

An Analysis of Reformatting Curriculum and Instruction in the Calculus Sequence

Mary Zachary, Clemson University, maryz@clemson.edu
Sherry Biggers, Clemson University, sbigger@clemson.edu

Abstract

This paper presents one university's experiment in reformatting the curriculum and instruction of its first and second semesters of Engineering Calculus. This new implementation draws upon active learning strategies to engage students in the material and utilizes cooperative learning to support students in their explorations. The paper discusses the history of Calculus reform at Clemson University for the last decade to provide motivation for the current reform efforts. The final aspect of the paper presents preliminary results of this reformatting. These early results show improvement in student success rates.

Introduction

The first two semesters of Engineering Calculus (Calculus I and Calculus II) at Clemson University were restructured in 2006-2007 in an effort to improve student performance by increasing student participation during class and by decreasing instructor lecturing activities. Preliminary results are encouraging. More analysis, including a comparison of performance by students taught in a scale-up classroom and those students taught in a more traditional classroom, is planned.

Many colleges and universities continue to examine and modify their first semester Calculus courses. For almost 20 years, through NSF grants and other funding sources, higher education institutes have reworked their Calculus curricula, moving from traditional large lecture sections to laboratory environments, hands-on classroom activities, or a combination of group activities, lecture, and laboratory experiments.^{1,2,3,4,5,6,7,8} The goal of these initiatives has been to improve student learning and understanding of Calculus concepts and to increase retention and achievement in the Calculus sequence.^{9,10,11}

At Clemson University, several initiatives have been introduced over the past decade to improve student learning outcomes in the Calculus sequence. There has been both a concern over the number of students who fail to complete Calculus I satisfactorily and concern over the number of students who complete Calculus I successfully yet fail to successfully complete those courses for which Calculus I is a prerequisite, especially Calculus II.

The first efforts to improve student performance focused on course coordination and placement testing. Calculus I has been coordinated since 1999. Originally, course coordination involved the use of a common syllabus and course objectives in all of the sections of a course. Testing was coordinated in that the coordinator prepared comparable tests and grading guidelines to be used for all sections. During each fall semester, 25 – 35 sections of Calculus I were taught at Clemson University. Coordinated testing began with preparation of 4 – 6 similar test versions to be administered by section and graded by each instructor according to guidelines. Initially, the course coordinator prepared the exams with input from all instructors teaching the course. However, coordinated testing has evolved to testing of all students at the same time with all tests graded by all instructors who teach the course. (For example, a team of two instructors may grade problem 1 for all students in the course.) The involvement of each of the instructors in the actual preparation of each exam has increased over time.

Prior to the 2001, placement recommendations were advisory. At registration, each student met with an advisor who helped him select courses. All students who had taken pre-

calculus were generally placed in Calculus I. Beginning in 2001, a student's performance on the Clemson Math Placement Test dictated his placement into the course sequence. A student not initially placed into Calculus I was required to earn credit in a college-level pre-calculus course before enrollment.

Students enrolled in Calculus I also took a Basic Skills Test at the second class meeting. These students received their grade on the Basic Skills Test at the third class meeting. Students were given instruction in the interpretation of their Basic Skills Test score and their likely readiness for Calculus I. Many students ignored the recommendation based on their Basic Skills Test score. The percentage of students who were unsuccessful in Calculus I during the fall semester remained near 40% from 2001 through 2005.

An analysis of student performance in Calculus I in fall 2005 showed that prediction for success in Calculus I based on both the Clemson Math Placement Test and the Basic Skills Test was correct for 86% of students. In 2006, placement in Calculus I was determined using both the Clemson Math Placement Test and the Basic Skill Test. However, placement was only a part of the effort to increase the rate of success for students in Calculus I and II. At this time, the Clemson Department of Mathematical Sciences based their reformed Calculus courses on the SCALE-UP model from North Carolina State University.

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SCALE-UP stands for Student Centered Activities for Large-Enrollment University Programs. The idea is that students work for most of the class period in groups of three on projects or problems connected to the curriculum. Rather than listening passively to a lecture, students are actively engaged in cooperatively solving problems based on material that they have read the night before in their textbook and discussed during the first 15 to 20 minutes of class.¹²

During the summer of 2006, several classrooms were adapted to accommodate this active learning environment. The rows of desks were removed and replaced with round tables that can seat 9 students. This formation allows for three groups of three to be placed at each table. Each room was designed to contain 45 students, plus one instructor, one graduate assistant, and one undergraduate assistant. The rooms also contained an overhead projector and a projection screen with a computer hook-up. There are future plans to install Symposium in each of the classrooms to maximize the outcomes of the shortened lecture. The shortened lecture and increased student participation are key components to the SCALE-UP model.

Active engagement by students leads to several positive outcomes. The group environment creates a non-threatening stage for students to ask questions of each other, the professor, or one of the two teaching assistants in the classroom. Students receive immediate feedback that is directed to the particular question. Active engagement also allows the professor and teaching assistants to monitor student work behaviors and to discern common mistakes. As the professor and assistants circulate around the groups, they offer advice or help on how to prepare for certain types of problems, and they also offer help on algebraic challenges that are often student specific.

The 2006-2007 academic year was the first instance of a course-wide emphasis on active learning in Calculus at Clemson University. Results from the two semesters are currently being analyzed. The 2006 students in Calculus I outperformed the 2005 students in Calculus I. In 2005, there was a 56.4% success rate, and in 2006, there was a 77.4% success rate. Taking into account the implementation of stricter placement criteria in 2006, if the students in Calculus I who had a combination of low placement test scores and low Basic Skills Test scores are removed from the 2005 data pool, the success rate for that year was 63%. The difference is smaller, but in 2006 more students were successful at completing the course.

Over the next few years, the research team and involved instructors are seeking to answer the following research questions:

Are more students successful when taught Calculus I in an active learning classroom?

Are more students successful when taught Calculus II in an active learning classroom?

Are there differences in Calculus II success when students were taught Calculus I in an active learning classroom?

Are students taught Calculus I and II in an active learning classroom successful in later classes (both mathematics and engineering)?

Are there differences in teaching evaluations completed by students in an active learning classroom and a traditional lecture classroom?

How satisfied are instructors with the active learning format? (Likert scale)

Are there significant concerns or comments from interviews with students who were taught Calculus I and/or II in an active learning classroom?

Using paired questions from exams in 2005 and 2006, does student understanding differ?

These preliminary results are promising, and the department is continuing to track students and collect performance data both in Calculus and in subsequent courses utilizing Calculus. The department is committed to teaching Calculus courses with an emphasis on active learning.

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