AC 2008-2079: BREAKING THE CYCLE OF CALCULUS FAILURE: MODELS OF EARLY MATH INTERVENTION TO ENHANCE ENGINEERING RETENTION

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Breaking the Cycle of Calculus Failure: Models of Early Math Intervention to Enhance Engineering Retention

Abstract

Since difficulty or failure in calculus is one reason students leave engineering during their freshman year, improving student performance and retention in Calculus 1 is expected to have a positive affect on freshman engineering retention. By identifying those engineering students who are having difficulty in calculus early in the semester, targeted interventions can be provided to help them successfully complete the course. For those who still withdraw midway through the semester, a one-credit mid-semester calculus preparation course can help them better prepare for their second attempt.

Supported by funding through a four-year NSF Grant, the WVU College of Engineering and Mineral Resources tried an intervention strategy of offering a calculus readiness course during the second half of the semester. The course was intended to help students who withdrew from Calculus 1 by midterm because they knew they were failing. It was designed to fill the gaps in student understanding of basic pre-calculus and early calculus skills and concepts and to prepare students to succeed in calculus the next semester. An analysis of student performance in subsequent calculus courses supports this model as an effective intervention strategy.

While student self-identification and selection yielded a level of success for this mid-semester course in preparing students for their next attempt, students who elected to remain in their calculus course did not have the benefit of the additional review provided in the intervention course. Hence, the intervention model was modified to include early identification of poorly prepared students within the first four weeks of the semester and the development of several additional intervention options, including targeted review sessions, and a "grade recovery program" offered at midterm for students who elect to remain in their calculus course. The goal of the new model is to help the struggling students before they withdraw from calculus at all. Results of an analysis of student success in Calculus 1 and in subsequent calculus courses and student retention in engineering are presented.

1.0 Introduction

Difficulty in succeeding in calculus is one of the primary reasons students transfer out of engineering. In fact, historically, calculus has served as a filter in many engineering schools[1]. Engineering schools and math departments in a variety of universities have worked together to address this problem. Approaches include: introducing additional cooperative learning and problem-solving opportunities for engineering students taking calculus[1]; creating learning communities based on math placement so students can help and encourage each other[2]; removing pre-requisites to permit students to take Calculus 1 in their second semester and still progress on schedule in their engineering curricula[3]; redefining how engineering math is taught and creating a hands-on, application-oriented approach addressing only topics relevant to the core engineering courses[4]; and instituting an "early warning" system with optional "intensive pre-calculus" mid-

semester math tracks for struggling students[5]. Many of these approaches have been successful in increasing student success in calculus and in increasing engineering retention at the specific university in which the method was implemented. Each university environment has a unique set of characteristics, policies and culture. What works effectively in one university, may not be easily accomplished or as effective in another.

Using several elements of successful retention programs from other universities, the West Virginia University (WVU) Department of Mathematics and the WVU College of Engineering and Mineral Resources (CEMR) worked together to develop a multi-faceted approach to help WVU engineering students succeed in their first calculus course. This evolving program uses stringent placement criteria, early "readiness testing," five-day engineering sections of Calculus 1, free tutoring, targeted review sessions, and a half-semester calculus preparation course for those who withdraw from Calculus 1 at mid-semester. Most recent interventions offered include (1) a "grade recovery" program during the second half of the semester to encourage students to stay in the course and persevere throughout the course and (2) the development and implementation of a two-semester version of Calculus 1, including a "just in time" review of the needed algebra and trigonometric concepts. The goals of this multi-faceted program are to accurately place students in an appropriate math course, to support their academic efforts throughout the course, and to provide remediation for failing students to prepare them for their next attempt.

2.0 Identification of Mathematically At Risk Students

Through structured placement procedures and follow-up calculus-readiness testing, students who are not ready to succeed in Calculus 1 are identified and counseled regarding their first math course at the University.

2.1 Math Placement

Placement of students into an appropriate math course is essential to a student's mathematical success. Currently, at WVU, students are placed into a math course based on their SAT-Math or ACT-Math scores. The placement scale is presented in Table 1. The objective of establishing math placement criteria is to match each student with a math curriculum that provides an appropriate level of academic challenge to and maximizes the opportunity for academic success for the student.

Table 1. Math placement based on standardized test scores.

SAT-M Score	ACT-M Score	Math Course Placement
≥ 600	≥ 26	Calculus I
560 – 590	24 – 25	Pre-Calculus
540 – 550	23	College Algebra & Trigonometry
480 – 530	20 – 22	5-Day version of College Algebra
≤ 480	≤ 20	Math Workshop

Students may challenge their math placement based on standardized math test scores by taking a university-developed math placement exam. Students who choose to take the placement exam typically take it during freshman orientation sessions.

2.2 Calculus Readiness

Beyond initial placement, students in Calculus 1 are given a "Calculus Readiness Test" during the second week of class. The results of this test are used to counsel students on whether or not they are academically prepared to stay in the "regular" section of Calculus 1. If their test scores indicate they are not ready to take Calculus 1, students are given three options: (1) Change to a Pre-Calculus course; (2) Take a two-semester Calculus 1 course with "just-in-time" review of algebra and trigonometry; or (3) Remain in the Calculus 1 course for which they are registered, but with the knowledge that they will need to work hard to succeed. The choice is completely the student's.

In spite of the test's accuracy in predicting student success in calculus, many students who are advised that their calculus readiness is low elect to remain in Calculus 1. They believe their performance on the test did not indicate their actual preparation and knowledge and they believe that they will succeed in Calculus 1. Students have the final choice in electing to remain in Calculus 1 or not. Frequently, these students, and others, need well-designed interventions to help them succeed in Calculus 1.

3.0 Intervention Strategies

Even with careful placement and calculus readiness counseling, several students each semester begin Calculus 1 without the sufficient background to understand the math content. Even students meeting the minimum ACT/SAT placement requirements for calculus may be missing key concepts necessary for success in calculus. Many students do not realize this problem until several weeks into the course, after they have failed two or more tests. At that point, many students choose to withdraw from calculus to avoid getting an undesirable grade.

There are four primary interventions designed to help students remain in and succeed in Calculus 1: (1) a two-semester Calculus 1 course; (2) an active academic support program; (3) a "grade recovery" program offered after midterm; and (4) a mid-semester calculus readiness course for students who withdraw from Calculus 1 at midterm.

3.1 Two-Semester Calculus 1 course

The two-semester Calculus 1 course is designed to help those students who place into Calculus, but have relatively weak algebra and trigonometry skills. These students are identified through the Math Readiness Test given during the first two weeks of the semester. The course covers all of the standard Calculus 1 content; however, at each point where algebraic or trigonometric concepts are used, the course pauses to review the basic algebra and trigonometric concepts. The students then apply these concepts in continuing to solve calculus problems.

3.2 Academic Support in Math

Significant academic support structures are in place to help the engineering students succeed as they work through Calculus 1. These resources include:

- Special 5-day sections of Calculus 1 offered only to engineering students;
- Topic Focused Review Sessions
- Free tutoring

3.2.1 Engineering Sections of Calculus 1

In coordination with CEMR, the WVU Department of Mathematics has developed a 5-day Calculus I course which is offered only to engineering students. The engineering sections of Calculus 1 meet Monday, Wednesday, and Friday for lectures taught by experienced mathematics faculty, and on Tuesday and Thursday for recitations. In recitations, students are engaged in problem-solving activities, both in groups and as individuals, and take quizzes. As students work on problems during a typical recitation, engineering upperclass "mentors" circulate throughout the room to provide assistance and encouragement as needed. These mentors offer technical assistance in solving calculus problems, as well as answer the typical "When am I ever going to use this?" questions. When asked, the mentors can provide several examples of when that concept is used in their engineering classes.

3.2.2 Topic-focused Review Sessions

For students who opt to stay in Calculus 1, but may need a brief review of certain pre-calculus topics, the Math Department offers several review sessions, each focused on a specific pre-calculus topic (such as rational functions, exponential and logarithmic functions, and trigonometry). In a typical semester, approximately five or six of these focused sessions are offered early in the semester. Additional "pre-test" review sessions are also held to assist students to prepare for an upcoming exam in calculus. Participation in either of these one-to-two hour evening sessions is voluntary.

3.2.3 Free Tutoring

Students can get homework help through CEMR-sponsored study labs. Study labs are offered five evenings per week. Each evening, graduate and upper level undergraduate students provide free tutoring for freshmen in five subjects: pre-calculus math (College Algebra, Trigonometry, and Pre-Calculus courses), calculus (Calculus 1 and Calculus 2), chemistry, physics, and engineering. The tutors occasionally hold additional review sessions to prepare students for tests as well.

In addition, the WVU Department of Mathematics operates a Math Learning Center, on campus, that is open weekdays from 10:00 AM through 8:00 PM. Mathematics, engineering, and other science majors with strong math skills serve as tutors in the Math Learning Center. Freshman Engineering students are encouraged to use the time between classes to go to the Math Learning Center and work on their homework or study for calculus in a tutor-supported environment.

All freshmen engineering students are required to study in a tutored environment for at least two hours each week. This requirement may be met by participating in the CEMR-sponsored study labs or by going to the Math Learning Center. Students must document their attendance at the study labs or the Math Learning Center. Mandatory study hours are tracked and are used as part of the student's grade in all of the Freshman Engineering Courses.

3.3 Grade Recovery Program

During Fall 2007, the Calculus Faculty implemented an experimental "Grade Recovery Program" for the engineering sections of Calculus 1. Despite the availability of significant academic support in math, a very high percentage of students were earning Ds or Fs in the course and several students were withdrawing from the course at midterm. One perceived and proposed reason for the problem is the typical "freshman freedom" issue. Freshmen are away from home for the first time in their lives; they are living in residence halls with many other students of the same age and similar interests; the exciting football season is in full swing; and most of these students have succeeded in high school classes without spending much time studying. They fully believe they will succeed in their classes without putting forth significant effort. Even though their early semester test and quiz grades are low, students often discount those grades and believe they will still succeed. It isn't until they receive midterm grade warnings that students realize that their past class attendance and study behavior is not what it needs to be in order to succeed in their college math classes.

The Grade Recovery Program was designed to give students who had fallen into the "freshman freedom" trap an opportunity to achieve some level of grade recovery, if they were willing to put forth the necessary effort to learn calculus. After midterm, students were given the opportunity to sign up for this program by signing a contract that specified they would attend all class sessions, complete all assigned homework, plus attend one extra study session per week lead by their math professor. Each Calculus 1 instructor and GTA designated a one-hour group study session outside of class time. Since students rarely take advantage of a professor's regular office hours, each faculty used one office hour per week to host a study session. Students were to come prepared to work on assigned homework and were encouraged to ask questions. During these study sessions, the faculty and teaching assistants circulated throughout the students, reviewed their work, and asked pointed questions to see if the student understood what he or she was doing. Soon, students began to ask the professor more questions and the professor would explain the solutions for everyone, as needed. Students who attended all study sessions between midterm and the end of the semester, were permitted to replace one of their first two test grades (the basis of their D or F midterm grade) with the final exam grade, if it would help. The final exam also counted as usual in the computation of their final grade. The ability to replace a D or F test with a higher final exam grade motivated students to persevere throughout the remainder of the semester to save their grade. In the process, they were working more diligently to learn calculus.

While the additional study and help sessions were open to all class members, the "grade recovery" program was only open to students who earned a D or F at midterm. Its purpose was to convince those students to remain in the course and keep trying, but not to discourage those students with a C or better by giving the D/F students an unfair grade advantage. It was also not

intended as an overall "grade inflation" policy, so grade limits were placed on how much "retroactive" improvement could be applied to one of their first test grades. The replacement of their lowest test with the final exam grade could raise their midterm test grade to a maximum of 70%. With effort, these D and F students could reclaim their midterm grade to a C and build on that grade with their performance in the second half of the course, including on the final exam.

3.4 Mid-Semester Calculus Readiness Course

A one-credit hour, mid-semester math review course is offered to students who withdraw from Calculus 1 by midterm, usually because they are failing the course.

3.4.1 Background

The typical freshmen engineering course load is between 15 and 18 credit hours. If students carrying 17 or 18 credit hours have difficulty in two courses and choose to withdraw from both courses, they are left with less than the 12 credit hours required to be a full-time student. Students who start the semester with fewer credit hours can find themselves as part-time students by dropping only one course. Since becoming a part-time student has serious financial aid and insurance consequences, students in this situation will typically try to find one or more one-credit hour courses to raise their total hours to 12 credit hours.

In the past, students who dropped the 4-credit hour Calculus 1 course and needed to add a course to maintain their full-time status typically added a one-credit physical education course. While that course solved their credit load problem, it did nothing to help them become better prepared to take calculus again, but merely increased their time away from math which exacerbated their problem.

3.4.2 Course Description

In order to create a better option for students in this situation, the WVU College of Engineering and Mineral Resources has developed and offers a one-credit half-semester math course designed to prepare students to re-enter Calculus 1 the next semester with a better understanding of the pre-requisite math skills. All students who withdraw from Calculus 1 by midterm are given the opportunity to register for this course. This course was originally designed to fill the gaps in the students' understanding of basic pre-calculus, and to introduce early calculus skills and concepts in order to prepare students to succeed in calculus the next semester.

As with most experimental courses, this course has evolved into its current structure. Originally, the following topics were included: rational functions; exponential and logarithmic functions; trigonometric functions and other concepts from trigonometry; function graphing; limits; continuity; and the definition of the derivative. The class met twice each week, and in each class session, the topic lecture was followed with opportunities for students to practice doing problems – both at their seats and on the board – related to the topic covered. In addition, students were required to do homework and take frequent quizzes to show their mastery of the topics. The final grade was based on homework, quizzes and a final exam. Analysis of course grades and subsequent student success in the following calculus course indicated that there is great

variability in student background, motivation, and persistence, as well as subsequent success. For those who were motivated to persist in their effort, they succeeded. Many did not. The lecture, homework, test model was too rigid for those with great content deficits, and especially for those with minimal motivation.

In an attempt to better accommodate the vast range of math preparation of the students, a more flexible, yet focused, course structure was selected. The early calculus topics of limits and derivatives were eliminated and the course was re-focused on helping students make up severe deficits in algebra and trigonometry. The online mathematics review courseware, ALEKS, is used. Students register and pay for a six-week "Preparation for Calculus" course, take the initial assessment, and work through the on-line lessons. ALEKS breaks pre-calculus topics into 239 concepts and uses artificial intelligence algorithms to assess which of these concepts the student has mastered and which are lacking. The student takes a series of online tutorials, with practice problems, quizzes and re-assessments, to complete all 239 concepts. Student mastery is tracked numerically and illustrated by filling in appropriate sections of the student's progress pie chart. Faculty and graduate assistant time is available to help students with any content topics, as needed, and the student's grade is based completely on mastery of the pre-calculus topics. Students who master 90% or more earn an A, 80% or more earn a B, 70% or more earn a C, 60% or more earn a D, and below 60% earn an F in the mid-semester math course. As a benefit to the instructor, ALEKS tracks each student's assessment records, the total time s/he spent in the course, and the average number of hours spent each week. Instructor time is spent answering direct student questions about content and sending email reminders and encouragement to students regarding their progress and upcoming deadlines.

4.0 Results

To measure the effect of the interventions of the grade recovery program and the mid-semester calculus readiness course on student academic achievement and retention, data was collected regarding the participating students' success in their subsequent Calculus 1 course and their retention in engineering. The following research questions were asked:

1. Does the grade recovery program have an effect on the student success and perseverance in Calculus 1?

2. Does the mid-semester calculus readiness/math review course prepare students to succeed in Calculus 1 the next time they attempt it?

3. Do the interventions have an effect on freshman engineering retention?

4.1 Data Analysis for the Grade Recovery Program

To measure the effect the Grade Recovery Program on student success in Calculus 1, student grade data was collected and analyzed. Of the 155 students who participated in the grade recovery program, 38 students' grades moved from a D or F at midterm to a final grade of C or better. One student's grade improved from a D at midterm to a final grade of A in Calculus 1; and one student's grade improved from an F at midterm to a final grade of B. While only a few

made such dramatic grade recoveries, 25% of those students who entered this grade recovery program were able to improve their grades to at least a C. Figure 1 illustrates this result.

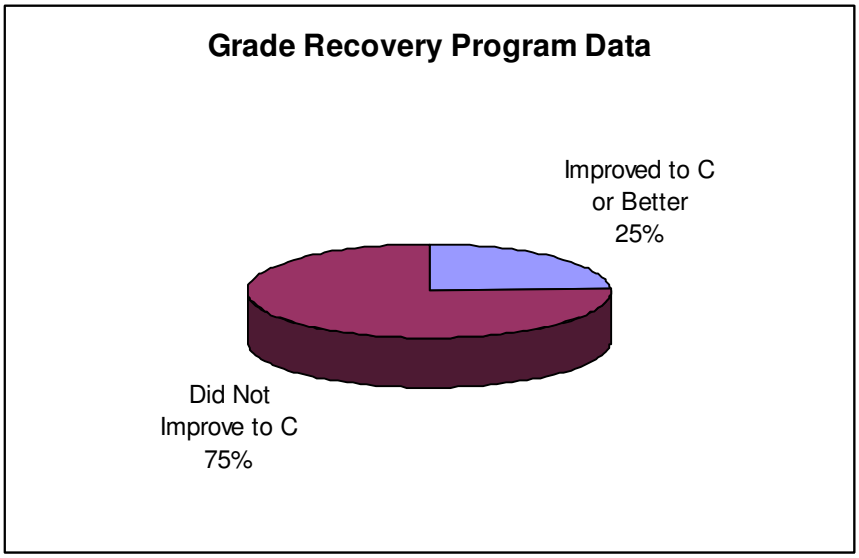


Figure 1. Calculus 1 Grade Recovery Program Data

Anecdotally, several students indicated they were planning to withdraw from Calculus 1, but decided to persevere if there was the hope of earning a C or better. That hope motivated several of the students; and one-fourth of that population persisted and succeeded in Calculus 1.

4.2 Data Analysis for the Mid-Semester Calculus Readiness/Math Review Course

The effects of the mid-semester calculus readiness course on the academic success in Calculus 1 and on freshman retention were analyzed. All of the students in this population either withdrew from or failed calculus one or more times before choosing to take the mid-semester intervention course. Not all students who completed the intervention course repeated Calculus 1. The data presented includes the 68% of the students who completed the intervention course with at least a D and repeated Calculus 1 in a subsequent semester. Thirty-two percent (32%) of those who registered for the mid-semester intervention course withdrew from or failed the course.

A full 50% of the population of students who withdrew from Calculus 1 because they were failing at midterm and who completed the intervention course with at least a D were able to earn either an A, B, or C in Calculus 1 the next time they took the course. As shown in Figure 2, of the 28 students who earned at least a D in the mid-semester math review course and re-attempted Calculus 1, 11% earned an A in their subsequent calculus course; 7% earned a B; 32% earned a C; 25% earned a D; 18% earned an F, and 7% withdrew from their subsequent calculus course.

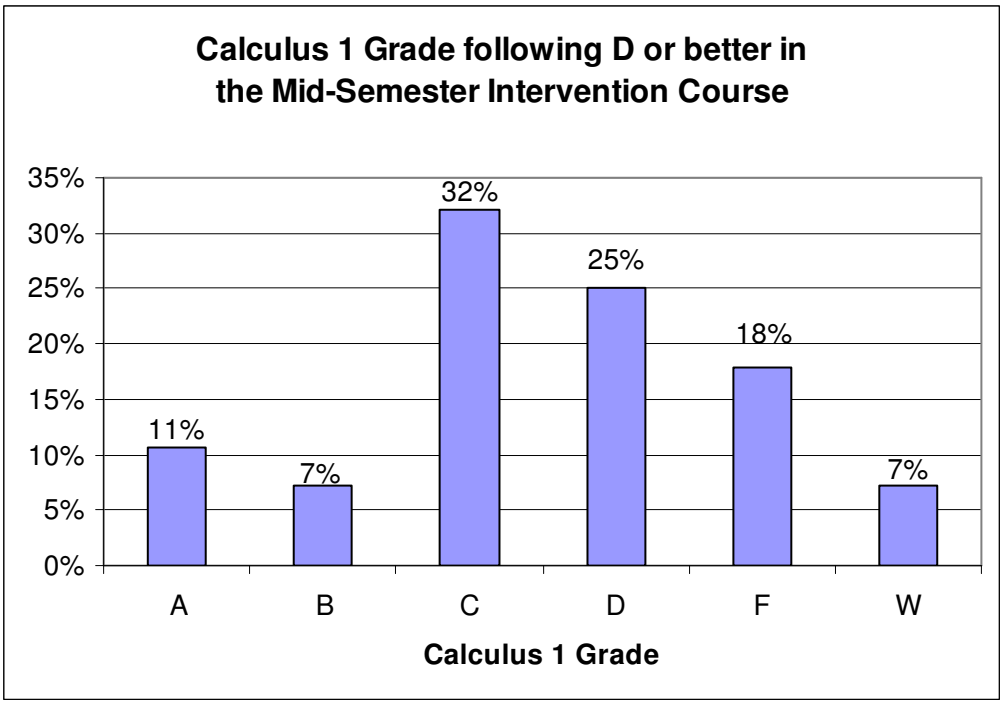


Figure 2. Calculus 1 Grades of students who earned a D or better in the Mid-Semester Intervention (Calculus Readiness/Math Review) Course.

Since a C or better in Calculus 1 is required to continue to Calculus 2 and to move into an engineering discipline major, obtaining a C or better in Calculus 1 is defined as "success."

To gain an indication of the significance of the 50% success rate in Calculus 1 for the mid-semester intervention course "graduates," their performance was compared to (1) the performance of students who did not take the course and who repeated Calculus 1 and (2) the performance of all engineering students in Calculus 1.

The success rate for students who earn a D, F or W in Calculus 1 and repeat the course in the next semester is approximately 39%. That means 39% of the students earn an A, B, or C in their second attempt at Calculus 1, following a first attempt grade of D, F. or W. That rate decreases if there is more time between the two attempts of calculus. The mid-semester intervention course graduate success rate of 50% is significantly higher than the overall success rate of "course repeaters."

Performance of over 500 engineering students in Calculus 1 per academic year is presented in Figure 3. While the percentage of students earning C or better appears to be generally increasing over the six year period from AY 2000-2001 to AY 2005-2006, the overall mean percent of students earning a C or better in Calculus 1 is 50.2%. That number includes those students who are taking Calculus 1 for the first time as well as those students who are repeating the course.

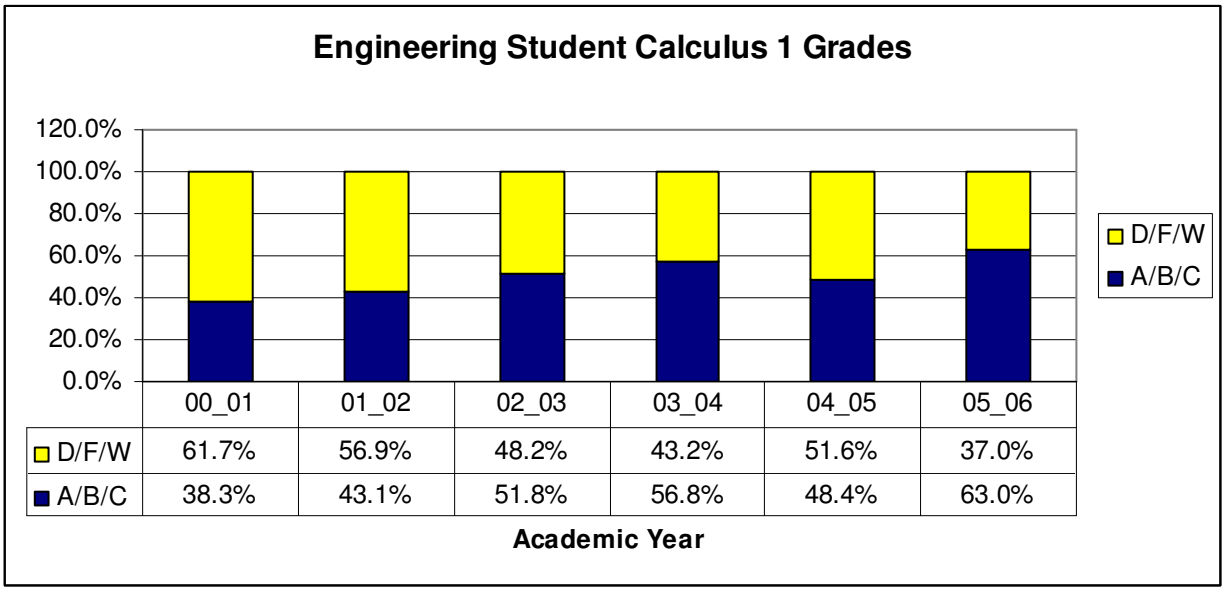


Figure 3. Percent of engineering students earning A, B, or C in Calculus 1 vs. the percent of engineering students earning D, F, or W in Calculus 1, AY 2000-01 through AY 2005-06[6].

Another measure of academic success is the overall GPA in that course. Figure 4 presents the Calculus 1 GPA of over 500 engineering students per academic year. While the GPA is generally trending upward, the average Calculus 1 GPA over the past six years is 1.78. The average GPA for the mid-semester math review course graduates is 1.54.

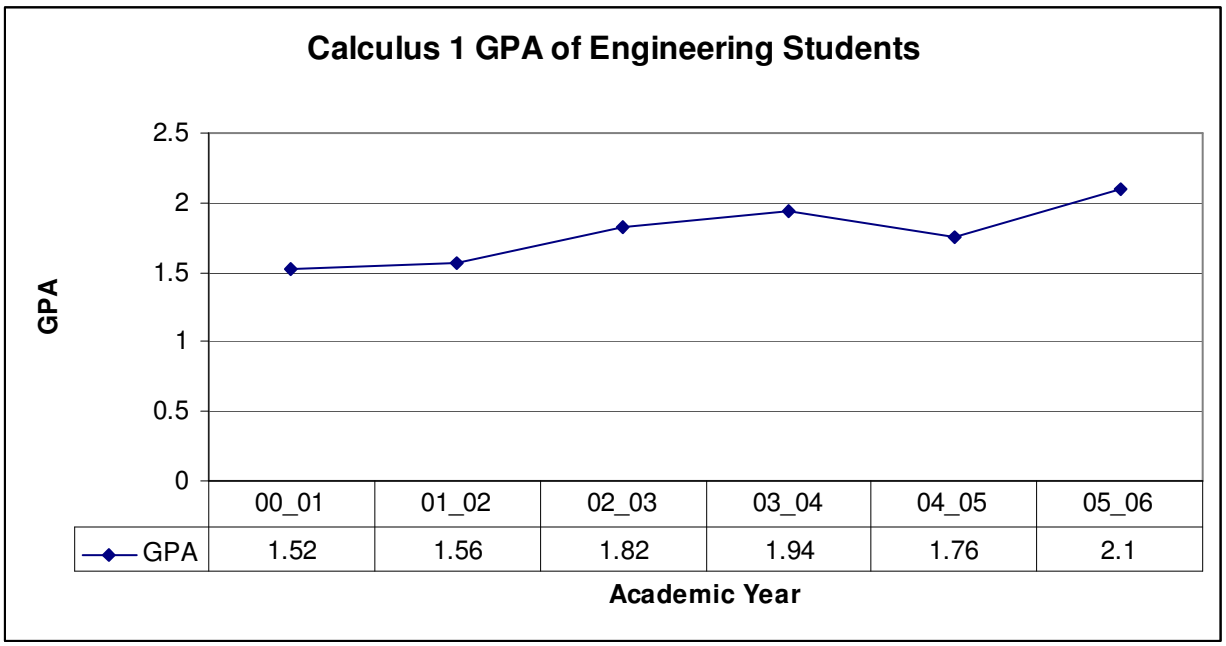


Figure 4. Calculus 1 GPA of Engineering Students, AY 2001-01 through AY 2005-06[6].

While the Calculus 1 GPA of the mid-semester course graduates is somewhat lower than the overall Calculus 1 GPA, the success rate (percent of students earning C or better) of the mid-

semester math review course graduates equals the overall success rate of all engineering students in the Calculus 1 course. Both means are 50%. The math review course graduates are all students who withdrew from Calculus 1 because they were failing in the first semester. With a few weeks of math review, those students who re-attempted Calculus 1, succeeded at a rate equal to the overall success rate of the course! This data suggests that the mid-semester math review course helps students to succeed in future attempts at calculus and is, therefore, a reasonably effective intervention strategy.

In addition to those students who withdrew from Calculus 1 and took the mid-semester math review course, some students who were earning a D or F at midterm, chose to take the mid-semester math review course, but remain in their Calculus 1 course. Figure 5 below shows the performance of these students.

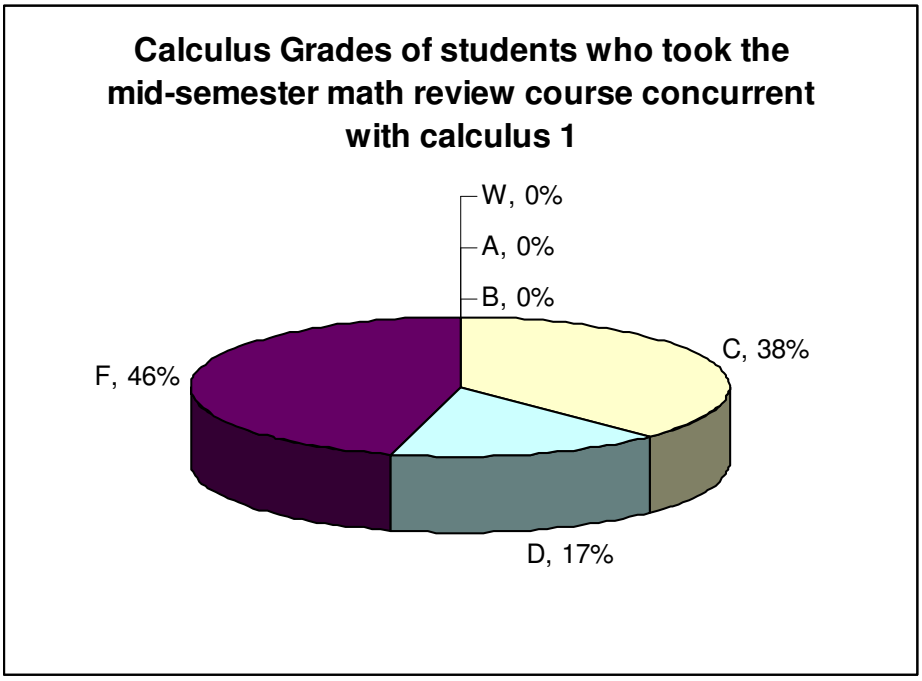


Figure 5. Calculus 1 Grades of students who took Calculus 1 and the Mid-Semester Math Review Course concurrently.

Of the students who remained in Calculus 1 and took the mid-semester math review course concurrently, 38% earned a C, while 62% earned a D or F in Calculus 1. For these students, it appears the intervention was too late to help them improve their grades above a C.

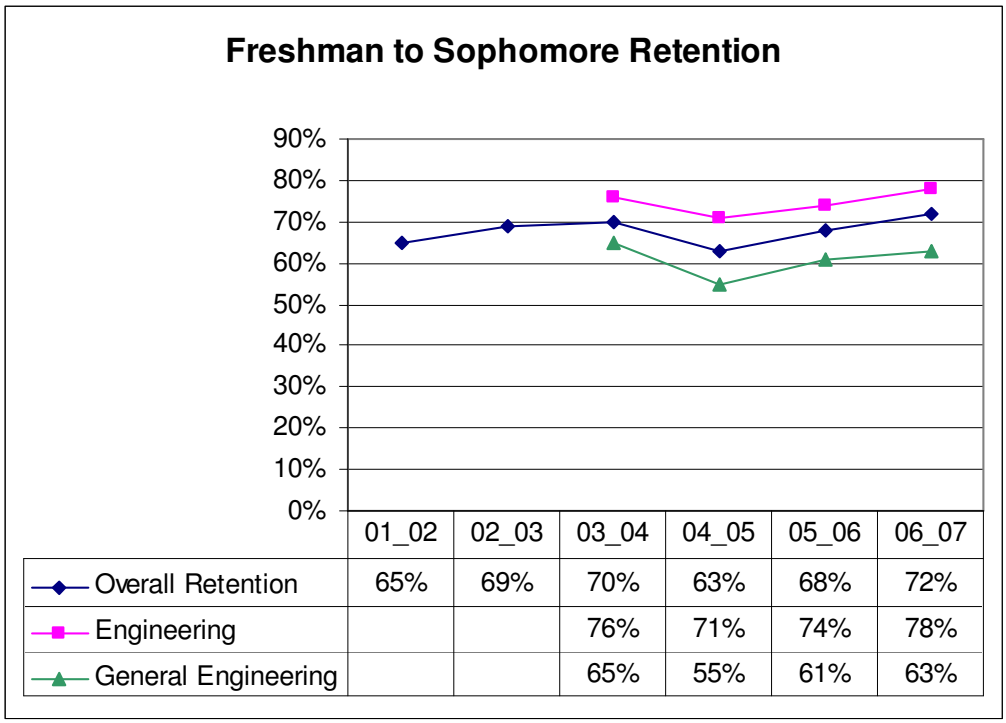
Students took the mid-semester course for many reasons. Some just wanted to add one more credit to their schedule after withdrawing from a 4 credit calculus course so they would keep their full-time student status, meet scholarship credit hour requirements, and improve their GPA. Others wanted to learn the mathematical concepts they needed to know for calculus. Not all students went on to take calculus the next semester. For those that did, sometimes the "next" semester was several months away (spring to fall). Given the mixed mathematics background and motivation level of the students who added this course, the results were fairly positive.

In addition to student performance data, student feedback was reviewed. While students commented positively on the early lecture-based structure of the course, there were a few problems: finding times to fit students schedule in the middle of the semester was difficult; and the six-week course was extremely fast-paced and rigid in its structure. Student feedback for the new, online course structure is positive. Students like the freedom to work on the course at times that best fit their schedule. They like the way ALEKS tracks their progress through completion of a pie chart. Students have said working on the course is a like playing a video game – they feel success after completing a number of problems and it becomes addicting! They keep working to fill their pie chart! Faculty time is focused on direct instruction that is relevant to the student. The student views the faculty as someone who will help him "win" against ALEKS!

4.3 Data Analysis for Freshman Engineering Retention

To determine whether or not the mid-semester calculus readiness course had an effect on freshman engineering retention, data was analyzed to see if the retention rate of those who passed both the mid-semester course and their subsequent Calculus 1 course was different from the overall freshman engineering retention rate.

Freshman retention is defined as the "percentage of freshman transferred to a discipline major or to sophomore status." Figure 6 plots retention by academic year for the past six years, from AY 2001-02 to AY 2006-07. WVU admits students as either Engineering students, those who are ready to enter Calculus 1 or higher as first semester freshmen, and General Engineering students, those who need to take pre-requisite math courses before taking Calculus 1. During the four-year period in which the Engineering and General Engineering tracks have been implemented, the average retention rate for Engineering students is 75% and the average retention rate for General Engineering students is 61%. The overall 4-year retention rate is 68.25%.



	01_02	02_03	03_04	04_05	05_06	06_07
Overall Retention	65%	69%	70%	63%	68%	72%
Engineering			76%	71%	74%	78%
General Engineering			65%	55%	61%	63%

Figure 6. Retention rate of freshman to a discipline major or the sophomore year[7]

As shown in Figures 7 below, the retention rate of students who passed the mid-semester math review course is 57.14%, while the retention rate of the students who failed the math review course was only 15.38%. While both retention rates are significantly lower that the four-year average overall retention rate of 68.25%, the results support the proposal that students who struggle with math leave engineering at a higher rate.

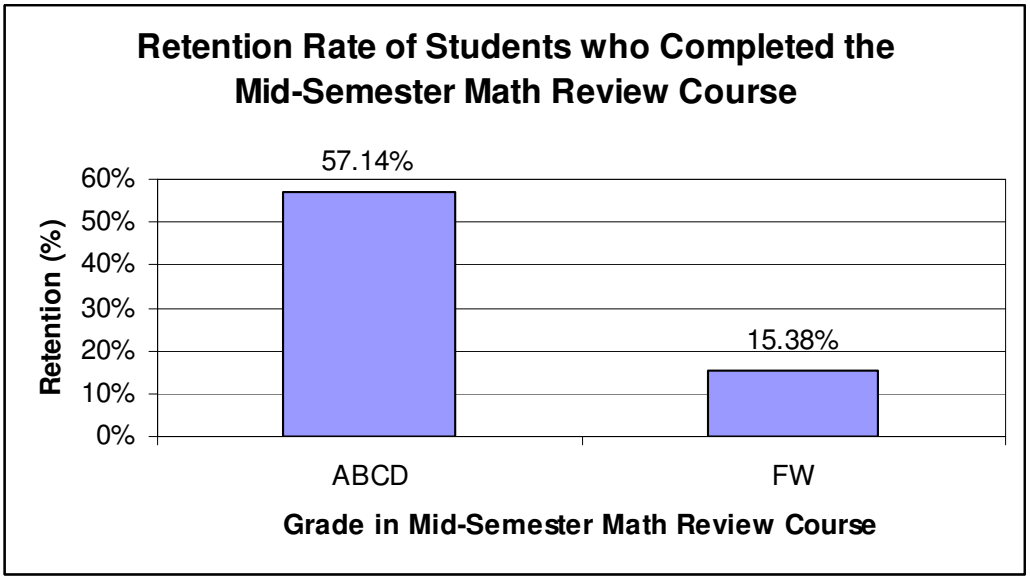


Figure 7. Retention of students who completed the mid-semester math review course.

Figure 8 shows that the retention rate of students who passed BOTH the mid-semester course and their subsequent Calculus 1 course is 64%. It is not surprising that more of the students who prepare to re-take Calculus 1 and then succeed in it on their second attempt would be more likely to remain in a major that requires a significant amount of calculus. It is also not surprising that this retention number is lower that that of the overall college average, since it represents those students who initially did not succeed in Calculus 1. Indeed, the retention of these students helps to increase the overall college retention rate. Many of these students would leave engineering if there was no intervention to help them succeed in calculus on their second attempt.

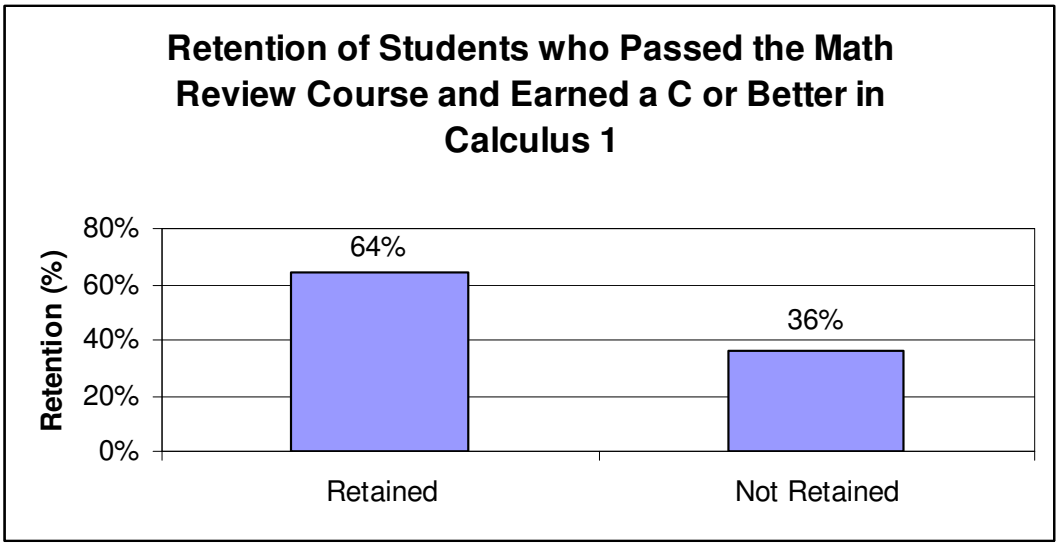


Figure 8. Retention of students who completed both the mid-semester math review course and their subsequent Calculus 1 course.

5.0 Conclusion and Recommendations

While calculus success and engineering retention depend on many factors, two specific calculus interventions investigated in this paper are the effect of a grade recovery program on the academic success of students who elected to remain in a Calculus 1 course in which they had earned a D or F at midterm and the effect of a mid-semester math review/calculus readiness course on the academic success of students who withdrew from the current semester's Calculus 1 course because they were failing, but re-attempted Calculus 1 in subsequent semesters. Both interventions appear to have an effect on student success in calculus.

The mid-semester grade recovery program helped 25% of the 155 students who persevered in Calculus 1 to reach at least a C or better by the end of the semester. Earning a C or better in a course is defined to be academic success. The program appears to have a positive effect on student persistence in the course as well as on student success. Student anecdotal evidence suggests that students were motivated to persist in Calculus 1, to work harder, and to follow the regimen prescribed by the program as long as they believed there was hope for them to improve their grade.

The data suggest that the mid-semester calculus readiness/math review course prepares students to succeed in Calculus 1 during their next attempt. Given that 100% of this population withdrew from Calculus 1 because they were failing, it is significant that students exiting the math review course have an equal rate of succeeding in Calculus 1 on their next attempt as do all students entering Calculus 1. The data is confounded by many variables, including student maturity, several motivation factors, and the student interest and goal changes that typically characterize the freshman year.

While we cannot directly attribute increases in freshman retention to any one of the academic success supports and interventions described in this paper, the combination of appropriate math placement, the provision of academic support, the opportunity to improve one's grade during the second half of a semester, and the provision of a math review course to students who have failed by midterm on their first attempt at Calculus 1, work together to provide a comprehensive student success program for first year engineering students.

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