Bio 204 Lab reform: End of Second Summer Report

1. Project motivation and goals:

Biology 204 Plant and Animal form and Function was developed in 2004 and first taught in 2005 as part of a re-design of the Biology Department's core undergraduate curriculum (now consisting of Biology 201, 202, 203 and 204). Since then a core group of plant and animal biologists (Cara-Lea Council-Garcia, David Hanson, Marcy Litvak, Diane Marshall, William Pockman, Irene Salinas, Marieken Shaner, Eric Toolson, and Blair Wolf) have worked together to implement and refine the course in a consistent manner. Our goals in the 2004 re-design included the development of an inquiry-based learning lab and to develop critical thinking skills. We were able to build new lab spaces, equip them and design labs, however, we did not have funding to develop or implement a plan for student learning outcomes for the course. Therefore, we have only had anecdotal information about the successes and failures of our existing program with respect to our learning goals. Starting in fall of 2013, the lecture portion was separated from the lab portion, creating two separate (but closely linked) courses and making this a good time to take advantage of the STEM Gateway program to add learning outcomes and goals. After our team began attending the redesign workshops, we learned about new methods for teaching in small groups along with ways to assess learning in order to achieve our desired outcomes. Therefore, we have implemented new approaches to improve learning during lab as part of our work to define and assess our learning goals.

2. Project summary:

Our goal was to improve 204L course by implementing or enhancing the 5 elements derived from the Carl Weiman Science Education Initiative and the Top 25 Project as recommended in the UNM STEM Gateway call for proposals. Below is a list of each elements with what we did to implement them:

Element 1: specification of measurable learning goals

We created overall learning goals for each lab, for multi-lab modules, and for the entire course. These goals have also been aligned to complement learning goals for the sister lecture course.

Element 2: rigorous objective assessment of student achievement of learning goals

We added low stakes pre-lab formative assessments for each lab in an effort to discover misconceptions and to increase learning. These include new course-related readings with guiding and muddy point questions. We also revised and aligned the high stakes summative assessments with our learning goals. These included exercises to demonstrate quantitative analytical skills and to reflect on what they had learned in lab by relating it to the pre-lab.

Element 3: implementation of teaching methods aimed at maximizing achievement with respect to the specified goals

During lab we have added time to discuss what student are confused about from pre-lab materials and the prior weeks work, we also added a clearer review of learning goals for the day, created individual roles/duties for students within groups, and developed new example exercises using class data from prior semesters to help students achieve learning goals such as improving quantitative competency.

Element 4: means for easy dissemination of materials, methods, and technology

In addition to moving lab assignments and materials for all ten sections into UNM Learn (and training TAs and faculty on the use of Learn), we have implemented an entirely new

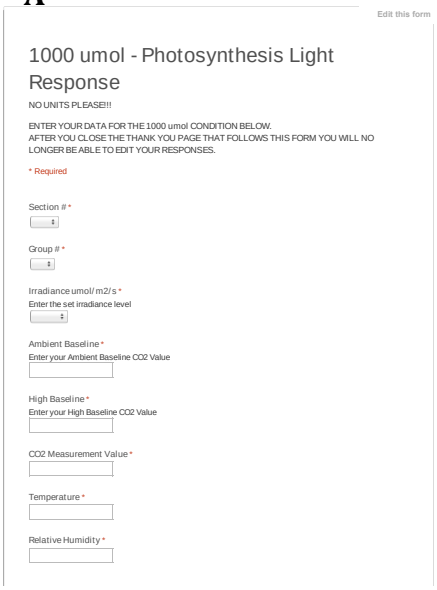
system for web-based data collection and integrated it into UNM Learn. Data collected in class is now entered into electronic forms in real time and automatically calibrated and compiled across all ten sections in Google Drive. These data are also used across semesters as examples of expected results and to increase sample size for statistical analyses. Finally, this large dataset will also be utilized at CNM the next time the course is taught there. CNM lacks the resources for extensive labs, but we envision giving a similar experience with demonstrations and access to real datasets.

Element 5: sustainable and continued optimization based on results of assessment. Bio 204L is taught by a single lab instructor in coordination with seven instructors for the sister lecture course (two every semester). We have created a set of common labs each semester to facilitate regular optimization and also developed question pools and tests on Learn that are shared by all instructors. Question types have been expanded to include short answer and muddy points, and student responses are used for optimization. Lastly, we have added student opinion surveys for the first and second half of the class to assess perceptions of learning. The lab instructor, all five TAs and at least one lecture instructor have been meeting weekly during the academic year to review and revise materials based on student and TA feedback and performance. Twice a semester, we discuss half of the course overall and we provide summaries once a semester to be discussed among all instructors participating in Bio 204. Finally, we have begun to track how student performance is affected by the separation of grades for the lab and lecture portion.

3. Assessment:

Our initial assessment of implementation success was accomplished by demonstrating that a novel web-based data entry approach could work to improve data collected in class. Students now fill out forms for their data on-line (Fig. 1A) and it auto-populates a spreadsheet in real time that the TA can track during lab (Fig. 1B). This has been a huge success in that we no longer spend time at TA meetings each week working to assemble and clean up data prior to distribution to the class.

A



B

Timestamp	Section #	Group #	Irradiance umol/m2/s	CO2 Measurement Value	Temperature	Relative Humidity	Ambient Baseline	High Baseline
9/10/2014 9:29:26	3	2	1000	387.24	20.28	48.2	414.94	1425.177
9/10/2014 9:52:22	3	5	1000	511.2	18.5	25.5	507.2	1474
9/10/2014 9:38:14	3	6	1000	614.5	20.4	43.66	626.2	893.7
9/10/2014 13:07:21	4	2	1000	371	20.01	47.02	395.49	1390
9/10/2014 13:06:49	4	3	1000	691.96	21.47	29.49	550	1400
9/10/2014 13:25:48	4	5	1000	479.2	18.95	36.27	503.3	1341.29
9/10/2014 13:25:49	4	6	1000	615.98	21.2	25.27	614.95	1525.63
9/10/2014 17:12:28	5	1	1000	1397.48	22.26	17.52	1397.48	2029.32
9/10/2014 17:10:31	5	2	1000	358.36	20.94	30.61	354.82	1370
9/10/2014 17:08:35	5	3	1000	640.6	22.7	18.68	644.81	1823
9/10/2014 17:12:51	5	5	1000	469	20.5	22	644.81	1206
9/10/2014 17:01:02	5	6	1000	590	23.14	44.01	474	1300
9/10/2014 20:33:55	6	2	1000	411.4	21.33	27.75	415.53	1501
9/10/2014 20:38:10	6	3	1000	706	21.86	14.89	707	1917
9/10/2014 20:52:53	6	5	1000	477.42	20.41	19.34	478.6	1280.58
9/10/2014 20:35:15	6	6	1000	601.78	22.92	30.38	610.03	1539.52
9/11/2014 9:15:58	7	2	1000	380	22	40.45	375	1373
9/11/2014 9:31:42	7	3	1000	723	36	30.4	1884	1872
9/11/2014 9:16:03	7	4	1000	648.71	20.9	31.31	640	1352
9/11/2014 9:14:32	7	5	1000	478	20.94	27.67	482	1300
9/11/2014 9:14:26	7	6	1000	593.14	22.39	49.77	629	1532
9/11/2014 13:58:04	8	1	1000	738	21.82	22.73	753	1722
9/11/2014 13:15:54	8	2	1000	793.73	22.22	17.14	780.76	1966.05
9/11/2014 13:08:35	8	5	1000	486.45	20.41	20.35	492.35	1332.5
9/11/2014 13:12:30	8	6	1000	630.66	22.39	26.04	633.61	1510.64
9/11/2014 17:07:32	9	1	1000	196	21	20	198	853
9/11/2014 16:54:15	9	2	1000	429.08	21.07	25.27	452	1425
9/11/2014 18:03:08	9	5	1000	490.39	20.94	17.6	495	1299

Figure 1: Example data collection form (A) and auto-compiled class data (B) from the form. This information is compiled in real-time and able to be viewed by students and teaching assistants during class.

In addition, the quality of the data collected in class is much better as it clearly shows expected trends with minimal quality control. Despite several years of lab adjustment, we had been unable to determine the source of errors that were not evident in trials outside of class but appeared consistently when all ten sections were running during the term. This was a repeated source of frustration for instructors, teaching assistants, and students. It also directly interfered with learning because it was not possible to apply a consistent approach for identifying good and bad data, thus it just appeared instructors were cherry picking good data. However, after we could collect calibrated data in real time it became possible to determine if a lab group was making an error or if equipment or plants were failing. We learned that much past variation that we had attributed to problems with plant health and student error was actually sporadic equipment noise that required more frequent calibration and some replacement of parts. We now have data stored on line from each semester and are using it to track equipment performance AND student performance (i.e. ability to conduct experiments). Finally, students are self-assessing each week by comparing their data to data from the whole class collected both the prior semester and the current semester. This semester (fall 2014) is the first term to have all of these benefits and it appears that student and teaching assistant attitudes and learning have improved, but we will not know until the mid-term survey and summary of assessments.

We also implemented a survey of student perceptions for each half of the course in spring 2015, where the first half of the course on plants had implemented reforms but the second half on animals had not. This initial survey (summarized in the tables below) identified several major issues. 1) Students ability to work with data in Excel was obscuring their ability to understand the course goals and benefits, thereby interfering with learning. 2) Students felt they were not effectively using their time in class. 3) Students were unclear about the learning objectives and how course material related to it. 4) A large number of students are dis-satisfied with the course irrespective of reform though there may have been a slight improvement during the plant half. In general, students believe they will enjoy the animal half more because it is easier to have human examples and relate what they learn to medical school. However, they also expect plants to be easier so making students understand the complexity and value of plants while also improving enjoyment of the material is challenging. Enjoyment was low in the plant portion, but we have never collected data like these aside from anecdotes, so the cause is unclear. It seems like we have reduced frustration with Excel this term, so the next survey should show an improvement. Students were more aware of outcomes in the reformed plant half than in the animal half. However connecting these outcomes to lab activities, connecting pre-lab to lab, and connecting lab to lecture are all areas that scored poorly. Again, we do not have prior data for these attitudes, but this is a clear area in need of improvement and we are working hard on this in the current semester.

204L Survey spring 2014		
Question	PLANT HALF (1 is best)	ANIMAL HALF (1 is best)
What grade would you define as success in the lab?	1.4/5 ± 0.7	1.3/5 ± 0.6
What is your most recent grade estimate in lab?	1.8/5 ± 0.7	1.6/5 ± 0.7

At the beginning of the semester, I was _____ about the value of the plant portion of this class.	2.3/3 ± 0.6	1.7/3 ± 0.7
Now, I am _____ about the value of the plant portion of this class.	2.0/3 ± 0.7	1.7/3 ± 0.6
How well did you learn?	2.1/4 ± 0.7	1.9/4 ± 0.6
How well did you enjoy the material?	2.8/5 ± 1.2	2.1/5 ± 1.0
Are you aware of the learning outcomes from the course?	81 yes	67 yes
Did you use the learning outcomes to study?	36 yes	24 yes
How effective were pre-class assignments overall in terms of preparing you for lab?	3.1/5 ± 1.3	2.6/5 ± 1.1
How effective was reading and discussing articles in terms of comprehending lab?	2.8/5 ± 1.1	2.7/5 ± 1.2
How effective was on-line data collection in terms of completing lab activities and assignments?	3.5/5 ± 1.4	N/A
The lab portion of the course was effective for preparing me to learn from the **lecture** portion of the class.	2.7/4 ± 0.9	2.9/4 ± 0.8
I preferred the FORMAT of the _____ portion of the lab.	85 animal, 19 no preference, 23 plant	N/A
What one was the main thing you preferred about the FORMAT of the animal or plant half?	Animal had no Excel homework Like online homework in plant part	N/A
Would you recommend the course to a friend?	55 yes	64 yes
What could be changed about the class to improve learning?	Excel help, data control, relate lab to lecture more	lab should correlate with lecture
What can the instructor do to improve learning?	better instructions	most satisfied with TA
What can you do to improve learning?	study more, ask questions	read more

In addition to the survey data, we also have data on student success in lecture (Figure 2, Table 1) and lab (Figure 3, Table 2) prior to substantial reform (fall 2013) and after one term of reform for the plant half (spring 2014). These are also the first two terms where the lab and lecture were separated and generated independent grades on student transcripts. The lecture portion of the class was not part of this reform effort, but it is included here because our goal is that learning in the lab would facilitate learning in the lecture. The first year of lab reform efforts (2013/2014) coincided with separation of the lecture and lab portion of the classes, so comparisons with prior years is not as direct. There are no differences in lecture performance in terms of course mean, percent A's, or

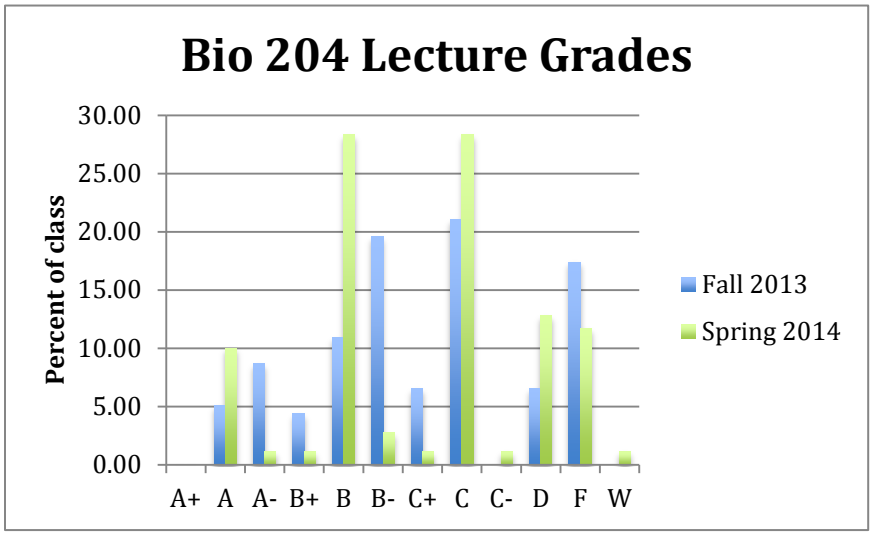


Figure 2: Final grade distribution for Bio 204 (lecture only)

Table 1		
Lecture	Fall 2013	Spring 2014
Mean Score %	73	74
>B+ % of class	14	11
<C % of class	24	27

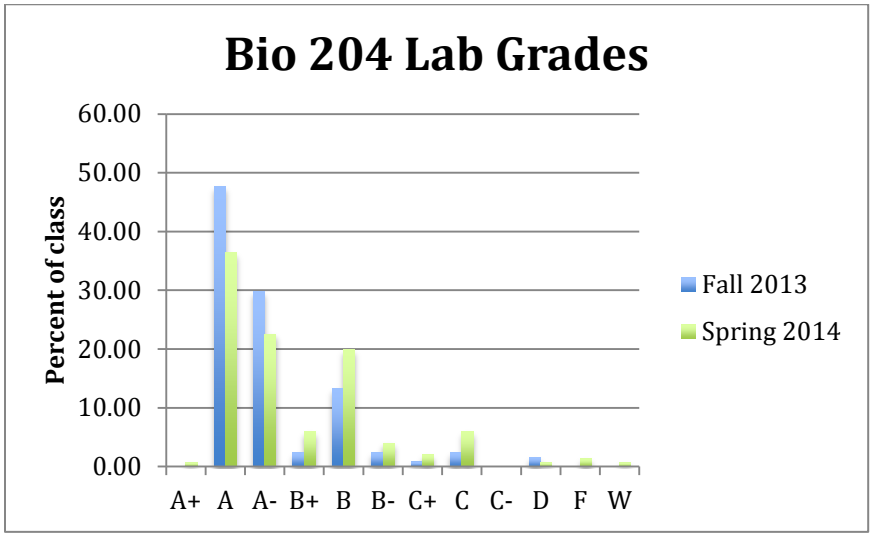


Figure 3: Final grade distribution for Bio 204L (lab only)

Table 2		
Lab	Fall 2013	Spring 2014
Mean Score %	91	88
>B+ % of class	77	60
<C % of class	2	3

of students passing (i.e. C or above) between fall 2013 (prior to substantial lab reform) and spring 2014 (plant half of lab reformed). When these lecture only scores are compared to fall semesters when the lab and lecture were combined (fall 2012, 2010, 2008), the percent of failing students has nearly doubled post separation while the percent of A students has stayed the same. This is likely due to two factors 1) students perform better in lab than lecture (compare Figures 2 and 3) and splitting removes the lab boost from the student's grade, and 2) students who failed lecture but passed lab can just re-take lecture and they may not be performing any better when taking lecture alone. If this pattern continues, then just removing the lab requirement is not helping students to pass on their second try and perhaps greater reform is warranted.

When comparing student performance in lab between fall 2013 and spring 2014, there has been a small decrease in student success post reform. This is not unexpected because the lab scores are so heavily skewed toward A's that it is clear the lab has not been discriminating between students with differing ability. Therefore, if the reformed course begins to relate learning to performance a decrease in most metrics would be expected despite an increase in learning. Unfortunately, we do not have robust assessments of learning in the labs that are separate from performance on graded materials. It is possible that performance in lecture is a good metric since lab is designed to complement lecture. Assuming that learning in the lab is correlated with performance in lecture, then the consistent lecture performance in the 2013/2014 academic year would suggest that the decrease in lab performance did not represent a decrease in learning.

4. Improvement:

We have already started implementing changes to address areas of student dissatisfaction identified in the surveys. Excel worksheets and exercises using prior class data seem to be helping get students past the Excel roadblocks. We have also increased efforts to make students aware of the learning goals and how they tie to course activities in lab and lecture. However, we need to develop better ways to quantitatively track assessment results across semesters. Developing metrics that can assess learning separately from student performance will are especially needed. We have also begun implementation of a second STEM Gateway reform effort for the lecture portion of the class that will increase integration of learning goals. It is encouraging that performance on the first lecture exam of the semester (fall 2014) is better than in prior years which is the first sign of improved performance related to the reforms. Finally, this term the anonymous lab survey will be conducted online and in-class to keep participation high and to facilitate analysis and record keeping.

5. Expansion:

Bio 204L has 10 sections every semester and reform efforts have been implemented in all of them. This will continue to be the case in fall 2014 and spring 2015. However, reform efforts for the animal portion of the class (second half of the semester) were not rolled out last year and are being implemented now. In fall 2014, the instructors are David Hanson (plant half of lecture) and Irene Salinas (animal half of lecture) with Cara Lea Council-Garcia running the labs. Blair Wolf will replace Irene Salinas in spring 2015, but the other instructors will remain the same. Irene and Blair are implementing four weeks of reformed labs for in fall 2014 and the remaining 4 weeks will be implemented in spring 2015. Finally, spring 2015, we will also be testing integration of one 204L section with English 219 into a learning community to see if that can improve student learning.

6. Sustaining:

We have created online repositories of all reform materials to date on both UNM Learn and Google Drive. Within UNM Learn, we have created a temporary section of the course that facilitates copying materials between semesters. Materials on Google Drive include class data archived by semester for use in subsequent terms and by CNM or any branch campus that would like to have a larger dataset to complement their respective labs. These repositories are available to all instructors for the course and will eventually be publicly

available if additional funding is found to create an exportable course module. Currently, team members are regularly (roughly monthly, but in the long term once or twice a semester) to discuss ways to improve the course. Much of the current time is spent discussing ways to make UNM Learn function as we expect and to convey this information to other instructors and teaching assistants. We believe the key for long-term successful implementation is making the sharing of materials and results simple.