1.0 Introduction

Difficulty in succeeding in calculus is one of the primary reasons students transfer out of engineering. Working closely with the West Virginia University (WVU) Department of Mathematics, the WVU College of Engineering and Mineral Resources (CEMR) has developed a multi-faceted approach to help students succeed in their first calculus course. This program uses stringent placement criteria, five-day engineering sections of Calculus 1 which include recitation activities, free tutoring offered through the engineering study lab system, targeted review sessions, and a half-semester calculus preparation course for those who withdraw from Calculus 1 at mid-semester. 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.

While many universities use placement procedures and offer tutoring or review sessions to help students succeed, the late semester course is a unique concept designed to provide instruction just at the point the student recognizes a need. Despite efforts to help students succeed in calculus 1, many students still withdraw from the course at midterm because they are failing. Students withdrawing from a 4-credit course at mid-semester frequently need to add a late-semester course to maintain their full-time student status. The intervention math course described in this paper was designed to fill the credit-hour gap with a calculus preparation course.

2.0 Math Placement

At WVU, students are placed 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 and 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.

<table>
<thead>
<tr>
<th>SAT-M Score</th>
<th>ACT-M Score</th>
<th>Math Course Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 600</td>
<td>&gt; 26</td>
<td>Calculus I [MATH 155]</td>
</tr>
<tr>
<td>560 – 590</td>
<td>24 – 25</td>
<td>Pre-Calculus [MATH 129]</td>
</tr>
<tr>
<td>540 – 550</td>
<td>23</td>
<td>Algebra [MATH 126] &amp; Trigonometry [MATH 128]</td>
</tr>
<tr>
<td>480 – 530</td>
<td>20 – 22</td>
<td>5-Day Algebra [MAT5 126]</td>
</tr>
<tr>
<td>≤ 480</td>
<td>≤ 20</td>
<td>Math Workshop</td>
</tr>
</tbody>
</table>

The College of Engineering and Mineral Resources also uses the SAT-Math and ACT-Math score placement criteria to define two engineering tracks: Engineering for students who qualify to take Calculus 1 in their first semester; and General Engineering for students who need to take a calculus pre-requisite math class during their first semester. Students are accepted into the College of Engineering and Mineral Resources as either “Engineering” students or “General Engineering” students. In addition to the pre-requisite math courses, “General Engineering” students take an introductory chemistry course and an online pre-engineering course before tackling the typical “first semester” Engineering courses of Calculus 1 (MATH 155), Fundamentals of Chemistry (CHEM 115), and Engineering Problem Solving 1 (ENGR 101).

**3.0 Academic Support in Math**

Students in the College of Engineering and Mineral Resources (CEMR) have access to several resources which are designed to help them learn mathematics and to succeed in their math courses. These resources include:

- Special 5-day sections of Calculus I offered only to engineering students;
- Mandatory study labs offered in five evenings each week;
- A Math Learning Center which is open throughout the day.

**3.1 Engineering Sections of Calculus 1**

In coordination with CEMR, the WVU Department of Mathematics has developed a 5-day Calculus 1 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. The total of all a student’s quiz grades can replace his or her lowest test grade. As students work on problems during a typical recitation, engineering upperclassmen circulate throughout the room to provide assistance and encouragement as needed. They are there to not only offer technical assistance in solving calculus problems, but to answer the frustrated “When am I ever going to use this?” questions as well. When asked, the upperclassmen can provide several examples of when that concept is used in their engineering classes.
3.2 CEMR-Sponsored Study Labs

In addition, students can get homework help through CEMR-sponsored study labs. These study labs are mandatory for all typical freshman engineering students. Students are required to participate in at least one 2-hour study lab per week. Study labs are offered five nights per week. Each night, graduate and upperclassmen 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 review sessions to prepare students for tests as well.

3.3 Math Learning Center

The WVU Department of Mathematics operates a Math Learning Center 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.

4.0 Interventions

If a student does not have the appropriate background to understand the math content, extra problem-solving and evening “study labs” may not be sufficient to help the student pass calculus. Even students meeting the minimum ACT/SAT requirements for calculus may be missing key concepts necessary for success in calculus. Many students do not realize this problem until several weeks into calculus, after they have failed two tests. At that point, many students choose to withdraw from calculus to avoid getting an undesirable grade. WVU has three approaches to helping the student identify and solve this problem: (1) advising based on the results of a “calculus readiness test” to help students understand their level of preparation to succeed in Calculus 1; (2) topic-focused review sessions; and (3) availability of a mid-semester “calculus preparation” class.

4.1 “Calculus readiness” Test and Advising

While students are placed into Calculus 1 based on SAT-M and ACT-M scores, these scores do not always predict accurately student success in Calculus 1. Some students take these standardized tests during their junior year in high school and do not take any math in their senior year. Others score well, but do not understand or remember sufficient algebra or trigonometry to be successful in calculus. Also, many students forget a significant amount of math during the summer.

For these reasons, the WVU Department of Mathematics gives all calculus students a “calculus readiness test” during the second week of Calculus 1. The results of this test are used to counsel students about their readiness to take calculus. Students scoring very poorly on this test are advised to switch into pre-calculus (Math 129) to gain the necessary skills before attempting to take Calculus 1. If a student chooses to take pre-calculus, the math department helps the student change his or her schedule to accommodate that change.
Several students are advised that their pre-calculus preparation is poor, but elect to remain in Calculus 1. Many believe 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.

The “calculus readiness test” is given during the second week of the semester for several reasons: (1) During the first week of the semester, many students change their course schedules, so class lists are “fluid;” (2) Faculty have the opportunity to “warn” students of the upcoming “calculus readiness test,” to explain its purpose and to encourage students to prepare to do their best on it; (3) Students have the opportunity to become “academically focused” after a summer away from school; and (4) Freshmen have the opportunity to become acclimated to the campus before taking a first “test.” The goal is for the student to be able to demonstrate his or her knowledge with reasonable accuracy. The test has proved to be quite accurate in predicting student success in Calculus 1.

4.2 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. Additional “pre-test” review sessions are also held to assist students to prepare for an upcoming first exam in calculus. Participation in either of these one-to-two hour evening sessions is voluntary.

4.3 Mid-Semester “calculus preparation” class

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

4.3.1 Background

Freshmen engineering schedules typically include: four credit hours of chemistry, four credit hours of calculus, three credit hours of English, three credit hours of engineering courses and one three-credit general education course. Variations exist, especially for musicians and athletes who need to take one or two credits of band or physical education to support their extra-curricular activity. While most students carry 17 or 18 credit hours in their first semester, some students choose to take only 14 or 15 credit hours. If students carrying 17 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 at WVU. Students who start the semester with fewer credit hours can find themselves as part-time students by only dropping 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 calculus 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.

4.3.2 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 (ENGR 493) 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 is 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.

The following topics are included in this course: 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 meets twice each week, and in each class session, the topic lecture is 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 are required to do homework and take frequent quizzes to show their mastery of the topics. The final grade is based on homework, quizzes and a final exam.

5.0 Results

To measure the effect of the intervention math 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 mid-semester math course prepare students to succeed in Calculus 1?
2. Does the mid-semester math course have an effect on freshman engineering retention?

5.1 Data Analysis for the Mid-Semester Math Course

The affect of the mid-semester course on the academic success in calculus 1 and on freshman retention were analyzed. The results of this analysis are presented in the following sections.

5.1.1 Academic Success

To determine whether or not the mid-semester math course prepares students to succeed in Calculus 1, data on student success in the mid-semester course, as well as student success in subsequent Calculus 1 courses, were collected from the first 3 semesters this course was offered.

As shown in Figure 1, of the students who repeated Calculus 1 after completing ENGR 493, 56% earned a higher grade in Calculus 1 than the first time they took Calculus 1. All of these students either withdrew or failed Calculus one or more times before choosing to take the
intervention course. Not all students who completed ENGR 493 repeated Calculus 1; and this data included all students who completed ENGR 493, both successfully and unsuccessfully.

While the percent of all students who earned a C or better in the engineering sections of Calculus 1 ranged from 38.3% in 2000-2001 to 63.0% in 2005-2006, the average percent of students who earned a C or better in Calculus 1 is over the past six years is approximately 50%.

![Calculus Scores After Prep Course](image)

**Figure 1.** Calculus scores after ENGR 493: Academic Years 2004/05 through 2005/06.

As shown in Figure 2, of the 56% of the students who improved their Calculus 1 grade after taking ENGR 493, 14% received a final calculus grade of an A, 10% received a B, 57% received a C. The 81% of students who earned a Calculus 1 grade of C or better were able to take subsequent math, physics, and engineering courses that have a pre-requisite of a “C or better in Math 155.” In addition, because of WVU’s generous D/F repeat rule which permits students to repeat courses taken within their first 60 credit hours and replace the new grades for the original D or F grades, many students can dramatically increase their GPAs and save their scholarships.
5.1.2 Retention

To determine whether or not the mid-semester math course had an effect on freshman engineering retention, data was analyzed to see if performance in Calculus 1 affected the engineering retention rate. As shown in Figure 3, only 9% of students who passed Calculus after taking ENGR 493 transferred out of the College of Engineering and Mineral Resources, while 50% of the students who either failed or withdrew from Calculus after taking ENGR 493 transferred.

Figure 4 illustrates the significance of calculus success to engineering retention in a different way. Of the ENR 493 students who transferred out of the College of Engineering, 80% were students who did not pass Calculus with a C or better, either before or after taking ENGR 493. The large difference in transfer rates points to the importance of providing the math intervention course to improve retention of students.
5.2 Overall Academic Performance of Freshman Engineering Students in Calculus 1

Performance in MATH 155 by academic year is presented in Figure 4. The MATH 155 GPA of all freshman engineering and general engineering students in the three years before this new multi-dimensional approach was taken (academic years 2000/01 through 2002/03) averaged 1.63, and averaged 1.93 for the three years after this approach was implemented (2003/04 through 2005/06). The difference in the averages indicates a 0.3 point increase in the MATH 155 GPA.

The percent of C or better grades in MATH 155 in the three years before the multi-dimensional approach was taken (academic years 2000/01 through 2002/03) averaged 44.4%, and averaged 56.1% for the three years after this approach was implemented (2003/04 through 2005/06). The difference in the averages indicates an 11.7% increase in the percent of C or better grades in MATH 155.
5.3 Overall Freshman Engineering Retention

Freshman retention has been defined as the “percentage of freshman transferred to a discipline major or to sophomore status.” Figure 1 plots retention by academic year for the last six years. The retention rate for the three years before the multi-dimensional approach was taken (academic years 2000/01 through 2002/03) averaged 65.7%, and averaged 67.0% for the three years after this approach was implemented (2003/04 through 2005/06). The difference in the averages indicates a 1.3% increase in the overall retention rate.

During the three-year period in which the Engineering and General Engineering tracks have been implemented, the retention rate for Engineering students averaged 73% compared to the average retention rate of 60% for General Engineering students.
6.0 Conclusion and Recommendations

The data suggest that the mid-semester calculus preparation course appears to prepare students to succeed in Calculus 1. Since the data included all students who took the course, not just those who passed ENGR 493, a future question for investigation is suggested: What percent of those students who pass ENGR 493, subsequently pass Calculus 1? The fact that several data points were missing because students took ENGR 493 and did not repeat Calculus 1, may indicate that some students merely traded a four-credit F (in MATH 155) for a one-credit grade (in ENGR 493). Further research is needed to see if these students transferred out of engineering or not.

The data also suggest that the mid-semester math course has a very positive effect on engineering retention. Analysis of the data confirms the anecdotal data received from students, that an inability to successfully complete Calculus 1 is a common reason for transferring out of the College of Engineering and Mineral Resources.

Since the improvement in retention and student success is an ongoing process, data collection and analysis must also continue to determine which modifications are beneficial and which are not. Continued tracking of student progress in MATH 155 following successful completion of ENGR 493 will help to better understand the effects of this early intervention course. With this data, along with student feedback, the class can be better tailored to meet student needs.

Overall, the data appears to indicate that the mid-semester math course has a positive effect on freshman engineering retention and appears to have moderate success in helping to prepare students to repeat 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.
Data analysis on the general freshman academic success and retention appears to indicate that while the efforts to accurately place students into the appropriate math course and provide academic support and interventions did not have a significant overall effect on the already high engineering retention rate, it did improve student performance in Calculus 1. The mean Calculus 1 GPA of the last 3 years is 0.3 points higher than the Calculus 1 GPA of the mean of the previous three years; and the differences in the average percent of students who earned a C or better in Calculus 1 improved 11.7% during the same time periods. These results are positive signs that the efforts made to increase freshman success in Calculus 1 appear to be effective.

Bibliography
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2. CEMR Academic Almanac, Prepared by the Office of the Associate Dean for Academic Affairs, 2005 – 2006