A COMMON CALCULUS LABORATORY COURSE FOR TRADITIONAL CALCULUS AND BIOCALCULUS STUDENTS

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A unique aspect of the first semester calculus experience at Benedictine University is that the concurrent lab course consists of students from both the traditional calculus course for mathematics, physics, and engineering majors and the biocalculus course for biology majors. In this one-credit lab course, students with different academic aspirations taking calculus courses with distinct syllabi and course goals learn how to collaborate effectively while developing skills to use the computer algebra system Derive to analyze and solve calculus problems. This course also provides us with the opportunity to compare performance of students taking the two different calculus courses. In this paper, we will describe the issues in developing this common lab course to serve the needs of both student audiences, the syllabus, the choice of projects, the advantages and disadvantages of the structure, and assessment of performance of the two groups of students.

To begin, allow us to give a little background of our particular institution and the calculus requirements. Benedictine University is a liberal arts university with just over 2000 undergraduate students. Nearly 500 of those students are biology majors, many focused on premedical or other graduate studies. To serve these students more appropriately, in Fall 2003 we offered our first course in biocalculus, with an emphasis on the mathematics necessary to understand and model applications that occur frequently in biology. This approach is not novel to Benedictine University; many institutions are now developing courses in mathematics specially tailored to the study of biology. Some examples of other such courses can be found at Macalester College [1], Appalachian State University [3], San Diego State University [2], and the University of British Columbia [6].

A number of events led to the development of both biocalculus and the separate lab experience for both calculus and biocalculus students. Traditionally, the Calculus I course at Benedictine University was a 5 credit hour experience, consisting of four meetings per week, including a 75 minute laboratory exploration using the computer algebra system Derive and formal written lab reports. The content focused physics and engineering applications. The labs were not very popular with students; they particularly did not find value in writing formal lab reports. It was clear that some revisions to the existing lab structure were necessary. The needs of the significant numbers of biology students led to the development of the Biocalculus course described above. Then, due to campus scheduling requirements, we recently had to restructure our courses. It became necessary to schedule the traditional Calculus I as a three day per week 4 credit hour course, with the lab now a separate, 1 credit hour course. The lab now meets for two hours and is taught by an instructor who might not be the students' professor for the lecture. With this new schedule in place, it was an ideal time to structure the biocalculus course in the same framework as the traditional calculus course, and the question became: could students in both traditional calculus and biocalculus succeed in the same lab?

The principle advantage to offering one lab experience for both kinds of students is one of unifying the calculus experience. Some concepts were moved from the lecture to the lab syllabus to make room in the shortened schedule; both students learn these concepts in the same laboratory environment. In lab, we like to focus on some useful applications of calculus; the biology applications fit naturally into this focus. We can assure that students in both calculus lectures are being held to similar learning objectives by assessing their mastery of calculus in the laboratory environment. Given our modest calculus enrollments (compared to, say, a large university), it seemed to be clear that the ease in scheduling several lab sessions which are available to either kind of student offers increased flexibility to the student course schedule. These advantages convinced the Benedictine University faculty to try this common laboratory schedule.

Now, of course there are some inherent disadvantages to this common laboratory experience. The primary hurdle to overcome was curricular: what content should be emphasized in laboratory rather than lecture, and how can we schedule the labs so that they are in sync with the disparate calculus contents?

A principle goal in the design of the lecture and labs is to maintain the same level of mathematical rigor so that successful students in lecture and lab will be able to succeed in either the traditional Calculus II or the Biocalculus II courses, including a switch by students between successive terms. In fact, we have had students successfully switch between successive terms in both directions. The biocalculus course has a greater emphasis on using and understanding biological data and models than the traditional course, but it is delivered with the same level of mathematical rigor as the traditional course. The difference in emphasis necessitates a different selection and ordering of content. Even so, we are able to coordinate the syllabi of the two calculus courses with the lab so that all students will be introduced to necessary content before the laboratory sessions.

Additionally, we have moved some of the calculus content from the lecture courses to this common lab course. This material includes parametric curves, conic sections, graph behavior from derivative information, and numerical integration. The lab design includes an introduction to the computer algebra system Derive as a calculating and graphing tool. This software also makes it easy to write informal reports within the Derive worksheets. We see the joint laboratory experience as an opportunity for students to expand their knowledge base rather than a time to provide content and activities merely at the intersection of the students' calculus backgrounds. This viewpoint guides us in our development of the lab syllabus: we select problems and content that are important to both the biocalculus students and also the traditional calculus students. Each term, two or three of the activities are devoted to biological models. Our goal became to design appropriate lab activities that could be completed within the two-hour lab session.

A typical laboratory experience begins with a prelab assignment, which is review or advance reading of calculus content, or reviewing some recently acquired Derive skills. Then the lab begins with the instructor setting the scene with either a 15 minute lecture on new content, a demo of some new Derive operations, or a quiz on the previous lab's content. For the remainder of the two hour session, the students work in groups on the day's activity, each submitting their own finished Derive worksheet consisting of relevant graphs and computations together with an appropriate discussion of interpretations or justifications of content.

An important feature of the laboratory course is the collaborative nature of the laboratory activities. The students will work together with students from both calculus courses, forcing them to share their particular expertise and backgrounds to solve problems together. This experience will translate nicely to interdisciplinary teams in academic research environments and in industry. As much scientific research is done at the intersection of disciplines and as biological research is becoming increasingly computational and quantitative, it is important that science and mathematics students learn to communicate with the each other. In particular, this lab experiences fosters an environment for biology majors and mathematics majors to work together and begin to develop a common language.

As we approach the end of this first year of a unified calculus lab, we have witnessed some of the advantages and disadvantages we predicted, as well as some unforeseen effects. Certainly, the lab allowed us to introduce problems and content of particular importance to the biocalculus students to all first semester calculus students. The flexible scheduling was a plus for both faculty and students, and the students benefited from working with various students in both lecture and lab. The lab professor is able to give feedback on calculus deficiencies to the lecture professor. Some topics really benefit from the additional reinforcement in the lab, and the removal of some content from the lecture frees up the professor to focus on additional topics or review more difficult topics. This is particularly helpful in the Biocalculus syllabus, which has a lot of content to cover.

The principle difficulty we encountered was, as predicted, scheduling. The course syllabi emphasize that the two lectures are frequently at the same content topic at different times. One fix to this problem was to cover conic sections and parametric equations early, until both lectures were well into the topics of differentiation. Another difficulty we encountered was the transition for professors who are used to timing their courses independently—the scheduling requires a common calendar agreed upon at the beginning of the term so that the students have the content mastery necessary for a scheduled lab. Most of the difficulties are related to the newness of this structure and will decrease with time and experience.

In order to insure the quality of this new dual lecture/unified lab format, we have several mechanisms in place. It is extremely beneficial that the biocalculus professor has extensive experience teaching our traditional calculus course from our text. In addition, the feedback from the lab professor helps to iron out difficulties that students may be experiencing. The unified lab experience gives us the chance to perform common assessments of all first semester calculus students at Benedictine University. These assessments enable us to ensure that all students who successfully complete either first semester calculus course have developed basic proficiency in a common core of calculus concepts and skills and will be able to succeed in *either* second semester calculus course. Assessments included the weekly laboratory activities, a derivative gateway quiz, a written component of the final exam covering the calculus content specific to the lab course, and a collaborative component of the final exam testing modeling, problem solving, and basic techniques and skills using Derive. Finally, our assessment structure makes sure that students from both lectures are achieving approximately the same level of mastery of beginning calculus. We ask a number of common final exam problems in both lectures. These include: **(1)** Sketch the tangent line at a point on a curve and estimate the value of the slope (derivative). **(2)** Find the equation of tangent line to a curve at a point, given the equation of the curve. **(3)** Compute a definite integral of a function from the given graph of the function. **(4)** Determine geometric properties of a function, given the graph of its derivative.

Below are the measured success rates of the students on these problems. We compare the success rate on the four problems from students who earned an A, B, or C in the courses. We would like the students from either class to have similar success rates. Our data seems to confirm our desire for uniform success rates. In these tables, there are 41 traditional calculus students and 10 biocalculus students.

Grade/ Problem	**1**	**2**	**3**	**4**	**Total**
A, Calculus	86.0%	98.7%	72.5%	94.3%	89.9%
A, Biocalculus	87.5%	90%	95%	93.3%	91.2%
B, Calculus	58.9%	92.2%	70.8%	87.8%	79.9%
B, Biocalculus	50%	100%	90%	93.3%	84.4%
C, Calculus	67.8%	67.8%	74.4%	56.9%	72.2%
C, Biocalculus	90%	0%	90%	90%	71.1%
Total, Calculus	73.6%	90.3%	67.8%	79.4%	82.3%
Biocalculus	81.7%	76.7%	91.7%	94.4%	87%

Table 1. Final Exam Common Problem Performance

Next, we compare the success rates of the two types of students in both the lab experience and lecture. Again, we would like these success rates to be similar. As is always the case, there are some students who are not successful for reasons beyond our control: mathematical preparation, motivation, and the shock of the transition to college-level expectations.

Semester Grades	Traditional Calculus	Biocalculus
A	13	2
B	22	6
C	3	1
D	1	0
F	0	0
W	2	1
Total	41	10

Table 2. Semester Grade Distribution, Calculus and Biocalculus

Measure of Success	Traditional Calculus	Biocalculus
Pass Rate	80.5%	60%
Continuing Students	8	4
Continuing/Passing	24.2%	66.7%
Continue (A/B/C)	5/1/2	3/1/0

Table 3. Pass Rate and Measure of Students Continuing in Calculus

In conclusion, we are quite happy with our experiment in mixing two types of calculus students into a common laboratory experience. The common course allows for both flexibility in scheduling and a wider exposure of applications to all calculus students, while allowing students to work in a collaborative environment with colleagues of different mathematics background. Based on current data, students from both courses perform comparably in the lab course and in the lecture courses, indicating some validity in our model. We are encouraged by the success thus far and plan to continue to modify and improve the lab experience to best serve this joint student population.

References

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