labs were evaluated by the CSU for accessibility prior to the negotiation of a contract for their use. The vendor implemented changes to the software in response to this evaluation. The Biology Labs OnLine simulations were developed in 1999 and have not been evaluated for accessibility. Talks are underway to develop an updated version which would be ADA compliant. All course materials were delivered through Moodle, the Cal State LA course management system. The University maintains an Office of Students with Disabilities where disabled students can arrange accommodations for all of their courses.

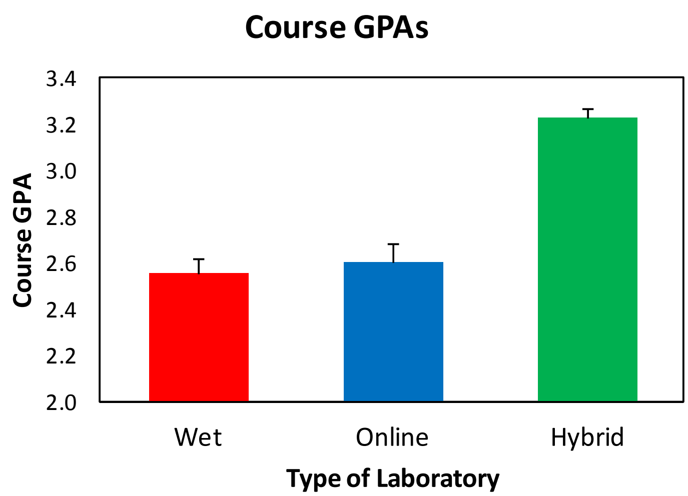
Students were subject to any additional expenses beyond the usual student fees. Students were not required to purchase a textbook or lab manual. All resources and references were provided online. The CSU paid the cost of using the commercial software for the laboratory portions of the courses. The students were not charged a lab fee.

Cal State LA has one of the most diverse student populations in the nation. In 2013 the students were 55.8% Hispanic, 16% Asian American, 9.9% White, and 4.7% African American. Among undergraduates, 59% of the students are female. Many students are older and have families; the average undergraduate is 23.4 years of age. Since it is a high enrollment required general education course, the students enrolled in the BIOL 155 sections reflected this diversity. Although the instructors involved in this project have a great deal of experience teaching in a diverse student environment, none of the course material itself dealt explicitly with diversity issues.

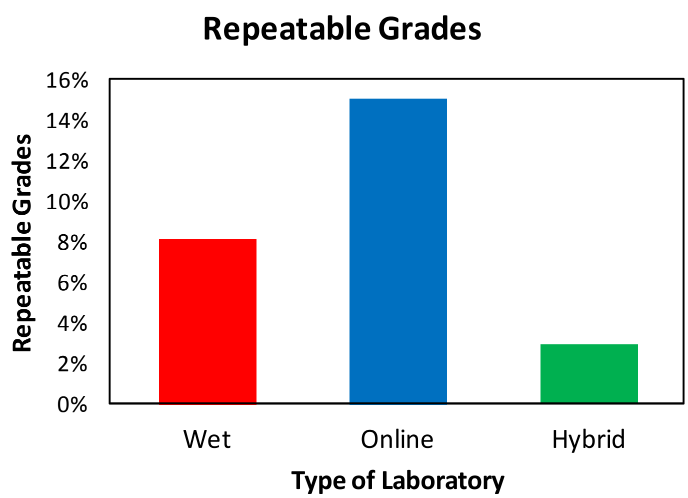
IMPACT ON TEACHING AND LEARNING

Grades

There were statistically significant differences in the student course grades for the three types of laboratory formats. The chart below shows that the students taking the courses with hybrid flipped labs showed a significant increase (P<0.001) in their mean GPA.



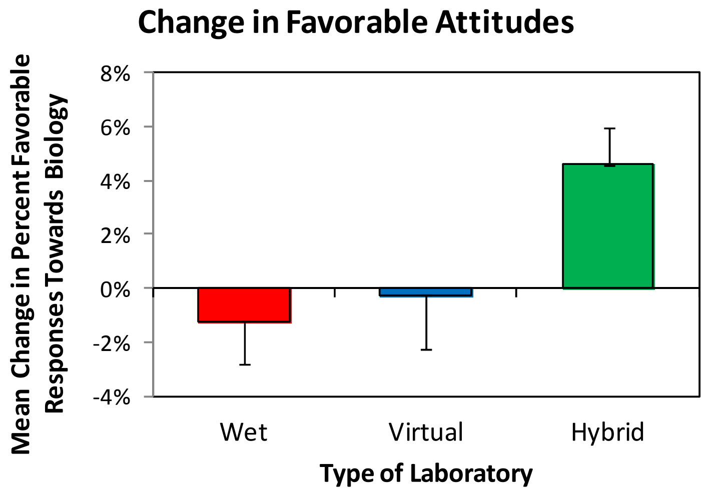
Similarly, there were significantly fewer repeatable grades (below C/W) for hybrid flipped labs (P<0.001):



Interestingly, the course with all virtual labs showed the highest proportion of repeatable grades, although the mean course GPA was not different from the wet labs. This suggests a shift towards a more bimodal distribution in student performance. This may indicate that some students floundered while other excelled when faced with the increased responsibility of completing lab assignments outside of the traditional laboratory setting.

Student Attitudes Towards Biology

The pre-post surveys allowed an assessment of the changes in students attitudes towards biology for the three types of laboratory formats. There were 31 questions organized into several categories. Overall, only the hybrid flipped labs showed a statistically significant positive increase in the percentage of favorable responses (P=0.016):



The small negative changes for the wet labs and virtual labs are not significantly different from zero. The following table shows the change in student attitudes towards biology broken down by category:

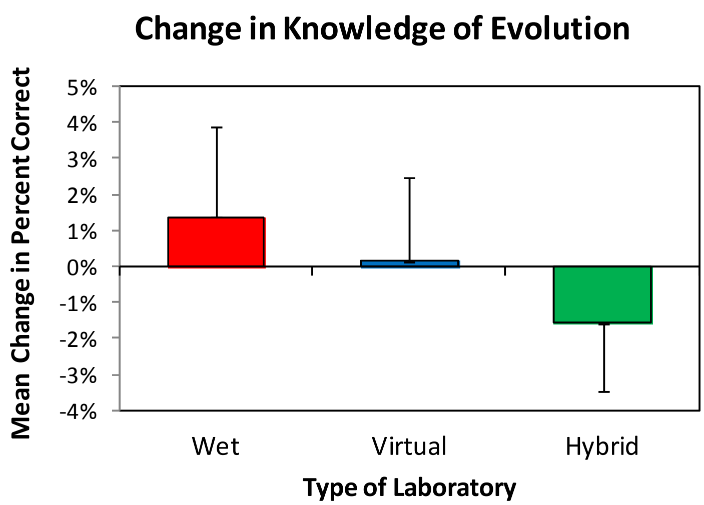
Mean Percent Change in Positive Attitudes Towards Biology

Attitudinal Category	Wet labs	Virtual labs	Hybrid labs
Problem-solving difficulty	–0.02% ± 2.69%	0.74% ± 2.97%	4.28% ± 2.14%
Problem solving effort	0.08% ± 2.38%	1.32% ± 2.97%	6.97% ± 2.39%
Problem solving strategies	–0.26% ± 3.22%	4.17% ± 3.59%	8.39% ± 2.91%
Conceptual connections	–4.04% ± 2.58%	1.02% ± 2.74%	3.21% ± 2.12%
Real world connections	–0.24% ± 2.62%	–2.43% ± 2.82%	5.25% ± 2.03%
Reasoning	–6.68% ± 2.80%	–4.41% ± 3.59%	2.44% ± 2.29%
Enjoyment	0.97% ± 2.15%	1.33% ± 2.62%	6.30% ± 1.95%

Shown are the mean and standard errors for the change in percent of favorable responses. Cells highlighted in green show a statistically significant positive change; red show a significant negative change. These results suggest that the hybrid-flipped lab format has the potential for increasing students' attitudes towards problem solving and their enjoyment of biology.

Knowledge of Evolution

The assessment of knowledge in the pre-post surveys focused on evolution by natural selection. This is because natural selection was a topic covered in wet labs as well as the virtual labs and hybrid flipped labs. Seven survey questions were focused on this topic. The chart below shows the mean change in percent correct answers for the three types of laboratory formats:

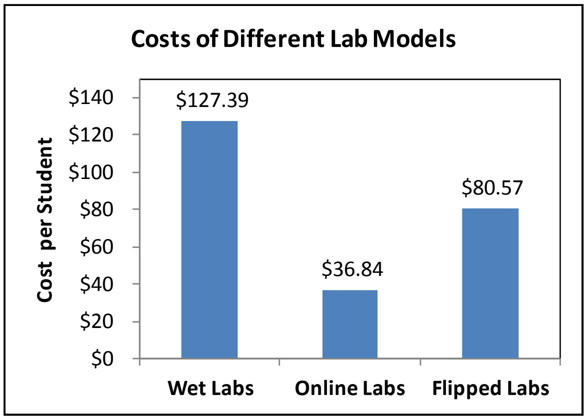


None of these changes are significantly different from zero nor are they different from one another (P = 0.623). It does not appear that the laboratory exercises dealing with evolution had a positive impact of the students' knowledge.

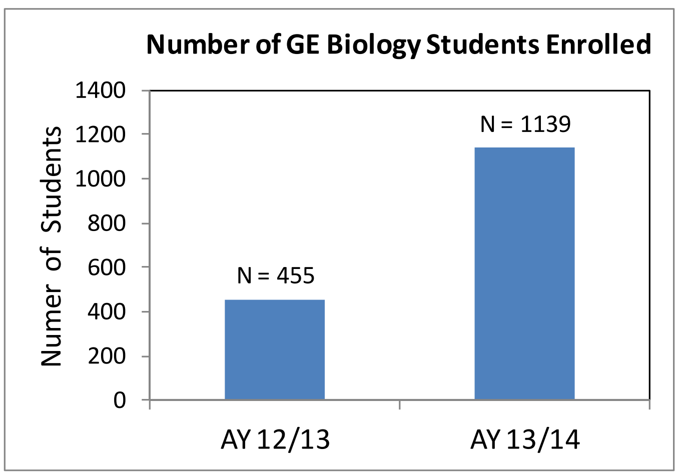
The pre-post surveys also dealt with the topic of research methodology. However, two of the four questions on this topic required a textual response. The 766 textual responses must be coded before a quantitative analysis can be conducted. Once this analysis is complete these results will be added to this section.

ADDRESSING THE BOTTLENECK ISSUE

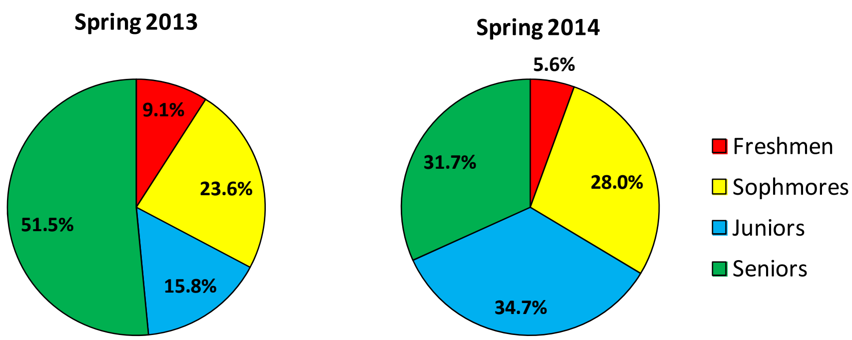
As a GE requirement, every CSU student must take a life science course with lab. These courses are limited by lab space and personnel costs. Each lab section accommodates 20-25 students and requires an instructor. Offering labs for evening students is an additional challenge. Online labs would allow enrollments to be increased to the capacity of the lecture hall, reduce the need for lab facilities, and reduce staffing costs. For example, at CSULA (quarter system) we offer BIOL 155 with 8 lab sections of 24 students each (38.4 FTES). Personnel needs are 22 units for instruction (6 units for large lecture and lab coordination, 16 units for labs) and 5 hours of graduate assistance (GA). Using a rate of $1105/unit instruction and $14.80/hr/GA, the total cost is $25,050. A course of the same size with virtual labs, assuming 30 hours of GA help for drop-in assistance and grading, would cost $11,070. Thus a course taught with all virtual labs could be offered at 44% of the current cost with no impact on physical lab facilities. A similar calculation for half online and half wet labs would be 71% of the traditional cost and would double the throughput capacity of the physical lab facilities. The chart below shows a comparison of the per student costs assuming a course with 8 labs sections of 24 student per section.



The virtual lab model allowed us to serve more students. During the previous academic year when all BIOL 155 was taught using the traditional wet labs, the Department of Biological Sciences only had enough resources to offer two sections (F12 & W13) with six lab sections each and one section (Sp13) with eight labs. The following academic year, when this course redesign project was implemented, we offered six sections of BIOL 155 with eight labs per section. The increased enrollments are illustrated in the figure below.



There is evidence that the increased enrollments allowed as a result of our course redesign is having a positive impact on the time to graduation. We compared the class levels of students who enrolled in BIOL 155 in Spring 2013 to those who enrolled in Spring 2014. The is summarized in the following chart.



There was a statistically significant (P < 0.0001) shift students taking this GE course as seniors to students taking the course in their junior year. If this trend continues, it may help decrease the time required for students to finish their lower division GE requirements.

ABOUT US

Bob Desharnais is a Professor of Biology and Director of the Virtual Courseware Project (ScienceCourseware.org), an innovative web site providing free interactive inquiry based simulations for science education. Beginning with the creation of the popular Virtual FlyLab genetics application in 1995, he has been at the cutting edge of web-based technology for science education. He is coauthor of the suite of web simulations called Biology Labs OnLine, which is published by Pearson Edcuation and used by hundreds of colleges and universities across the nation, as well as several other freely available web-based programs. The Virtual Courseware Project was developed and supported by grants from the National Science Foundation.

Desharnais received his Ph.D. in Zoology in 1982 from the University of Rhode Island. He was a Killam Postdoctoral Fellow at Dalhousie University in Halifax, Nova Scotia and then spent five years as a postdoctoral fellow, research associate, and assistant professor of populations at Rockefeller University. He joined the faculty in the Department of Biological Sciences at Cal State LA in Fall 1988 where he has taught courses in biostatistics, ecology, genetics, and general biology. He received the CSULA Outstanding Professor Award in 1998, the Richard Nicholson Award for Excellence in Science Teaching from the Washington DC-based Quality Education for Minorities Network in 2006, and was named the CSULA President’s Distinguished Professor in 2010.

In addition to interests in the application of technology to science education, Desharnais maintains an active NSF-funded research program in the area of theoretical population biology. With students and colleagues, he has published over 50 papers in peer reviewed journals, including Nature, Science, and PNAS. In 1997 Desharnais and his colleagues were credited for the first experimental demonstration of chaotic dynamics in an ecological population.

Paul Narguizian joined the faculty of the Charter College of Education after eight years of teaching high school biology and chemistry in Los Angeles, CA. During this time, he also completed a Master of Science degree in Cell & Molecular Biology at California State University, Northridge. His research at CSUN involved taking a closer look at the role of cell membrane structures (i.e. amino acids) and cancer. Realizing the dual importance of science content and science education/pedagogy in being a more effective science educator, he continued his education at the University of Southern California where he received a Doctorate in Science Education. During his tenure at USC, he became interested in the Nature and History of Science (i.e. the processes and mechanisms involved in science) and as a result he made it the focal point of his dissertation. His university teaching experience prior to CSULA included a position as an adjunct professor of science education at California State University, Long Beach.

Narguizian's areas of interest include Curriculum and Instruction with a specialization in Science & Biology Education. He taught EDSE 421C: Secondary Science Teaching Methods, EDEL 418: Elementary Science Teaching Methods, EDSE 401: Instructional Strategies in Secondary Teaching along with Elementary Science Education graduate courses at CSULA. His expertise is in K12 science instruction, curriculum development and design issues associated with science education.

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