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Understanding the Educational Path of Non-Calculus-Ready Students in Engineering

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Mrs. Pirkey also works as a Graduate Research Assistant with the Fundamentals of Engineering Department as a continuation of her undergraduate research focusing on increasing retention rates of non-calculus ready first year engineering students by improving their problem solving and critical thinking skills in mathematics. Other publications to which she has contributed include "Introducing First Year Engineering Students to Engineering Reasoning" and "Critical Thinking Skills in First Year Engineering Students" presented at the Annual ASEE Conferences in 2017 and 2016 respectively.

Awards include 1st Place in the Student Poster Session - Individual Researchers Category and 1st Place in the North Central US Region Student Paper Competition, both of which were received at the 2017 ASEE Zone II Conference in San Juan, Puerto Rico.

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Understanding the Educational Path Followed by Non-Calculus Ready Students in Engineering

Background

Students' higher educational path is shaped by the knowledge and skills gained in their elementary, middle, and high school courses. With the inequality in educational opportunities for students across the United States, students that are intelligent but that are economically disadvantaged have been left behind in terms of opportunities and knowledge gained. Many of these students start college interested in engineering, but not ready to begin their education at the College Calculus level [1-2]. These students start in college either at the Algebra, Trigonometry, or Pre-calculus level.

Since these students are initially enrolled in math and science courses to remediate their deficiencies, it is expected that once they complete those basic courses, they will perform better in upper level courses. However, based on our experience, these students continue struggling and many drop out of college.

This study addresses the educational path followed by students enrolled in engineering, but not ready for Calculus when they start in college. Questions addressed in this study include: Are remedial math courses sufficient to promote the success of these students in engineering?, What is the timeline for the migration of non-calculus ready student out of engineering?, and Is progress in math hampering these students' ability to succeed in engineering?.

The persistence of non-calculus ready student in engineering and at the university level is discussed in this paper. Burdens to student success are presented and the role of math in student persistence are also discussed.

Methodology

Program for Non-Calculus Ready Students: The engineering program at West Virginia University accepts non-calculus ready students in two different tracks. Track 2 students place in a pre-calculus class. Track 3 students, which are considered in this study, are those students that start in engineering at the College Algebra level. The math path expected to be followed by Track 3 students is: College Algebra, Trigonometry, Calculus 1 – Part 1, Calculus 1 – Part 2, Calculus 2, and Differential Equations. For these students, Calculus 1 is typically divided in two semesters, Calculus 1 Part 1 and Calculus 1 Part 2, though some students will attempt to complete the entire course in a single semester. After completing College Algebra, students were given the opportunity to progress to the one-semester or two semesters Calculus 1 course based on Math placement using the ALEKs test. Only a small proportion of the students in this study used ALEKs to skip Trigonometry and progress to Calculus 1; this option is no longer available at the institution. Students could also take summer courses to further progress in math.

Student Demographics: Two-hundred forty two students enrolled in the Fundamentals of Engineering Program at West Virginia University were part of the study. These students began in engineering at the College Algebra level. Table 1 summarizes the characteristics of these non-calculus ready students. As Table 1 indicates, most participants were male (81%) and the average high school GPA for the group was 3.51±0.46. Average Math SAT and ACT scores for this group of students were 531±40 and 24±1 respectively. This study combines data from two cohorts of students that began in engineering in two consecutive years. This study was approved by the Institutional Review Board (IRB).

Table 1: Demographics of students included in the study

Parameter	Value
Gender Distribution	81% Male (n=197) 19% Female (n=45)
High School GPA	3.51±0.46*
Math SAT	531±40*
Comp SAT	1034±92*
Math ACT	24±1*

***Average ± Standard Deviation**

Students' cGPA, Grades in Math courses, and Persistence:

Students' persistence in engineering and at the institutional level, cumulative grade point average (cGPA), and grades in Math courses were monitored for 4 semesters.

Results

Figure 1 summarizes the persistence of non-calculus ready students in Engineering and at the institutional level during four semesters. Persistence in this study was determined by the number of students retained in engineering or at the institution per semester.

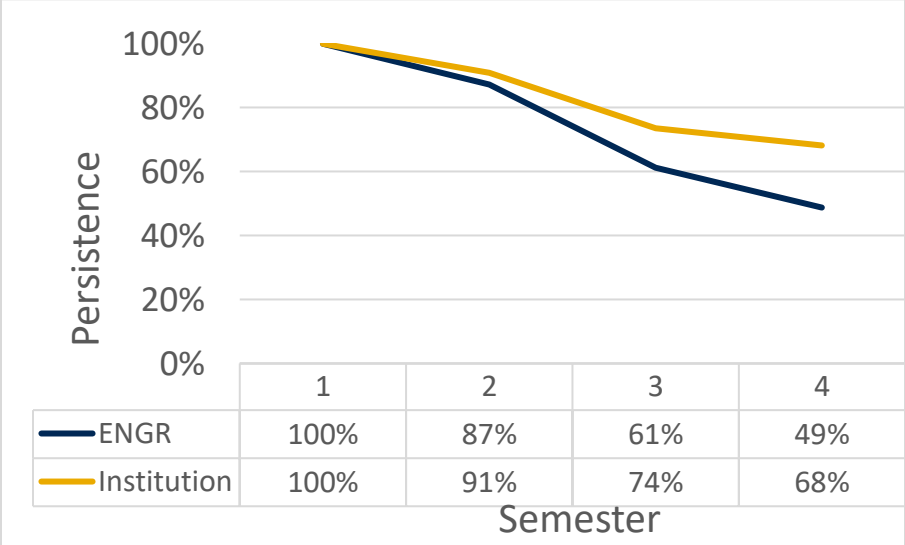

Figure 1. Student Persistence in Engineering and at the Institution

As Figure 1 illustrates, there is a large percent of non-calculus ready students that transfer out of engineering or leave the institution in their third and fourth semesters. By the end of the 4th semester 51% of the non-calculus ready students have left engineering.

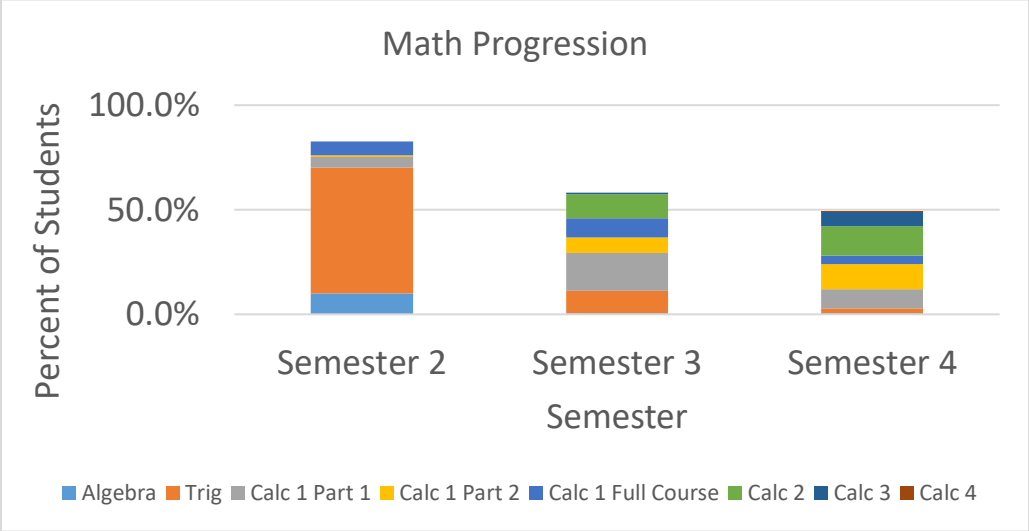

Figure 2. Math Progression for those Students Retained in Engineering

Figure 2 illustrates the math course progression among students retained in engineering. During the fourth semester, 14% of the students were enrolled in Calculus 2 and 12% were enrolled in the second part of Calculus 1.

The study showed that failure to progress in math contributes to students' transferring out of engineering or dropping from the institution.

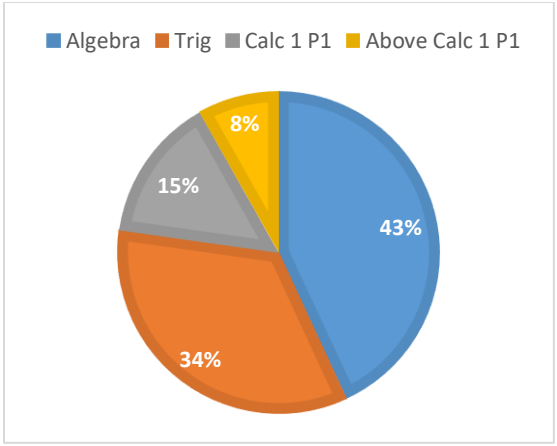

Figure 3. Last math course taken before transferring out of engineering or leaving the institution, assessed at the end of the fourth semester

According to Figure 3, 77% of the students that have transferred out of engineering or left the institution by the end of their 4th semester were enrolled in either College Algebra or

Trigonometry at the time of the switch or drop. 68% of the students that transferred out of engineering or dropped from the institution failed their last math course taken.

The study also showed that multiples failures in math courses were common among non-calculus ready students. Of the 242 students that started in College Algebra, 69.4 % of them (168 out of 242) have failed one or more math courses (information assessed at the end of the fourth semester). Among these students, 22.7% (55 out of 242) have failed in at least 2 math courses.

As students transfer out of engineering or leave the institution, the cumulative GPA for the cohort that stay in engineering rises slightly (see Figure 4).

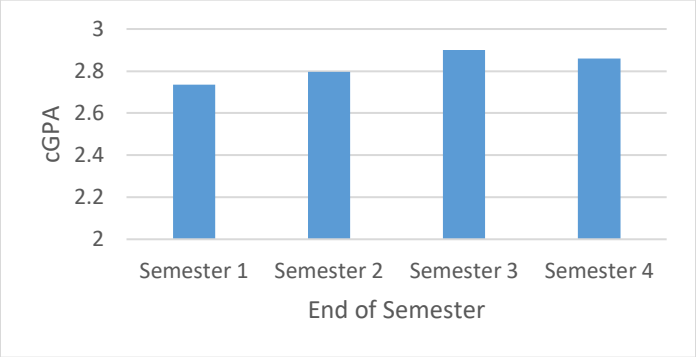

Figure 4. cGPA at the end of each semester for students that remained in engineering

Table 2. Of all attempts (including repeats) made per course, overall failure rate and repeat rate assessed at the end of the 4th semester

Course	Failure Rate**	Repeat Rate*
College Algebra	22%	43%
Trigonometry	35%	26%
Calculus 1 (Part 1, Part 2, and one semester)	40%	31%
Calculus 2	42%	38%

*Repeat rate= Percent of students that failed the class and repeated it

**Failure rate= Failure rates are defined by the number of failures (D/F/W) divided by the total number of attempts per course.

Table 2 summarizes failure and repeat rates observed in the different math courses. As Table 2 indicates, the number of students willing to attempt a class (repeat rate) after failing it is higher for College Algebra. Although Calculus 1 and 2 have high failure rates, the data shows that non-calculus ready students transfer out or drop out of college when they cannot succeed in early math courses such as Algebra and Trigonometry.

For those students that left engineering (or drop from the institution) and had College Algebra as their last math course, 62% of them failed that Algebra course. The same observation was made

for Trigonometry, in which 62% of the student that left engineering (or drop from the institution) while enrolled in that class failed the course. For students that switch out or drop from WVU, 94% of those with Calculus 1 Part 1 as their last class have failed the course. The study also shows that non-calculus ready students that transfer out of engineering at WVU for the most part transfer to the Business or to Agricultural Sciences Colleges.

Discussion:

The low persistence rates observed in this study (for non-calculus ready students) have also been reported by other investigators [2]. For instance, Jacquez and colleagues reported graduation rates of 20% [2]. The study also reports high failure rates in College Algebra.

The percentage of students entering college but not ready to start Calculus in their first semester has been rising [1]. Some of these non-calculus ready students have taken Pre-Calculus or Calculus 1 in high school, but their standardized tests (ACT, SAT) scores place them to start in College Algebra. Once in college they are enrolled in remedial courses. Most of these students never receive an appropriate intervention in those remedial courses and many continue failing math. This inability to succeed in math courses contributes to students' transfer out of engineering or to their drop from college.

One key finding in this study is the fact that a large percentage of these non-calculus ready students enrolled in engineering don't progress beyond College Algebra or Trigonometry. Another observation from the study is that students who are able to move into Calculus 1 continue struggling in math courses. We have observed that issues with Math proficiency is a main contributor to student non-persistence in engineering. However, it was not clear what math courses served as obstacles for the attrition of non-calculus ready students.

Other factors have been identified as contributors to attrition in engineering. Seymour and Hewitt published a book in which they rank factors contributing to switching decisions [3]. In their book, they mentioned poor teaching by Science, Math and Engineering (SME) faculty, curriculums that are overloaded and fast paced that become overwhelming, inadequate high school preparation, lack or loss of interest in SME, conceptual difficulties in one or more SME subjects, non-SME majors offering better education or more interest, and loss of confidence due to low grades in early years as contributing factors for attrition.

Students' misconceptions and the inability to solve word problems have been found to be main contributors for students' failures in math and engineering courses [4-6]. Without an appropriate remedial intervention, the path of these students in engineering is infeasible.

Conclusions and Recommendations:

This paper summarizes the results from a study that addresses the path followed by students that begin in engineering while enrolled in College Algebra. In the United States, this population of students is on the rise [1]. This study shows that even though these students enroll in and complete remedial courses (such as College Algebra and Trigonometry) these remedial courses are not sufficient to promote their success in engineering. Students fail in those remedial math courses and continue to struggle in upper level math courses. Remedial courses should be

modified to consider the fact that these students bring misconceptions and are unable to solve word problems [4-6]. At our institution, we are currently working with these non-calculus ready students to improve their problem solving skills and to address their misconceptions.

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