

2006-775: INTERVENTION STRATEGY FOR IMPROVING SUCCESS RATES IN CALCULUS

Darryl Koch, University of Michigan

Darryl M. Koch is Coordinator of Academic Support Services in the Minority Engineering Program Office at The University of Michigan. He received his BS and MS degrees in Mathematics and Industrial and Operations Engineering from the University of Chicago and the University of Michigan. He is an active member in National Association of Minority Engineering Program Administrators (NAMEPA) and the American Society of Engineering Education. He can be reached at koch@umich.edu

Gary D. Herrin, University of Michigan

Gary D. Herrin, Ph.D. is Interim Associate Dean of Undergraduate Education of the College of Engineering and Professor of Industrial and Operations Engineering at the University of Michigan. He has authored over 150 papers in Industrial Engineering. His professional affiliations include ASEE and ASQ. He may be reached at gdherrin@umich.edu

Intervention Strategy for Improving Success Rates in Calculus

I. Introduction

Certain introductory courses for engineering students act as “gateway” courses, meaning that students will have difficulty progressing successfully through the engineering program without solid performance in these foundation courses. Designing interventions that help students pass these “gateway” courses successfully can be an important strategy for improving overall student retention rates. In general, we believe that student retention efforts are particularly important during the first year since students are encountering a variety of transition issues, including the rigorous academic demands. We also believe that first-year retention initiatives which identify specific challenges for students early on in the term and provide quick and responsive intervention measures provide the greatest impact. Finally, retention initiatives are likely to be most effective when they involve both academic departments and student support services offices working collaboratively.

In this paper, we will describe an intervention measure that we developed to improve student success rates in Calculus I for engineering students at the University of Michigan. This particular initiative involves collaboration among an academic department and several student support services offices and is targeted towards entering first-year students. We will also present the preliminary data that suggests the intervention has a positive impact.

II. Background

At the University of Michigan, students are admitted to the College of Engineering either directly as entering first-year students or through the transfer process (internally from another college on campus, or externally from another institution). Approximately 80-85% of the admitted students each year are admitted as entering freshmen.

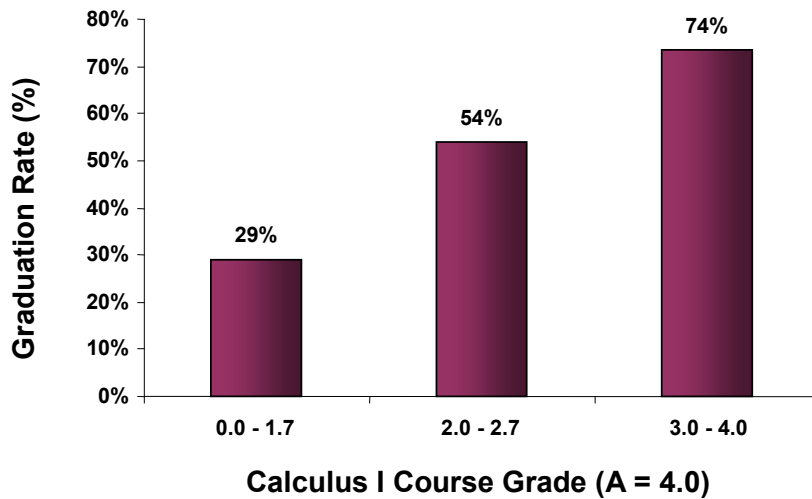
Students who are admitted to the College of Engineering as new freshmen are required to pass a set of core pre-engineering courses in mathematics and science during their first several terms before selecting a specific engineering department as their major. During the time before an engineering student has selected a particular department, academic advising matters for the student are conducted by the Engineering Advising Center. After declaring a particular department as a major, the student’s advising issues are then handled by the respective departmental advising team.

Various student support services offices in the College of Engineering such as the Engineering Advising Center, the Engineering Learning Resource Center, and others are fully invested in helping students succeed academically in their first several terms, so that the student is eligible for declaring a major. As such, it is common for these offices to collaborate on student retention initiatives, particularly on initiatives that target first-year students. In addition, it is known that the initial pre-engineering core mathematics and science courses form an essential foundation for the later departmental engineering

courses. So it is very important that engineering students perform at a high level in these core courses before proceeding to their declared engineering department.

In an attempt to identify specific strategies for improving student retention, a study was conducted to identify particular core courses which appeared to be critical for student success. A report was produced that indicated, as hypothesized, that a strong correlation exists between performance in Calculus I and eventual graduation success of students in engineering, as shown in the chart below. (The data was collected from three consecutive entering cohorts of engineering students.)

6-Year Graduation Rates of Engineering Students vs. Calculus I Grade (first attempt)



Based on this data, we decided to create an intervention strategy aimed at increasing the percentage of engineering students who succeed in Calculus I.

III. Problem Statement

Entering first-year engineering students are recommended for pre-calculus or calculus based on a placement exam and high school profile information (high school GPA and college test scores). Even though great care is taken in placing students in the correct course, it is impossible to predict with complete accuracy the likelihood of success in Calculus I of an entering first-year student. Furthermore, some students may elect, on their own, to enroll in Calculus I, even though they are recommended for pre-calculus. Therefore, it happens that some students enroll in calculus without being adequately prepared, or, a combination of other factors (heavy course load, inadequate study skills, etc.) may prevent them from achieving appropriately in this critical course.

Approximately 40% of the incoming engineering students enroll in Calculus I for the Fall Term. (The majority of engineering students enroll in Calculus II or higher based on AP test scores or transfer credit, and approximately 95% of the admitted students have ACT

math scores of 27 or higher.) The first exam in Calculus I typically occurs during the 5th week of the 15-week semester and primarily reviews pre-calculus topics and covers the fundamental concepts of the derivative. If a student does not perform well on the first exam, it may be a good indicator that the student lacks the necessary pre-calculus background and/or may lack adequate study skills for a course of this rigor. Furthermore, in the particular case of the Calculus I course at the University of Michigan, the exams heavily emphasize quantitative reasoning, conceptual understanding of topics, and interpretation of graphs and formulas. Little emphasis is placed on routine computational skills. In fact, students who struggle in the course often report that there is a disconnect between what was expected of them in their high school math course and what is expected in the university course based on the style of exams. Consequently, for various reasons, poor performance on the first exam is usually a good indicator that the student will struggle throughout the entire course.

IV. Intervention Strategy

Beginning in the Fall 2004 term, the Engineering Advising Center, the Engineering Learning Resource Center, and the Mathematics Department in the College of Literature, Science, and the Arts (LSA) collaborated on an initiative to improve the rate of engineering student success in Calculus I. The initiative consisted of an “early warning” and intervention approach in which students who performed poorly on the first exam in Calculus I were given the option of switching into a half-term, 2-credit hour intensive pre-calculus course, Math 110, before retaking Calculus I the following term. This option had actually existed for a number of years within the College of LSA and carried the added benefit that if students chose to switch to Math 110, the Calculus I course would be removed from their transcript for that term. In effect, students could get a fresh start for preparing for calculus with no penalty.

However, prior to Fall 2004, very few engineering students took advantage of this Math 110 option for several reasons. First, most students who did not do well on the first exam were convinced that by staying in the course and “working harder”, they could succeed in the course and avoid the self-perceived stigma of having to drop down to pre-calculus. Second, the Math 110 course was offered only as an independent study course with scheduled quizzes and tests and supervised by a math graduate student. (Math 110 was offered as an independent study course for practical reasons because it was considered too difficult to find a feasible class meeting time for students who would switch into that course mid term.) Finally, there was no specific advising intervention about the merits of this option because academic advisors in the Engineering Advising Center would typically not know which students had not performed well on the first exam. So outside of the student’s calculus instructor informing him or her about the Math 110 option, a student would typically make his or her decision about next steps by themselves, absent of any data or encouragement about choosing an option that would likely lead to better long-term results.

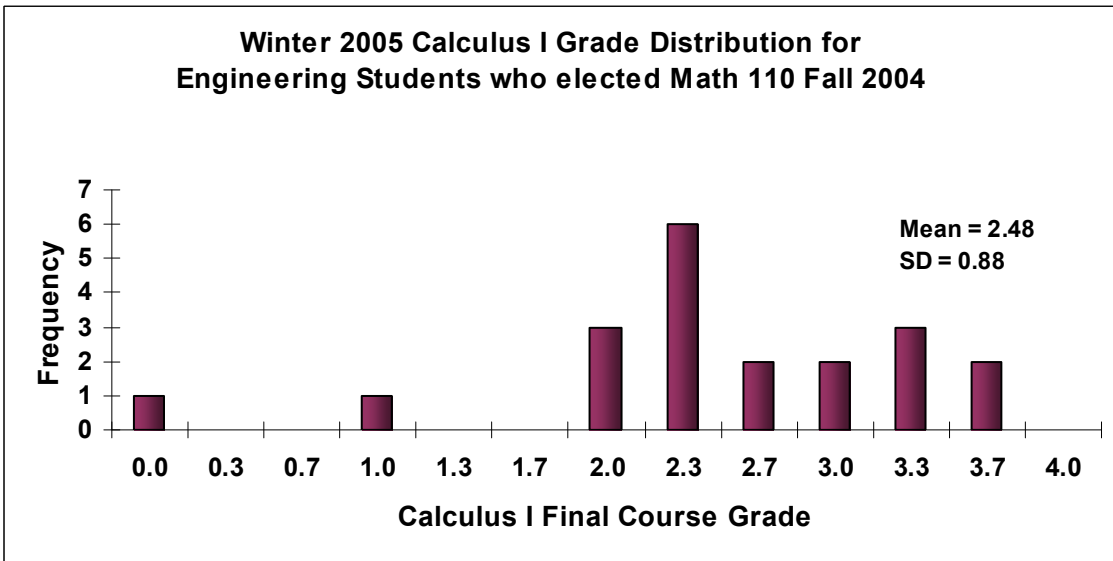
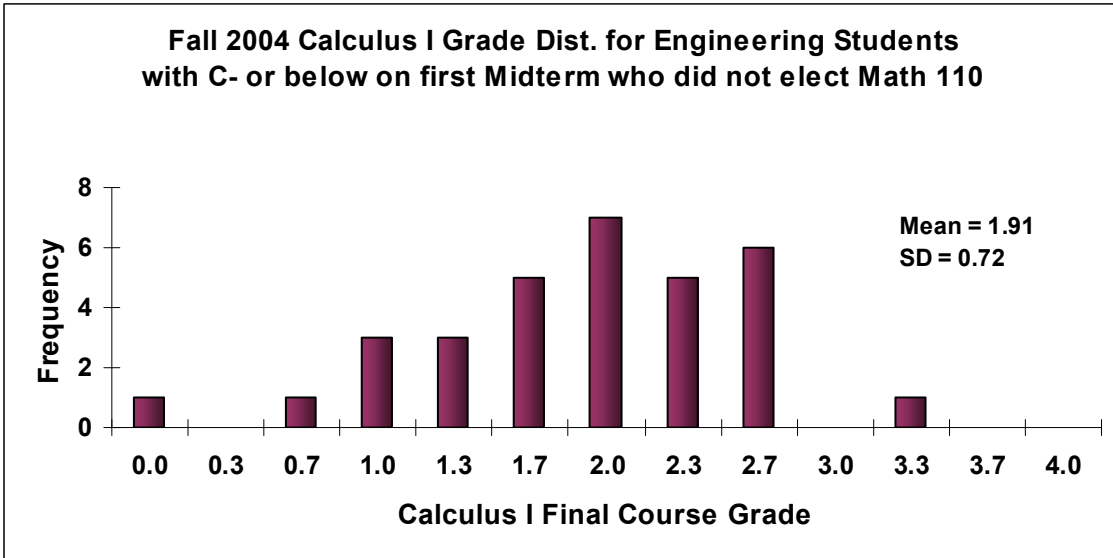
To implement an effective intervention strategy for students who performed poorly on the first calculus exam that took advantage of the existing Math 110 option, the directors of the Engineering Advising Center and the Engineering Learning Resource Center met with the course director for Calculus I and formulated the following plan:

1. The course director would release a list of all engineering students who earned a C- or lower on the first exam to the Engineering Advising Center within two days of the exam being taken.
2. The directors of the Engineering Advising Center and Engineering Learning Resource Center would contact all students on the list and require them to attend a group advising session the following week. The group advising session would be used to present data to the students about the importance of doing well in calculus, give advice about the likelihood of success in calculus if students remain in the course, and discuss the details of the Math 110 course with a strong recommendation for pursuing that option. The course director for the Calculus I course would also be present to offer advice and answer student questions about Math 110.
3. The Engineering Advising Center would review class schedules of all engineering students interested in taking Math 110 to identify feasible class meeting times; the Mathematics Department would identify an instructor who could teach the course.
4. The directors of the Engineering Advising Center and Engineering Learning Resource Center would work closely with the Math 110 instructor to monitor student attendance and progress throughout the course.

V. Results

The intervention strategy as outlined above was implemented during the Fall 2004 Term. Of the 397 engineering students who were enrolled in Calculus I, fifty-seven (57) received a C- or less on the first exam. These students were called to a group advising session to discuss the Math 110 option. Of the fifty-seven students, twenty-five (25) of them chose to take Math 110 and the thirty-two (32) remained in the Calculus I course. (Prior to Fall 2004, less than a total of 10 engineering students over a period of five years had taken the Math 110 course for the likely reasons as discussed above.) In order to measure the impact of this intervention, we chose to compare the Calculus I grades of those students who remained in Calculus I for the remainder of the Fall 2004 Term with those who switched to Math 110 and then took Calculus I the following Winter 2005 Term.

The two histograms below display the grade distribution for each group:



The grade distributions clearly indicate a higher success rate in Calculus I for those students who switched to Math 110 and then took Calculus I in the following term. In particular, of the 32 students who remained in Calculus I, only 7 (22%) achieved B- or better (a critical indicator for success in engineering). Of the 21 who switched to Math 110 and then followed up with Calculus I, 9 (43%) achieved B- or better, which is double the rate of the control group.

VI. Conclusions

Clearly, the first trial of this intervention strategy proved to increase the success rate in Calculus I for students who encountered difficulty early on. The intervention also has the added benefits for the students in that it allows them to salvage 2 credit hours by taking the Math 110 course and earning a grade in that course, rather than simply withdrawing from the calculus course or continuing in the calculus course and possibly earning a poor grade that will negatively affect their first term GPA.

For the future, we will continue implementing this intervention strategy and continue to collect data to assess its effectiveness and make improvements. For example, based on the data and other considerations we will also consider:

- a. mandating the Math 110 option for students who receive a D or less on the first calculus midterm;
- b. identifying and implementing a better math placement process to minimize the number of students who struggle in calculus early on; and
- c. exploring the possibility of creating a similar model for other critical gateway courses (e.g. physics).