ARTICLE

Transformation of a Traditional, Freshman Biology, Three-Semester Sequence, to a Two-Semester, Integrated Thematically Organized, and Team-Taught Course

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Abstract: Biology faculty at San José State University developed, piloted, implemented, and assessed a freshmen course sequence based on the macro-to micro-teaching approach that was team-taught, and organized around unifying themes. Content learning assessment drove the conceptual framework of our course sequence. Content student learning increased significantly in 12 of the categories examined using pre and post assessment instruments. Focus and individual student interviews revealed that students experienced a sense of ownership after completing two, five-week guided inquiry projects. Pass rate for the second semester class increased significantly from 55% to 85%. The percentage of underrepresented students passing the new sequence was higher than 72%, and was 86% at the end of the second year of full course sequence implementation.

Keywords: Team teaching, macro to micro teaching approach

INTRODUCTION

Traditionally, freshmen biology course sequences at the university level begin with basic chemistry concepts, have an extended animal and plant taxonomy component, and end with ecology, regardless of the intellectual maturity of the students taking the course. Concepts are organized as silos and instructors assume that students can make connections between disparate content (Gardner & Belland, 2012). Making matters worse is that most chosen textbooks are encyclopedic in nature.

In traditional biology freshman courses, both instructors and students place an emphasis on learning definitions, recalling memorized information, or recognizing word patterns in order to answer multiple choice exam questions (Martin, 2015; Momsen et al., 2010). Information learned at this low level is only retained for the exam. Content superficiality is not amenable for the construction of cognitive conceptual scaffolds that aid in learning more complex concepts in upper division courses, where application of knowledge is essential (Momsen et al., 2010). Furthermore, some biology university faculty stress the importance of learning facts without questioning what students should learn, how the concepts are taught, and when students should learn the material (Gardner & Belland, 2012; Momsen et al., 2010).

Several national reports have stressed the importance of teaching biology not as a collection of historical facts, but as an active, participatory endeavor that should mimic the way science is done (Committee on undergraduate education to prepare research scientists for the 21st century, NRC, 2003; PCAST, 2012). Furthermore, the Vision & Change Report provided the biology community at large with core concepts that a modern biology university education should follow (American Association for the Advancement of Science, 2011; Musante, 2011).

Our previous freshman biology sequence consisted of three semesters (Plant Biology, Animal Biology, and Cell Biology), with 3 hr lectures and 2 hr lab sections per week.

The first two semesters (Plant Biology and Animal Biology) were taxonomy heavy. Content was organized in silos and there was no reinforcement of concepts within each semester. Students had low retention rates and were unprepared for upper division work. The new two-semester course sequence was designed to increase student persistence, reduce the failure rate for students enrolled in the new core (without reducing academic standards), increase conceptual understanding, and incorporate active learning strategies that were absent in the previous freshmen sequence.

We present results from the development, piloting, and implementation of a highly innovative two-semester freshman biology sequence. We present several lines of evidence that demonstrate that students' success (such as concept gains, increase passing rates) can increase in a large freshman class, at a public comprehensive university.

METHODS

Data included in this article, such as: students' demographics, passing rates, pre/post concept assessment, SALG (Student Assessment of their Learning Gains) responses, surveys, students interviews, were from those who consented to participate in a research approved by San José State University IRB (protocol F1002051). Participation rates exceeded 90% during the study (2009-2012).

Developing an innovative freshman biology foundational sequence

In 2009, three faculty in the Department of Biological Sciences embarked on the development, piloting, and implementation of the entire freshman sequence. This process provided an unparalleled opportunity to examine curriculum at the freshman level that has not been done in our institution since the 1960s. Revision of the underlying teaching philosophy also brought the challenge of additional efforts in terms of developing team-taught lectures, a new activity/problem solving component, new lab exercises, two short research projects, and the development of assessment strategies to examine the success or failure of this sequence. We implemented the team teaching model described by Friend & Cook (2010, p168-169), in which one instructor led the lectures and two others observed and answered questions when needed. Two sets of objectives (success and pedagogy) were used to guide our curriculum implementation at the freshman level. The success objective was to reduce the failure rate for students enrolled in the new core, without reducing academic standards. The following five pedagogical objectives were used: (a) students will be able to formulate hypotheses and design experimental approaches to answer research questions, (b) students will be able to use quantitative analysis to understand complex scientific concepts, (c) students will be able to work effectively in groups to solve problems, (d) students will be able to use multiple approaches to answer complex questions, and (e) students will be able to construct logical conclusions based on the different types of data they collect.

The new two-semester sequence implemented a macro-micro approach that began with biodiversity (including microbes) in the first semester, and ended with cancer in the second semester. In this approach students begin with material that is more familiar and contain larger levels of biological organization (for example biomes) followed by more abstract and smaller levels of biological organization (molecules and cells). Several biology instructors at different institutions have reversed the traditional organization of the freshmen biology sequence and have implemented a similar approach (Gwynee, 1997). There were several reasons for using this conceptual approach of covering the material. First, students (of the three-semester sequence) had a better understanding of macro concepts (such as biodiversity, ecology, development), and had great difficulty with micro concepts (such as cell-cell communication, cellular energetics, translation). Second, the material was organized in themes in order to make conceptual connections easier. Third, students needed to understand concepts covered in the first semester of the freshman Chemistry sequence in order to do well in the Cell Biology portion of the class. Therefore, the first semester of the freshman Chemistry sequence became a co-requisite of the first-semester biology sequence, and a requirement for the second semester. In the three semester sequence, Soto & Anand (2009) demonstrated that a strong predictor of students succeeding in the cell biology portion of our institution freshmen sequence was passing the first semester of college Chemistry with a grade of "C" or better. Thus, we anticipated that students would do better in the cell biology & physiology semester if they had passed the first semester of Chemistry with a "C" or better.

Pass/fail rates analyses

Historical (2005-2009), aggregated without personal identifiers, pass data from the three-semester Biology sequence were compared with the total number of students who passed the new sequence and were willing to participate in this study (two-semester sequence, 2010-2012). Pass rates of underrepresented (URM) students as defined by the National Science Foundation (African American, Latina/o, and Pacific Islanders) were collected from students who consented to participate in our study and enrolled in the two-semester sequence.

Core concept assessment

Pre and post surveys were given to the students who were enrolled in the three-semester sequence in 2009-2010 and in the two-semester sequence (2009-2012). The content pre and post surveys contained questions on: scientific method, natural selection, phylogenetics, mitosis/meiosis, developmental biology, plant evolution, ecology, anatomy, taxonomy, mendelian genetics, population genetics, protein function, amino acids, energetics, protein structure, enzymes, nucleic acids, electrophoresis, carbohydrates, membrane structure, cancer, extracellular matrix, Kreb's cycle, glycolysis, electron transport systems, DNA structure, DNA replication, transcription, alternative splicing, gene structure, and action potential. Data from 2010-2012 courses were aggregated for pre- and post-assessment results and compared with data collected from the previous course sequence (2009-2010) for statistical significance using T-tests.

Students' self-assessment of gains

Students enrolled in the two-semester sequence (2010-2012) were given a modified SALG (Students Assessment of their Learning Gains) instrument to assess their learning gains related to the attitudes regarding their behavior in each component of the course. Two hundred and twenty students responded to the survey. The SALG site (www.salgsite.org) analyzed collected data as means +/- standard deviations.

Students' interviews

Jerry Everhart interviewed students (one-on one, focus groups, and Skype) at several times during the duration of the project (2009-2012). Focus group interviews occurred after lab sections. The purpose of the interviews was to gather students' impressions about course design, study strategies, and the research projects in the labs. Two hundred students were interviewed from the new sequence (2010-2012). The notes were transcribed without identifiable information, and the information reported as is.

Videos

Students' research presentations were videotaped. A random sample of 22 videos was evaluated to examine if students exhibited acceptable scientific practices. Observations were transcribed and reported as is. These included: use of scientific terminology contextually, appropriate information, apply useful information, use lab techniques to answer questions and test hypotheses, and consider alternative explanations.

RESULTS

Student Sample

Fig. 1 shows the data sample for the two-semester biology freshman sequence examined in this study, including the number of URM students. URM students corresponded to 19% of the total number of students who were willing to participate in our study (2010-2012). This percentage composition was the same when the total number of students enrolled was considered.

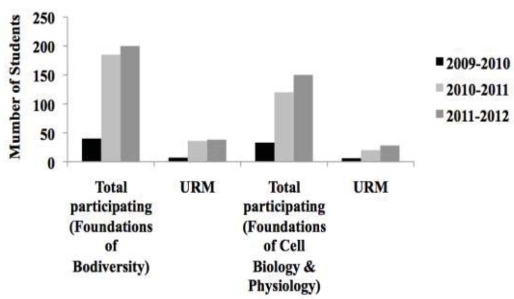

Fig. 1. Total and URM student participation in this study.

Pilot

In 2009-2010, faculty in the Department of Biological Sciences confronted many philosophical and logistical issues to deliver an innovative, introductory course to biology majors (mostly freshmen). The team consolidated a three-semester, topic-driven sequence into a two-semester, team-taught, integrated, theme-based experience (Tables 1 and 2; Fig. 2). Students chose to be enrolled in the pilot course. Participants had to qualify to participate in the piloting of the two-course sequence. From the students willing to participate in the course, academic advising staff selected 40 students based on academic criteria (not remedial, able to co-enroll in the freshman Chemistry sequence, and English composition courses).

Three substantial changes were made to the new courses. First, a team of three instructors delivered lectures in weekly classes. The instructors represented various areas of expertise within biology. All

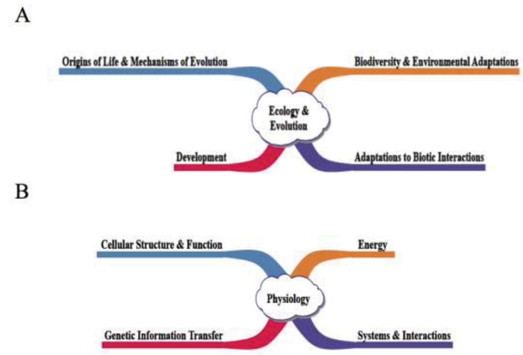

Fig. 2. Conceptual Framework of the freshman, two-semester biology sequence. (A) First semester: Foundations of Biodiversity. The unifying theme was ecology & evolution. (B) Second semester: Foundations of Cell Biology & Physiology. The unifying theme was physiology.

attended each lecture and contributed information as subject matter emerged. Second, the laboratory portion of the course was aligned to the concepts presented in lecture. A short research component was added to the lab with expectations that students conduct research, collect and analyze data, and present conclusions to others. Third, a two-hour per week activity component was added. The activity section helped students with complex ideas introduced in lectures by using hands-on, quantitative, problem-based, and kinesthetic approaches to learning. The activity sections emphasized students to do group work and communicate effectively. In the pilot year, upper division students facilitated the activity section.

Several challenges were present. Both Biology freshman sequences were taught concurrently. Delivery of traditional and pilot classes concurrently allowed the instructional team to have a control group, but also increased logistical challenges, as lab technicians could not devote the time needed to implement new labs. One of the logistical consequences was the misalignment of some of the activities/lab exercises with the material presented in lecture. In addition, some of the new lab exercises did not work as planned and new ones were developed as a consequence.

Table 1. Comparison between Plant Biology, Animal Biology, and Foundations of Biodiversity

	Plant Biology (3 semester sequence)	Animal Biology (3 semester sequence)	Foundations of Biodiversity (2 semester sequence)
Chemistry	Not required	Not required	Chem 1A (Co-requisite)
Exam Type	Simple multiple choice	Simple multiple choice	Conceptual short answers, Quantitative problems
Class Components (per week)	3 hr of passive lectures: • Silos • Memorization of definitions, and taxonomy groups 2 hrs of labs ("cookbook") • Not linked to lecture material	3 hr of passive lectures: • Silos • Memorization of definitions, and taxonomy groups 2 hrs of labs ("cookbook") • Not linked to lecture material	3 hr lectures (team-taught) • Conceptually integrated • Thematically-organized 2 hrs labs • Reinforced lecture material • 4 weeks of research projects • Student research papers 2 hrs activity • Modified TBL • Reinforced lecture material • Active learning techniques
Contact hrs	5	5	7
Concepts (new concepts in **bold**)	Taxonomy of plants Mendelian Genetics Natural selection Ecology Plant physiology Plant Evolution Population demography and life history Plant Development	Taxonomy of animals Population genetics Ecology Species Interactions Animal physiology Animal Evolution Population growth Animal development	**Origins of life: bacteria, archae, eukaryotes** Mendelian Genetics Natural Selection **Speciation** Population Genetics **Adaptations to living on land (plants & animals)** **Animal and plant form and function** Gas exchange (animals & plants) Population growth Population demography and life history Species interactions Development (animal and plant) **Evo-Devo**

Table 2. Comparison between Cell Biology and Foundations of Cellular Biology & Physiology

	Cell Biology (3 semester sequence)	**Foundations of Cellular Biology & Physiology (2 semester sequence)**
Chemistry	Chem 1A (Co-requisite)	Chem 1A with a C or better (Pre-requisite), Chem 1B (Co-requisite)
Exam Type	Short answers	Conceptual short answers, quantitative problems
Class Components (per week)	3 hr of passive lectures: • Silos • Memorization of concepts 2 hrs of labs ("cookbook") • Not linked to lecture material	3 hr lectures (team-taught) • Conceptually integrated • Thematically-organized 2 hrs labs • Reinforced lecture material • 4 weeks of research projects • Student research papers and poster presentations 2 hrs activity • Modified TBL • Reinforced lecture material • Active learning techniques
Contact hrs	5	7
Concepts (new concepts in **bold**)	Organic molecules found in cells Cellular structure Enzymes and enzyme regulation Cellular energetics DNA replication, transcription, translation Alternative splicing Membrane structure and transport Cell-cell communications (signal transduction) Cell cycle and Cancer Cancer	Molecules of life Membrane structure and transport Cellular structures **Molecular evolution (origin or chloroplasts and mitochondria)** **Genome evolution** Enzymes and enzyme regulation **Digestive system** **Respiratory system** Cellular energetics DNA replication, transcription, translation **Nervous system, action potential** **Endocrine system** Cell-cell communications (signal transduction) **Plant hormones** Cell cycle and Cancer

Finally, students were not comfortable with students facilitating the activity sections.

Implementation

During the first year of implementation, all of the freshmen students who were academically prepared to take the new sequence were allowed to do so. In addition, the three-semester sequence was discontinued.

Intense planning and anticipation of potential problems made the transition to full implementation relatively free of major problems. Activity and laboratory exercises were linked with the concepts presented in lecture. Although the lecture component had large enrollments (over 120 students), activity section enrollment was limited to 22 students per section. The activity exercises were greatly refined and faculty began to facilitate these sections. The instructors in charge of the entire sequence had weekly meetings with lab and activity instructors.

Table 3. Assessed concepts that were not different in the three- and two-semester sequences.

Concept	Course where it was assessed
Mitosis/meiosis	Plant Biology Foundations of Biodiversity
Plant evolution	Plant Biology Foundations of Biodiversity
Plant anatomy	Plant Biology Foundations of Biodiversity
Animal anatomy	Animal Biology Foundations of Biodiversity
Protein structure	Cell Biology Foundations of Cell Biology & Physiology
Protein function	Cell Biology Foundations of Cell Biology & Physiology
Amino acids	Cell Biology Foundations of Cell Biology & Physiology
Nucleic acids	Cell Biology Foundations of Cell Biology & Physiology
Carbohydrates	Cell Biology Foundations of Cell Biology & Physiology
Membrane structure	Cell Biology Foundations of Cell Biology & Physiology
Electrophoresis	Cell Biology Foundations of Cell Biology & Physiology
Gene structure	Cell Biology Foundations of Cell Biology & Physiology
Extracellular matrix	Cell Biology Foundations of Cell Biology & Physiology
Cancer	Cell Biology Foundations of Cell Biology & Physiology
Membrane structure	Cell Biology Foundations of Cell Biology & Physiology

Concept Learning Gains

Learning gains of concept comparisons between old and new courses yielded mixed results. Pre-assessment results indicate that students in both types of freshman core sequences had comparable concept understanding (Fig. 3A). The only differences were in the concept of transcription and translation, were students from the three-semester sequence scored significantly higher in the pre-assessment test ($p<0.001$).

When the post-assessment scores were compared, there were no statistically significant differences between both sets of students in 15 categories (Table 3). Students who enrolled in the three-semester sequence outperformed students enrolled in the two-semester sequence in three categories: plant and animal taxonomy and alternative splicing (data not shown).

Fig. 3B shows the statistically significant gains of concept competency in specific areas of biology covered in the three-semester and two-semester sequences ($p<0.001$). Students who took the two-semester sequence outperformed students who took the three-semester sequence in 12 concept categories: scientific method,

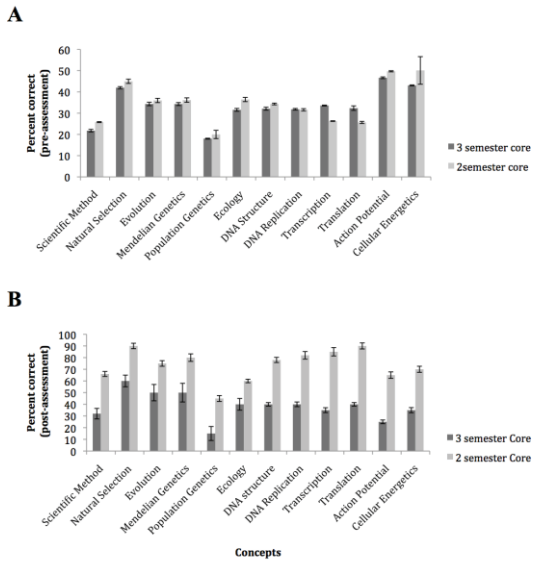

Fig. 3. Conceptual Learning Gains. (A) Pre-assessment. (B) Post-assessment. Differences between the 3-semester and the second semester post assessment data were significant ($p<0.001$).

natural selection, Mendelian genetics, population genetics, ecology, DNA structure, DNA replication, transcription, translation, action potential, and cellular energetics. Faculty members were invited to give guest lectures and write activity problems for several concepts. For instance, Mendelian and population genetic problems were designed by the faculty who teach in the upper division Genetics course. The included problems were examples of some of the basic concepts students have difficulty in their upper division Genetics course. The department's neuroanatomist gave guest lectures on the nervous system and wrote conceptual problems that included action potential. One of the instructors, a cell biologist, designed kinesthetic modeling activities to reinforce the concepts of DNA replication, transcription, and translation. In these kinesthetic activities, students create models of these processes using props and themselves as part of the models. The models, then, were scored for accuracy.

Pass rates

Pass rates were compared between historical data (2005-2009) and students who agreed to participate in this study (2010-2012). Comparisons were made with appropriate course equivalencies (Tables 1 and 2; Fig. 4A-B). Thus, the Plant Biology and Animal Biology (one semester each) courses were compared with the Foundations of Biodiversity (one semester) course. Cell Biology, the third course in the three-semester sequence, was compared with the Foundations of Cell Biology & Physiology, the second course of the two-semester sequence. Data analysis indicated no statistically significant difference between the pass rates of the two-semester, taxonomy-heavy, Plant Biology and Animal Biology courses (77.37% +/- 9.87) and the Foundations of Biodiversity course (86.17% +/- 7.69, Fig. 4A). However, there was a statistically significant difference between the pass rate of Cell Biology (63.9% +/- 4.34) and the Foundations of Cell Biology & Physiology course (85.9% +/- 4.04, Fig. 4B).

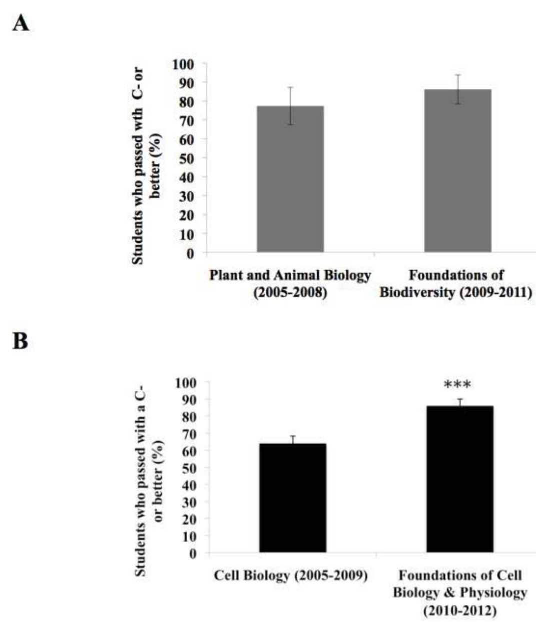

Fig. 4. Pass rate comparisons between the three- and two-semesters' sequence. (A) There were no statistical significant differences between the pass rate of Plant Biology and Animal Biology and the first semester of the two-semester sequence (Foundations of Biodiversity), $p>0.5$. (B) Significant increased pass rate of students enrolled in the second semester of the two-semester sequence (Foundations of Cell Biology & Physiology). $^{***}p<0.001$.

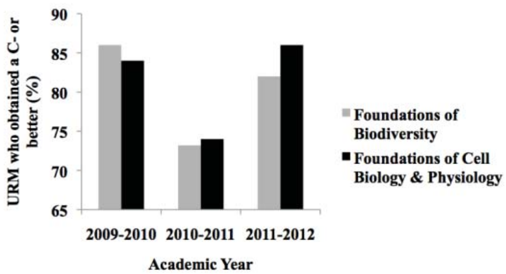

Fig. 5. URM pass rate in the two-semester sequence

The URM pass rate was also calculated for students enrolled in the two-semester sequence (2009-2012). Fig. 5 shows the percentage of URM students who obtained a C- or better. For academic year 2009-2010, the pass rates were 86% and 84% in the first and second semester, respectively. However, it is important to note that this sample size was small, 7 students in the first semester and 6 students in the second semester. For the academic year 2010-2011, the first year of implementation, the pass rates were 73.2% and 74% in the first and second semester, respectively. The sample size was 36 students in the first semester and 20 students in the second semester. For the second year of implementation, 2011-2012, the URM pass rate increased to 82% and 86%, for the first semester and second semester, respectively. The sample size was 38 students in the first semester and 28 students in the second semester.

Students Perceptions about their own learning

SALG results captured students' perceptions about what components of the class were beneficial to their own learning gains (Table 4). Overall, students found the activity sections to be the most beneficial aspect of the 2-semester course sequence.

All the students interviewed believed that they were ready for advanced biology coursework. Students appeared pleased at their ability to make connections among concepts. They stated that they better understood "*how science works*". The most surprising finding was the use of social media as a study tool.

Student Research Projects

Students performed a 4-week research project in each lab component of the two-semester sequence. During the first semester, students were responsible for writing a research paper presenting their findings. During the second semester, students were expected to present a group poster presentation of their research project. A biodiversity project was used in which in semester one, students examined plant biodiversity using traditional field techniques, and during the second semester students examined the genetic diversity of mitochondrial genes of the samples

Table 4. Active learning techniques used to teach concepts with statistically significant learning gains.

Concept	Class Component	Technique
Scientific Method	Labs in both courses	Two, 4-week Research Projects
Natural Selection	Activity	Simulation
Evolution	Activity	Simulation
Mendelian Genetics	Lab	Fruit fly Crosses
Mendelian Genetics	Activity	Quantitative Group Problems
Population Genetics	Activity	Quantitative Group Problems
DNA Structure	Activity	Conceptual Group Problems
DNA Replication	Activity	Kinesthetic Group Modeling
Transcription	Activity	Kinesthetic Group Modeling
Translation	Activity	Kinesthetic Group Modeling
Action Potential	Activity	Conceptual Group Problems
Cellular Energetics	Activity	Conceptual and Quantitative

collected during the first semester. Students in the pilot were surprised at realizing the connections between fieldwork and genetic analysis. However due to logistical issues, research projects were unlinked during implementation. Students thought that the research project assignments (group research projects, research papers, and poster presentation) helped their learning (Table 5).

Student poster research presentations were videotaped and analyzed. After examining the video presentations, patterns in the qualitative analyses indicated that students were able to: 1) use scientific terminology contextually and with fluidity; 2) recall and sequence information consistent with accepted scientific practices; 3) locate and apply useful information; 4) employ lab techniques to answer questions and test hypotheses; and 5) consider alternative explanations.

DISCUSSION

Success and pedagogical objectives were achieved in the implementation of the two-semester sequence. Pass rates were significantly increased in the most difficult part of the freshman sequence. This increase was not the outcome of making the sequence easier. Exams consisted of conceptual questions in which students were expected to demonstrate information synthesis rather than a memorization of factoids. Students had to demonstrate concept understanding by performance in both the activity/problem solving and lab sections and by communicating research findings technically in both oral and written form. Of the strategies we implemented into the two-semester sequence, problem solving (Freeman et al., 2007) and group discussions (Dori and Belcher, 2005), have been shown to increase pass rates.

All five pedagogical objectives were met in the two-semester sequence. Four of these relate to the goal described by the Vision & Change Report (American Association for the Advancement of Science, 2011) of students understanding and utilizing the scientific process. In the research projects portion of the labs, students formulated testable hypotheses, worked effectively in groups, used multiple approaches to answer complex questions, and constructed logical conclusions based on the data they collected. The quantitative analysis objective was met during the activity/problem-based sections.

Conceptual gains and increased pass rates

Both the three-semester and two-semester sequences have comparable learning gains in 15 of the concepts assessed (Table 1). At first, this result may suggest that the active learning strategies we implemented in our sequence were not very effective. However, this should be considered a success considering that the content was reduced by a third (from three to two semesters).

Analysis of the data collected showed differences in concept learning gains in two

Table 5. Students' perceptions about the effectiveness of research projects on their own learning gains.

HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING? N=220 students	1:no help	2:a little help	3:moderate help	4:much help	5:great help	Mean +/- St.Dv.
Final lab paper Fall semester	5%	22%	37%	26%	10%	3.2 +/- 1.07
Final lab poster Spring semester	5%	15%	30%	25%	25%	3.5 +/- 1.19
Final Research paper spring semester	5%	21%	37%	26%	11%	3.2 +/- 1.07
Group research projects	10%	15%	25%	35%	15%	3.3 +/- 1.22

different situations. First, students enrolled in the three-semester sequence obtained higher learning gains in concepts that were not covered in the new sequence. These gains were in the areas of animal and plant taxonomy and alternative splicing. Second, students who took the two-semester sequence obtained higher learning gains in 12 concept categories where active learning strategies were developed and used. These concepts were reinforced in lab or activity sections with techniques that were developed to help different types of learners (Table 4). The incorporation of active learning techniques in STEM education have been recommended by national reports (NRC, 2015; PCAST, 2012) and have been shown to be effective in increasing academic success in introductory STEM courses (Freeman, et al., 2014; Freeman et al., 2007).

Our data suggest that most of URM students passed our re-developed sequence. However, our URM sample size was too small and we did not evaluate the reasons for this success. The researchers surmise that peer interactions in the activity/problem solving sections contributed to URM success. The 22-student activity/problem solving section with a faculty facilitator provides the environment with greater and more meaningful student interactions that can result in greater academic success (Snyder et al., 2016; Preszler, 2009).

Team-based learning in the activity/problem solving sections

Students self-reported that the most effective portion of the new sequence was the weekly, activity/problem solving section (Table 3). These sections can be described as modified team-based learning or TBL (Metayer et al., 2014). TBL provides means to improve cognition as this approach allows students to analyze data and evaluate information (Metayer et al., 2014). TBL is also an active learning strategy that incorporates problem solving, group discussions, and technology-based activities (Gardner & Belland, 2012). Moreover, TBL is based on evidence-based teaching (Leisey et al., 2014).

In our modified TBL sections, groups were not pre-formed and the assessment was not based on quizzes but on either graded group problems or accuracy of kinesthetic models. Peer feedback and evaluation was part of our modified TBL strategy. In our activity/problem solving sections, students worked in groups to solve conceptual and quantitative problems, build kinesthetic models, and use computer simulations to extend their learning beyond what was covered in lecture.

CONCLUSIONS

Our data collection and analyses were not designed to determine specific strategies that resulted in students' success as evidence by an increase in pass rates, concept learning gains, and positive attitudes toward biological research. We used a collection of active learning strategies that might have helped our students learned the concepts, but we also changed the entire structure and organization of the class. Based on our results, we suggest that the incorporation of active learning strategies and a re-examination of an entire course structure and delivery in tandem are essential in order to increase students' ability to build high levels of conceptual understanding.

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