STEM GATEWAY

FINAL REPORT: BIOL 203/203L Course Redesign Project

Abstract

The goals of the Ecology and Evolution BIOL 203/203L redesign were to create laboratory activities that 1) reinforced lecture material, 2) focused on inquiry-based and active learning, 3) improved quantitative skills, and 4) engaged students in UNM-based or New Mexico-based research. Redesign was initiated in March 2015 by faculty members Jennifer Rudgers (lead), Ken Whitney, and Seth Newsome, Lecturer and Lab coordinator Cara Lea Council-Garcia, and graduate assistant Eva Dettweiler-Robinson. A key purpose of redesign efforts was to improve retention, particularly of under-represented minority students, in the core biology curriculum. BIOL 203 has been a bottleneck because the students cannot proceed through the core curriculum without passing both the lecture and lab section. Previously these components covered distinct material; redesign focused on integration and enhanced complementarity to increase student learning. The design was focused around building all new, inquiry-based and active learning exercises to improve student learning in both lecture and laboratory, as well as to increase retention of under-represented groups. A stronger emphasis on quantitative skills was intended to build these skills earlier in the core curriculum. A focus on NM-based research was intended not only to increase student engagement by using local examples and datasets but also to facilitate earlier matriculation of undergraduate students into research labs.

We developed student learning goals for each lab and for the entire course, and we revised the course assessment plan accordingly. We then created and implemented 14 new teachable units, produced a new 226-page laboratory manual, developed accompanying online resources, instructor resources for TAs, and lab prep notes, and generated novel and potentially publishable student-led data. Two of us (Rudgers, Dettweiler-Robinson) attended the National Academies workshop on Course Based Undergraduate Research Design during summer 2015. We built new laboratory exercises during summer and fall 2014, then piloted them with a small group of graduate student teaching assistants during fall 2015. We rolled out the first semester of redesign during spring 2016 for a cohort of 141 students.

To assess our progress, we began surveying students for outcomes, successes, and attitudes in May 2015. Thus far, we have built datasets for three semesters pre-redesign and two semesters post-redesign. We found that student learning in both ecology and evolution increased following course re-design, with a 2.4- to 7.3-fold increase in success on some concept inventory questions relative to pre-redesign scores. Other questions did not indicate post-redesign improvements in learning, perhaps indicating poor question design. Students perceived that the new activities improved their ability to create and interpret graphs and charts, work with real data, and write in a scientific format. Students also perceived that new laboratory activities improved their understanding of lecture material by as much as 39%. We found that student grades in the lab increased by 4–7% following the first semester of implementation of course redesign.

We have made improvements to the course by continually revising the teachable units based on input from students, faculty, teaching assistants, and prep teams during both spring and summer 2016. We intend to sustain revisions through our continued involvement in teaching the course and dedication to making materials available to instructors at other institutions. Significant revisions already include a substantial revision of the grading rubric in response to the challenge of grading weekly written assignments for ~48 students per TA and creation of sample assignments to help students better understand expectations and improve their writing and critical thinking accordingly. Midway through our first semester, we implemented new pre-class quizzes to increase student preparedness prior to each lab. After the first semester of redesign, we also created new curriculum to improve student perception of their understanding of primary literature, including new in-class discussions. Recognizing that the amount of content in some teachable units posed a challenge for students and teaching assistants, we further refined activities and material to include a smaller number of key points as part of the revisions made during summer 2016.

We plan to distribute teaching units to interested instructors and have already shared materials with another minority-majority institution. We have made resources easily accessible to other instructors through extensive documentation that accompanies each teachable unit, including lab manual materials, teaching how to documents, annotated powerpoint presentations, online quiz banks, and lab prep documents.

Project Motivation and Objectives

We were motivated to redesign BIOL 230/203L because it is an early gateway course for retaining students in the Biology major. BIOL 203 and BIOL 203L are typically taken by second year undergraduates. Historically, BIOL 203L has been an impediment to retention and graduation because students achieving a passing grade in the lecture course do not pass the lab. The prior 203L lab was entirely independent of the lecture (the former focused on diversity of life, while the latter focused on general principles of ecology and evolution). The redesign aimed to create a complementary lab in order to give students deeper exposure to the lecture material, improve student success in both courses, and build quantitative and critical thinking skills that are critical for upper division coursework.

Objectives and Rationale:
(1) Create a new laboratory that complements lecture with laboratory exercises that focus on the application and analysis of lecture topics.

To build new teachable units for the redesign, we first developed new Course Goals and course-level Student Learning Objectives, which are now formalized as part of the departmental and university course assessment plan for this course and the Biology core curriculum (Table 1).

(2) Design lectures and laboratories that include inquiry-based, active learning and student-collaborative learning.

Inquiry-based labs teach students the process of science, creating more competent researchers and deepening critical thinking skills. Inquiry-based labs increase recruitment and retention because students recognize their ability to contribute to science, have opportunities to develop professional skills, and begin to move away from the perception of learning as studying a body of facts.

Collaborative learning promotes learning and retention of underrepresented students. Social, collaborative learning is more closely aligned with cultural learning experiences (Sanchez 2000) that are common among Hispanic and Native American students.

(3) Develop laboratory exercises that focus on quantitative skills and correspondingly increase the lecture material devoted to analysis and models.

The development of quantitative skills and toolsets builds bridges between biology and other disciplines (e.g., mathematics, physics, chemistry) that can increase student performance across STEM fields.

(4) Feature research by UNM Biology faculty and New Mexico-based research in both lecture and laboratories.

We hypothesized that students who interact with meaningful data from local, ongoing and cutting-edge research will be more engaged in the learning process and more likely to remain in STEM fields. A subset of students will be able to target their area of interest more quickly than in a traditional classroom, and become involved with current research earlier in their careers. Key benefits that R1 institutions provide to undergraduates include exposure to and engagement in the most cutting-edge research. Our course reform leveraged these benefits by creating synergies between UNM teaching and research.

Table 1. Revised Course Goals and SLOs following BIOL 203/203L course redesign efforts.

I. Course Goals

A. Students will demonstrate an understanding of key principles in ecology and evolution.
B. Students will be able to apply ecological and evolutionary concepts to problems faced by modern society.
C. Students will demonstrate a capacity for visualizing and analyzing quantitative, biological data.
D. Students will be able to create and edit written documents that summarize and interpret findings of research activities.
E. Students will be able to read, distill, and interpret primary scientific literature.
F. Students will be able to design, test, and evaluate scientific hypotheses in ecology and evolution.
G. Students will be able to collaborate effectively in teams to organize and prioritize work.

II. Student Learning Outcomes

SLO 1: Students will be able to evaluate the forces of evolution that are acting upon a real or hypothetical population. (UNM/HED Area 3, Competency 1)

SLO 2: Students will be able to explain the concept of "species" and the most important mechanisms by which new species arise. (UNM/HED Area 3, Competency 1)

SLO 3: Students will be able to analyze relatedness among organisms, including using data to evaluate the theory of common descent (UNM/HED Area 3, Competency 2, 4)

SLO 4: Students will be able to apply quantitative models to predict how single species populations grow and are regulated (UNM/HED Area 2, Competency 2, 3; UNM/HED Area 3, Competency 4)

SLO 5: Students will be able to predict the structure and function of communities as a function of biotic and/or abiotic drivers. (UNM/HED Area 3, Competency 1)

SLO 6: Students will be able to describe how energy and nutrients move within and between biotic and abiotic components of ecosystems via physical, chemical and biological processes (UNM/HED Area 3, Competency 3, 4)

SLO 7: Students will be able to use ecological and evolutionary principles to propose solutions to applied problems, such as designing a restoration strategy or increasing agricultural production. (UNM/HED Area 3, Competency 5)

SLO 8: Students will be able to write scientific research briefs that include an introduction, methods, results and discussion. (UNM/HED Area 1, Competency 2, 4; UNM/HED Area 3, Competency 3)

SLO 9: When presented with data, students will be able to show the data in an appropriate visual format and interpret the data in light of core ecological and evolutionary theory. (UNM/HED Area 2, Competency 1; UNM/HED Area 3, Competency 4)

SLO 10: When presented with text from the primary literature, students will be able summarize and interpret the information, using clear, concise language. (UNM/HED Area 1, Competency 5; UNM/HED Area 3, Competency 3, 5)

SLO 11: Students will be able to design a study that tests a scientific hypothesis in ecology or evolution and then evaluate results in light of their hypothesis. (UNM/HED Area 3, Competency 1, 2, 3, 4)

SLO 12: Students will be able to assume different roles within a group and articulate key principles of effective group work. (UNM/HED Area 1, Competency 6)

Project Summary

For the lab redesign, we started from scratch and produced entirely new activities for the semester. Because of the large number of students and UNM's urban setting, we focused on collecting and analyzing datasets in ecology and evolution to teach the nature and process of science in the classroom (rather than the field). We focused new course content on research that is based in New Mexico and/or conducted by UNM faculty.

To develop new skills for effective redesign, in addition to UNM STEM Gateway workshops, two of us also attended the National Academies Special Topics Summer Institute on Course-based Undergraduate Research Experiences (CURE Summer Institute) (Rudgers and Dettweiler-Robinson). This working meeting allowed us to learn about and use evidence-based teaching strategies to develop CURE teachable units for our redesign. Working sessions focused on the features of science research projects that lend themselves to CUREs, and on teaching CUREs using evidence-based teaching strategies, such as active learning, assessment, and mentoring.

We then solicited datasets, data 'nuggets,' and hands-on learning problems from UNM faculty and other colleagues. Dettweiler-Robinson gathered further data on effective labs by submitting a survey on memorable undergraduate laboratories to a popular Ecology and Evolution blog. Because we intended students to engage in authentic problem-solving in the lab, rather than "cookie-cutter" exercises where the outcome is known, we invested substantial time in developing original resources.

We hypothesized that research-based activities that connect students to the local environment and to ongoing research at UNM will more deeply engage students in the learning process and bridge transitions into independent research projects (e.g., senior honors theses) with UNM faculty. While we have only implemented one semester and one summer of the new course, tracking student progress, retention, and learning as part of the course redevelopment will aid in evaluating this hypothesis over the long-term.

Specific Activities:
We completed the following specific activities during redesign efforts.

(1) Integrate lecture information with the hands-on activities and discussions that occur in the lab.

Reinforcement based on application of the material will increase learning and retention, especially when addressing common misconceptions in evolution and ecology (Hoskinson et al. 2013, Sundberg 2003). Rudgers, Newsome, and Whitney developed lecture materials for BIOL 203 that are used by the team of instructors who teach this course each semester. We used these lecture materials as a source of inspiration for developing new laboratories that would reinforce the previously developed lecture material. We also directly incorporated overlapping and complementary material into TA lectures for the new laboratory.

(2) Increase active and collaborative learning to improve student success, based on research by Sanchez (2000), Hoskinson et al. (2014), and Freeman et al. (2014).

Each new laboratory teachable unit is divided into two components. First, students work in pairs or small groups to learn key skills, tools, models, or statistical techniques as part of a Tool Skill exercise. Second, students apply these new skills to a new Research Activity, many of which are self-directed and generate new data. Students must distill and interpret relevant scientific literature and their new data in weekly Research Briefs, which are the main form of graded course assessment. Active learning elements we incorporated into the redesign include: weekly iclicker quizzes at the beginning of every lab section to jump-start critical thinking with low-stakes grading, weekly in-class small group data collection and analysis or problem solving as part of the Tool Skill and Research Activity components of each lab, in-class discussion of primary literature for a subset of teachable units, an in-class student debate (one unit), and a capstone (final lab) project applying ecological principles to a complex and authentic conservation problem. In fall 2016, we will increase the use of in-class clicker questions and activities (think-pair-share), which will now constitute 10% of the grade for the lecture course.

(3) Increase course structure to improve student outcomes for first generation college students and underrepresented minorities than for other student sub-populations (Eddy and Hogan 2014).

Key, new elements we incorporated into the laboratory redesign include weekly pre-lab quizzes, weekly in-class clicker questions, and weekly written Guided Research Briefs (worksheet style reports with guided questions) or full Research Briefs (scientific paper format). In fall 2016, we are implementing 10 new pre-lecture quizzes (10% of grade) to increase structure of the lecture course.

Deliverables:

(1) Fourteen new teachable units for the laboratory that focus on quantitative skills, inquiry-based learning, and small group work.

(2) Completely new Lab Manual (226 pages)

(3) CURE Dataset #1: New data on fungal growth rates alone and in competition which serve to characterize the ecology of root-associated fungi from Chihuahuan Desert soils for the first time (Rudgers, Chung, Dettweiler-Robinson, Robinson).

(4) CURE Dataset #2: New, student-curated museum data for bat species identities based on original recordings of bat calls throughout the state of New Mexico (provided by Dr. Bill Gannon).

Assessment

Below, we present data obtained as part of our course redesign assessment plan, subdivided into three categories: Learning, Success, and Attitudes. Learning reflected student performance on concept inventory questions delivered during the first and last week of each class. Success was assessed through changes in student's final grades, and Attitudes were assessed with an end of semester survey (8 questions), some of which required students to assess the collective impact of lab plus lecture. We do not have access to student demographic data (gender, race, ethnicity) at this time.

Assessment: **Learning**

We delivered pre- and post-class surveys. Our survey instrument included five questions in Evolution and five questions in Ecology, similar to concept inventory questions approved for biology (Fisher and Williams 2011). Some of our questions performed poorly. Thus, we only present results from questions that did not result in high student success at the beginning of the survey (leaving little room for us to see improvement) or negative change from beginning to end.

Questions were designed as either single correct answer (binomial data) or choose all that apply (proportional correct data). For these analyses, we focused on Fall 2015 and Spring 2016 datasets only because summer class sizes were small, limiting the effectiveness of the paired design, and because in Spring 2015 we only surveyed students at the end of the semester.

To determine the change in performance pre- versus post-completion of the course, we compared scores on the same questions at two time points, paired by student identity. For binomial data we used generalized linear mixed effects models with the random effect of student identity, which paired the beginning and end scores of each student. Models included the fixed factors of semester, timing (pre/post), and the semester x timing interaction. A significant interaction would indicate that the magnitude of difference between pre-class and post-class assessment significantly differed among semesters. Our expectation was that the magnitude of pre/post difference would increase following implementation of our course redesign. Binomial models were run in <glmer> within the {lme4} package (R Core Team 2016), using maximum likelihood and a binomial distribution family. For proportional data, we used Gaussian general linear mixed effects models, with the random effect of student identity and the fixed factors of semester and timing (pre/post). These models were implemented in lmer in the {lme4} package. In all cases, we report analysis of deviance results with Chi-Square (X^2) statistical tests. To evaluate results, we additionally calculated pre/post **effect sizes** using the formula: [(post score – pre score)/pre score x 100].

Evolution questions
Of our five evolution questions, only one showed stronger pre/post improvement following the course redesign. Student performance on Q5 ("Eukaryotes are thought to have originated when a prokaryote engulfed another prokaryote; the latter then gave rise to some of the organelles in the cell (True/False)") increased by an effect size of 55% from pre to post, prior to course redesign (log odds $\pm$ s.e., pre=1.7$\pm$0.4, post=2.8$\pm$0.6), but increased by an effect size of 160% following course redesign (pre=1.3$\pm$0.4, post=3.5$\pm$0.7). Thus, course redesign increased student learning by 2.9-fold. For two other evolution questions (Q1: "Look at the phylogenetic tree. Which two species are **more** closely related: (multiple choice)", Q3: "Which of these processes results in **random** changes in allele frequency from one generation to the next? (list all that apply)"), student performance increased substantially following completion of the course, but the magnitude of this increase was similar both before and after implementation of the course redesign. For one question (Q4: "There was a single origin of all extant life on earth (True/False)"), student learning declined following redesign: a 125% increase pre to post in Fall 2015, and only a 3% increase in Spring 2016.

Ecology questions
Of our five ecology questions, three showed greater student improvement following course redesign than prior to course redesign (Table 2, Q6: "For **most** natural populations, if you plotted population size over time, your graph would look like: (multiple choice)", Q9: "Two species can each eat two food resources. Which of the following describes an outcome(s) that shows evidence that the two species are competitors. (list all that apply) ", Q10: "Which of the following components are part of or affect the global carbon cycle (list all that apply)?"). For Q6, the magnitude of improvement (effect size) was 220% prior to redesign and 540% after redesign (2.4-fold change). For Q9, the magnitude of improvement was 9% prior to redesign and 30% after redesign (3.4-fold change). For Q10, the magnitude of improvement was 170% prior to redesign and 1250% after redesign (7.3-fold change). The other two were poor questions that did not show significant student improvement pre- versus post-completion of the course in any semester.

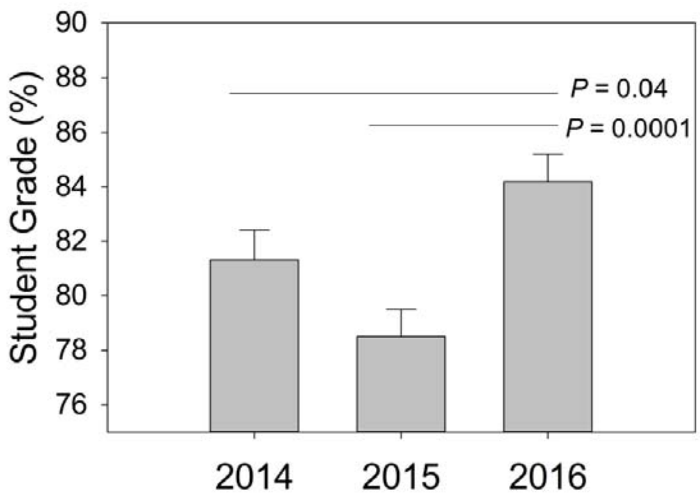
Table 2. Summary of results from mixed effects models examining change in student outcomes on concept inventory questions pre- and post-completion of the course. We compared two semesters: Fall 2015 and Spring 2016.

	Semester		**Timing (pre/post)**		**Semester X Timing**		**Qualitative result**
	X^2	*P*	X^2	*P*	X^2	*P*	
Q1	0.10	0.761	13.65	**<0.001**	2.43	0.119	Similar improvement pre/post
Q2	5.56	0.018	4.07	**0.044**	11.40	**<0.001**	Poor question: performance was higher pre than post
Q3	0.10	0.752	3.83	**0.050**	0.12	0.733	Similar improvement pre/post
Q4	0.00	0.980	8.50	**0.004**	4.35	**0.037**	Less improvement post-redesign than pre-
Q5	0.94	0.333	5.64	**0.018**	3.37	***0.066***	**More improvement post-redesign than pre-**
Q6	0.09	0.770	8.75	**0.003**	3.05	***0.081***	**More improvement post-redesign than pre-**
Q7	1.11	0.293	1.22	0.267	1.62	0.203	Poor question
Q8	0.73	0.392	0.30	0.584	0.03	0.855	Poor question
Q9	0.48	0.487	2.65	0.103	6.26	**0.012**	**More improvement post-redesign than pre-**
Q10	12497.90	**<0.001**	10597.700	**<0.001**	248308.50	**<0.001**	**More improvement post-redesign than pre-**

Assessment: **Success**

We tracked changes over time in the laboratory grade for 203L. To contrast comparable cohorts, we focused only on Spring semester (we have not implemented redesign during Fall semester yet) and used student course grades (converted from letter grade to percentage) from 2014 and 2015 as pre-redesign comparisons, with each student as an independent replicate. ANOVA revealed a significant effect of year on grades ($F_{2,2497} = 7.9$, $P = 0.0004$). Course redesign increased the average student grade by 4% compared to pre-redesign grades in 2014 and by 7% compared to pre-redesign grades in 2015 (Fig. S1).

Fig. S1. Mean with s.e. for each year of BIOL 203L. Years 2014 and 2015 are pre-redesign, 2016 was the first semester of course redesign. *P*-values come from planned pairwise contrasts.



We do not have 2016 grades for lecture yet, nor do we yet have access to student demographic data (race, gender, major).

Assessment: **Attitudes**
We instituted student surveys beginning Spring 2015 to acquire pre- and post- course redesign data on student attitudes toward their learning. The surveys included the eight questions to assess attitudes at the end of the semester. Surveys were completed on paper documents in each lab section. Student scores were ranks using a scale of (1) not at all, (2) a little, (3) moderately, or (4) substantially, with one possible answer for each question. We analyzed student data with ANOVA with the response variable of rank and the fixed factor of semester using the function <lm> in the {stats} package in R (R Core Team 2016). For pairwise contrasts between each semester/summer, we used the Benjamini–Hochberg procedure for false discovery rate (FDR correction) for multiple comparisons with <lsmeans> in the {lsmeans} package (R Core Team 2016); significant pairwise differences are shown by different letters in the figures below. Sample sizes (number of students) per semester are reported on the bottom of the bars in Figures A1-8; summer sample sizes are always low.

Student attitudes improved substantially following course redesign. Students reported, on average, a 36-39% increase in their understanding of lecture material following the redesign (Fig. A1, $F_{4,456} = 20.2$, $P < 0.0001$). Perceived improvements in understanding of mathematical models increased by 15% (Spring 2016) to 25% (Summer 2016) compared to pre-redesign scores (Fig. A2, $F_{4,456} = 6.9$, $P < 0.0001$). We produced large gains in student perceptions of their graphical and database literacy, with a 24-25% increase in post-redesign survey responses relative to pre-redesign (Fig. A3, $F_{4,456} = 14.5$, $P < 0.0001$).

Fig. A1. Student attitude ranks in response to the question: *The lab section of this course improved my understanding of lecture material.* Bars show means ± s.e.

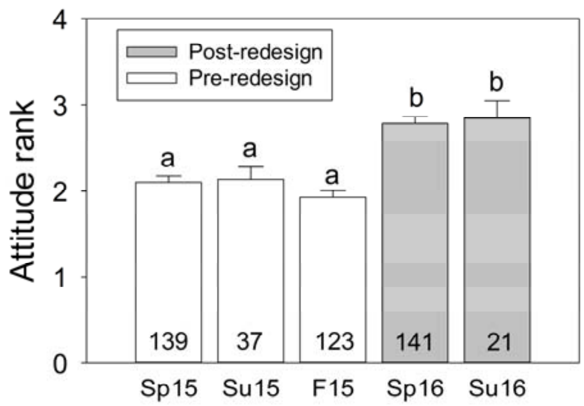


Fig. A2. Student attitude ranks in response to: *This course (lecture + lab) helped me to learn how to apply fundamental models (mathematical equations) in evolution and ecology.* Bars show means ± s.e.

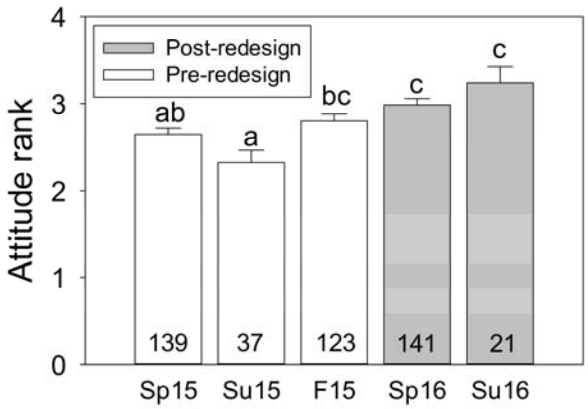
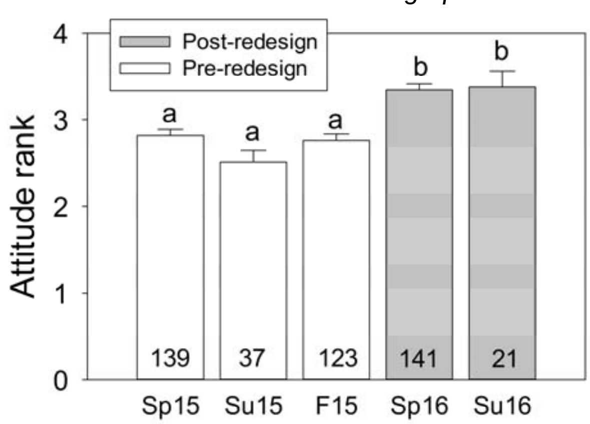
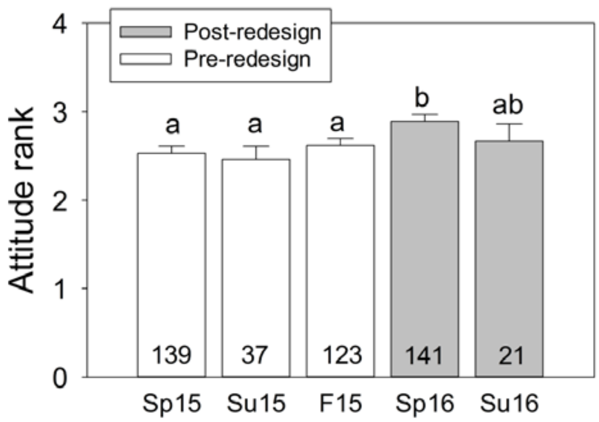


Fig. A3. Student attitude ranks in response to the question: *This course (lecture + lab) helped me to learn how to work with real data and read graphs and charts.* Bars show means ± s.e.



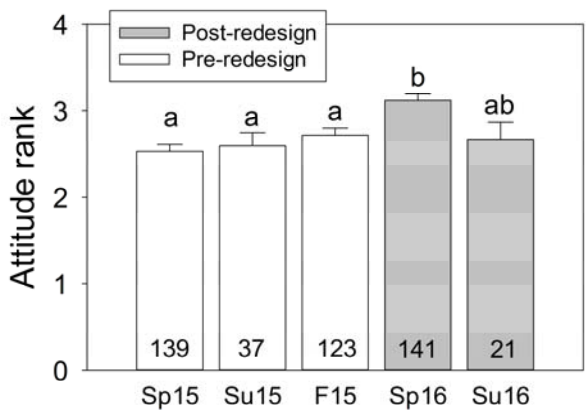
The student experience of collaboration with diverse peers in the classroom improved following course redesign, with a 14% increase during Spring 2016 relative to pre-redesign survey scores (Fig. A4, $F_{4,455}$ = 3.6, P= 0.007). It is not surprising that the attitude shift toward diversity was small (5% increase) and non-significant during summer 2016 (Fig. A4) because summer class sizes are small and less diverse.

Fig. A4. Student attitude ranks in response to the question: *This course (lecture + lab) gave me competency in collaborating with diverse groups of people.* Bars show means ± s.e.



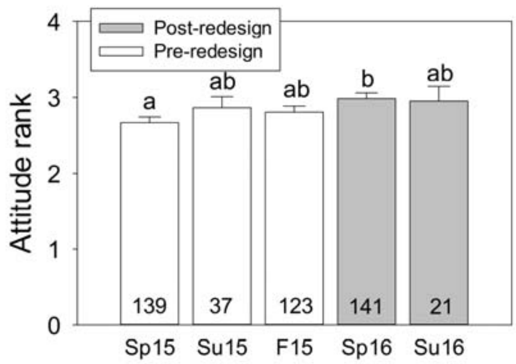
Student perception of their writing skills was strongly affected by course redesign, with a ~20% increase during Spring 2016 relative to the average of pre-redesign survey scores (Fig. A5, $F_{4,455} = 7.9$, $P < 0.0001$). We interpret this as a direct result of the weekly writing assignments (Research Briefs) that were a new element of the redesign.

Fig. A5. Student attitude ranks in response to the question: *This course (lecture + lab) improved my scientific writing.* Bars show means ± s.e.



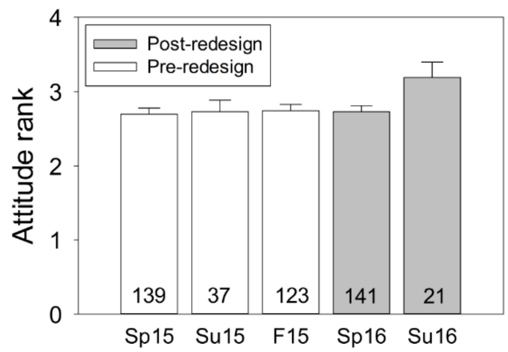
There were small or no gains in other attitude metrics, suggesting areas for further improvement. Some of these smaller gains may have occurred because survey questions required that students evaluate lecture and lab components jointly in their answer. We have not yet implemented large changes to the lecture format because the redesign team will teach the lecture for the first time during Fall 2016. For example, students reported only an 8% increase in their understanding of the scientific process in spring 2016 (post) compared to spring 2015 (pre), with non-significant differences among other semester pairs (Fig. A6, $F_{4,456} = 2.4$, $P = 0.05$).

Fig. A6. Student attitude ranks in response to the question: *This course (lecture + lab) increased my understanding of the scientific process.* Bars show means ± s.e.



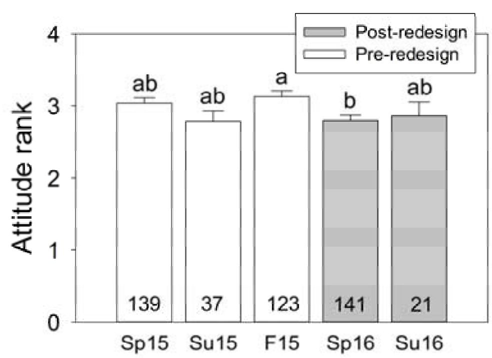
We were surprised to find that students reported no significant gains in their level of interest in the subject matter (Fig. A7, $F_{4,456} = 1.3$, $P = 0.29$). This metric increased by 17% between summer 2015 and summer 2016; however, because summer class sizes were small, statistical power for this contrast was low.

Fig. A7. Student attitude ranks in response to the question: *This course (lecture + lab) allowed me to engage in learning and discovery on topics that interest me.* Bars show means ± s.e., all differences n.s.



Student perception of their understanding of primary scientific literature declined by 11% between Fall 2015 (pre-redesign) and Spring 2016 (first implementation of the redesign) ($F_{4,456} = 3.0$, $P = 0.018$), although other pairwise contrasts were not significantly different (Fig. A8).

Fig. A8. Student attitude ranks in response to the question: *This course (lecture + lab) helped me to learn how to read, distill, and synthesize primary scientific literature.* Bars show means ± s.e.



Future Assessment Activities:

We intend to continue surveys during 2016-2017, with the addition of some new concept inventory questions. We have not yet met our goal of disaggregating student subpopulations (different underrepresented minority groups, first generation college students) to refine data analysis and specifically target activities that benefit URMs and first generation students. We also will collect student data that assesses student values and behaviors in the course (time spent outside of class, classroom culture, course value).

Improvements

We have continually improved redesign efforts and plan to implement future refinements. To improve student success, we will continue to refine materials for both laboratory and lecture, focused on assessment questions (surveys) and exam questions (formal course assessment plan) which show low/no improvement in student success. To improve student perceptions, during Summer 2016, we changed several of the primary scientific readings to tighten the connection between the reading and the inquiry-based work. We also implemented a new process and TA instruction for how to discuss and interpret the literature during laboratory class time. We have also increased attention to student meta-cognition and course buy-in with new written and oral materials (for TAs and lectures) to be implemented during fall 2016. We are curious to see whether these changes will shift student attitudes during fall 2016 and beyond.

Specific improvements include a complete revision (during summer 2016) of the grading rubric in response to the challenge of grading weekly written assignments for up to 48 students per TA (to be implemented fall 2016). Recognizing that the amount of content in some teachable units posed a challenge for students and teaching assistants, we further refined activities and material to include a smaller number of key points during revisions made summer 2016. We also created qualitatively similar samples of assignments to help students better understanding expectations and improve their writing accordingly. Midway through our first semester, we implemented new pre-class quizzes to increase student preparedness prior to each lab. After the first semester of redesign, we also created new curriculum to improve student perception of their understanding of primary literature, including new in-class discussions.

Expansion

Because the laboratory component is entirely new and is taught by graduate student TAs, expansion will be global to all sections. We anticipate approximately 120-150 students per semester in Fall 2016 and Spring 2017. Cara Lea Council-Garcia trains the graduate student TAs in weekly meetings. Rudgers and Whitney co-teach the lecture course during fall 2016, and Newsome will teach the Ecology portion of the lecture in Spring 2017. The incorporation of changes to the lecture will likely be slower than changes to the laboratory. However, we have agreement from all faculty that currently teach the course that they are willing to participate (even if not members of the redesign team); and there is general agreement that course redesign is necessary. During Spring 2016, lecture faculty used the lecture materials that we developed, we aim to have a single set of lecture materials adopted by all faculty lecturers (with minor, personal modifications). Making all materials available will (hopefully) facilitate the continued development of materials and their transfer.

Sustaining

We see no impediments to sustaining the laboratory redesign into the future. Because we engaged in a complete overhaul, it would not be possible to revert to prior materials. Our teachable units are fully curated and easily accessible by outside instructors. We plan to distribute teaching units to interested professors and have already shared materials with another minority-majority institution. We have made resources accessible to other instructors through extensive documentation in each teachable unit.

We plan to continue to assess outcomes and attitudes during 2016–2017. Plans for long-term data collection on retention in STEM would require additional funding, and we will seek out opportunities to fund further study of the success of the redesign. Our long-term goal is to generate a publishable dataset on effective teaching methods from the redesign.

(1) We have disseminated teaching units to an adjunct professor at Northern New Mexico college (69% Hispanic, 10% American Indian or Alaksan, 59% female) and plan to make teaching units available by request.

(2) We plan to continue surveys as well as add better questions to assess student learning Fall 2016.

(3) We have all documents for the students (lab manual, Learn resources), TAs (TA notes and additional helpful resources), and lab prep archived on Google Drive.

Challenges

Below, we separately enumerate major challenges for different personnel. We include our attempts thus far to address these challenges, and how we will continue to address them with further refinements to the redesign.

Challenges for the TAs:

(1) Grading of Research briefs is taking too long because students struggle with how to write cogently.

We have made several modifications. First, we changed some assignments to “Guided Research Briefs” with short answer questions. Students were still expected to think critically about the biology of the activity and interpret their results, however, they did not have to present the information in the structure of a scientific paper. This made it easier for the TAs to determine whether students had included the relevant answer rather than searching through long paragraphs. In addition, by front-loading these guided briefs at the beginning of the course, we hope to give students a better understanding of the structure and expectations of full Research Briefs.

We next revised the grading rubric to include one page of detailed (though not inclusive) instructions of what information is expected in each section for an adequate assignment. Additional points are available for the TAs to award for writing that shows clear thinking about the biological question and scientific process in addition to the specific items that the students are required to include. Additionally, we created a new, qualitative grading scale that provides clearer suggestions on how to improve on either the biological information or writing clarity. Finally, we provided new examples of “good”, “adequate”, and “needs work” Research Briefs for the students as further guidance.

We may initiate a peer review system to increase student metacognition about what makes a piece of scientific writing good or poor.

Challenges for the Students:

(2) Some students are missing the big picture/main point of the lab; for some labs, this was a majority of students during the first semester of implementation. Students also complained that the labs felt disorganized or full of “busywork” rather than seeing how the activities tied together to the theme of the lab.

We made several changes:

A) We created new TA lecture slides and “checklists” in the lab manual, showing marketable professional skills that they will acquire by completing the activities (including Excel skills, interpreting graphical information, and working in groups). We hope this also helps to inspire a new sense of professional identity as a scientist in our students.

B) We created new TA slide(s) for each lab that shows the roadmap of the lab activities and how the activities relate to each other (e.g., Tool Skill → Research Activity). In every TA lecture, we include the specific learning goals and notes for how TAs should explain to students why they are doing what they will be doing. We created a summary slide at the end of each lab to remind students of the big picture and how the exercises contributed to that big picture.

C) We replaced some of the activities with in-class discussions of the pre-lab reading or more time for analysis of the remaining assignments to focus on fewer key points, so that attention was not directed away from the big picture concepts of each lab.

We plan to continue to improve materials based on feedback from the weekly TA meetings, and to improve our ability to teach TAs how to best communicate the main point of the lab to students

(3) Students were not completing pre-lab activities, were not reading the lab manual before class, and arrived at class unprepared.

A) We created an online pre-lab quiz to provide incentive to complete the pre-lab activities before lab.

(4) All students in the team are not participating, even with the repeated mixing up of teams

A) We changed from a group of 4 to group of 2 format for most activities.

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