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Emulating the Wright State Model for Engineering Mathematics Education: Improving First-Year Engineering Student Retention

Leroy L. Long III
Embry-Riddle Aeronautical University, longl2@erau.edu

Lisa M. Abrams
Ohio State University - Main Campus, abrams.34@osu.edu

Lisa Barclay
Ohio State University - Main Campus, barclay.4@osu.edu

Jamie Paulson
Ohio State University - Main Campus, paulson.38@osu.edu

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Leroy L. Long III, Lisa M. Abrams, Lisa Barclay and Jamie Paulson
LongL2@erau.edu, Abrams.34@osu.edu, Barclay.4@osu.edu, Paulson.38@osu.edu

Abstract **- In 2004, Wright State University developed an innovative mathematics course for first-year engineering undergraduates in order to increase student retention, motivation and academic success. To date, the Wright State model has had a positive impact on student retention, motivation and academic success by increasing graduation rates and GPAs among participants. During the fall of 2014 and 2015, one large public university in the Midwest with more selective admission criteria decided to pilot a course based on the Wright State Model for Engineering Mathematics Education. Using the Wright State model, a mathematics for engineering course was offered to prospective students so they could subsequently begin engineering classes without a traditional calculus prerequisite. Each semester, a cohort of 31 first-year engineering students enrolled in the course. Instructors distributed surveys to students at the beginning and end of each term. In addition, university administrators tracked student grades in subsequent math and engineering courses. This paper will outline the details of the course as well as the academic performance and retention of these students. Preliminary findings suggest first to second year retention is higher with students who have taken the mathematics for engineering course. First-year students who take the course also earn higher grades in algebra, trigonometry, and introductory engineering courses, but not in Calculus I.**

Index Terms - diversity and inclusion, engineering mathematics, retention and academic success

INTRODUCTION

Mathematics courses sometimes pose an obstacle or bottleneck for undergraduate engineering students' degree completion [1-2]. Many four-year engineering degree programs list Calculus I as a course that students should complete during their first collegiate term or year. Calculus sequences also serve as prerequisites to core undergraduate engineering courses. After taking university-administered math placement exams, engineering students who are unable to test into Calculus I or higher must begin with remedial math coursework instead. In technical majors, students are expected to immediately enter and succeed in a series of required calculus and physics courses. So, taking remedial math courses can increase student costs as well as time to degree.

The Wright State Model for Engineering Mathematics Education allows first-year engineering students to meet traditional math prerequisite requirements through immediate exposure to math topics that are used in core engineering courses [3]. The Wright State Model differs in several ways from traditional mathematics courses that are required of undergraduate engineering students. First, the course is taught by engineering faculty. Secondly, it only includes relevant math topics that are used in core engineering classes and all math concepts are presented within an engineering context. Lastly, it uses a hands-on, application-oriented approach through lecture, laboratory and recitation sessions.

By focusing on engineering students' content knowledge in mathematics, the Wright State Model has led to increased student graduation rates and GPAs, with the greatest impact on underrepresented students [4]. However, student success is also dependent on academic behaviors such as strong self-awareness, utilization of study or test tips, and effective time management skills [5]. Student success can also depend on institutional type, selectivity and location.

This paper will explore the development and results of a new mathematics for engineering course – one based on the Wright State Model for Engineering Mathematics Education. This work took place at a large, more selective public university in the Midwest. The mathematics for engineering course was created to meet university, state and federal initiatives to increase the total number of U.S. degree recipients in science, technology, engineering and math (STEM). The course was also implemented to address challenges faced by incoming students who sought to advance beyond the first year of engineering. Lastly, the course was designed to provide early engineering exposure to students who lacked the required prerequisites to begin introductory engineering courses.

COURSE DEVELOPMENT

At one large, more selective public university in the Midwest, a pilot version of the mathematics for engineering course was created to emulate the Wright State Model for Engineering Mathematics Education. During the summer before the course was piloted, university faculty and staff contacted prospective students about the course based on students' math placement level. A four-member instructional team developed curriculum and later taught the course.

I. Recruitment

During summer orientation, faculty and staff targeted students who did not receive a math placement level of pre-calculus or above for inclusion in the mathematics for engineering course. Students at the university who did not qualify for at least pre-calculus or above have traditionally been unable to meet pre-requisite requirements necessary to begin introductory engineering courses. As a result, some students who are interested in engineering face early frustration and discouragement. Despite the perception that the aforementioned students are underprepared, it is unclear if students' placement score indicates (a) poor test performance, (b) the need for a short math refresher on material that has already been learned, or (c) completion of an entire semester-long course on material that has not been learned. So, faculty and staff stressed the advantage students would receive by learning math concepts within an engineering context as well as having the opportunity to begin engineering courses sooner. A total of 31 students enrolled in the course during both the Autumn 2014 (AU14) and 2015 (AU15) terms. Students with a major of Engineering were recruited from the College of Engineering. In addition, students with a major of "Exploration" and an area of interest of Engineering were recruited from the College of Arts and Sciences. In this paper, students are referred to as engineering and exploration majors respectively.

II. Curriculum

Instructional staff adapted curriculum from Wright State University for lecture and laboratory sessions. Most curriculum was adapted during the summer before the university piloted the course. The lead instructor for the course generated student assignments and presentation slides for daily lecture sessions. A graduate and undergraduate teaching assistant produced a manual and set of presentation slides for laboratory sessions. The teaching assistants also worked with a laboratory supervisor to purchase and test all necessary lab equipment. Lab equipment totaled approximately $420 per group of two students, not including existing computers and work stations along with software such as Microsoft Office and MATLAB. Some parts were made with university-owned 3-D printers.

The new course primarily focused on engineering students' content knowledge in mathematics. The course also contained a unique coverage of college success strategies and academic behaviors. During weekly recitation sessions, another instructor presented numerous college success strategies to students such as self-awareness and time management skills in addition to study or test-taking tips.

METHODS

I. Research Question

This investigation was guided by the following research questions:

1. What were the academic outcomes for new first-year engineering and exploration students who took a pilot version of the mathematics for engineering course in the AU14 and AU15?
2. How likely were new first-year engineering and exploration students who took a pilot version of the mathematics for engineering course in the AU14 and AU15 to remain in engineering?

II. Participants

Institutional data was collected for students who met the following criteria: (a) who entered the university as new first-year students in Autumn 2012, 2013, 2014, or 2015 terms; (b) who declared an engineering area of interest in their first academic term; and (c) who earned a grade in college algebra during their first academic term. This population is comprised of N=204 students, 50 of whom completed the mathematics for engineering course in AU14 and AU15. Therefore, the control group consisted of 154 new first-year students while the treatment group consisted of 50 new first-year engineering students. Additional students who completed the mathematics for engineering course but did not meet the above criteria were not included in the analysis. Students who did not meet the above criteria may have included transfer or continuing students, students who did not have a declared area of interest in engineering, or students who changed to a math class at a level above or below algebra during their first Autumn term.

III. Data Collection and Analysis

Data consisted of the following items: term of admission; degree program during term of admission; sex; race/ethnicity; enrollment status and degree program during each Autumn 2012-2015 term; grades in the mathematics for engineering course; grades in introductory engineering courses; grades in algebra, trigonometry and Calculus I courses, and institutional/survey data on retention.

PRELIMINARY FINDINGS

Research Q1: What were the academic outcomes for new first-year engineering and exploration students who took a pilot version of the mathematics for engineering course in the AU14 and AU15?

The following preliminary findings are the academic outcomes for new first-year engineering and exploration students who took a pilot version of the mathematics for engineering course in the AU14 and AU15 terms:

1. Students who complete the mathematics for engineering course earn higher mean grades in

algebra and trigonometry courses than their peers who do not complete the course. See Table I.

2. Students who complete the mathematics for engineering course do not earn higher mean grades in Calculus I courses than their peers who do not complete the course. See Table II.
3. Students who complete the mathematics for engineering course earn slightly higher mean grades in their first introductory engineering course but lower mean grades in their second introductory engineering course than their peers who do not complete the course. See Table III.
4. Underrepresented engineering students – specifically Blacks, Hispanics and females – who completed the mathematics for engineering course earn higher mean math grades than their same race/gender peers who do not complete the course. See Tables IV-VI.
5. A greater proportion of students admitted during the AU14 term (i.e., 20 out of 30 students) who took the mathematics for engineering course advanced to a Calculus I course than their peers who do not complete the course (i.e., 7 out of 19 students).

TABLE I

MEAN ALGEBRA AND TRIGONOMETRY GRADES

Math Course	Completed Math for Eng. Course			
	No		Yes	
	Mean Grade	N	Mean Grade	N
Algebra	2.5	174	3.1	52
Trig.	2.6	100	2.9	28

TABLE II

MEAN CALCULUS I GRADES

Math Course	Completed Math for Eng. Course			
	No		Yes	
	Mean Grade	N	Mean Grade	N
Calc. I	1.7	92	1.1	20

TABLE III

MEAN INTRODUCTORY TO ENGINEERING GRADES

Intro. Eng. Course	Completed Math for Eng. Course			
	No		Yes	
	Mean Grade	N	Mean Grade	N
Course 1	2.6	91	2.7	25
Course 2	3.3	50	2.9	17

TABLE IV

MEAN ALGEBRA AND TRIGONOMETRY GRADES

FOR BLACK STUDENTS

Math Course	Completed Math for Eng. Course			
	No		Yes	
	Mean Grade	N	Mean Grade	N
Algebra	2.3	42	2.4	9
Trig.	2.3	19	3.4	3

TABLE V

MEAN ALGEBRA AND TRIGONOMETRY GRADES

FOR HISPANIC STUDENTS

Math Course	Completed Math for Eng. Course			
	No		Yes	
	Mean Grade	N	Mean Grade	N
Algebra	1.7	13	3.0	4
Trig.	3.0	5	3.3	1

TABLE VI

MEAN ALGEBRA AND TRIGONOMETRY GRADES FOR FEMALE STUDENTS

Math Course	Completed Math for Eng. Course			
	No		Yes	
	Mean Grade	N	Mean Grade	N
Algebra	2.6	31	3.1	17
Trig.	2.5	23	3.5	7

Research Q2: How likely were new first-year engineering and exploration students who took a pilot version of the mathematics for engineering course in the AU14 and AU15 to remain in engineering?

The following preliminary findings indicate how likely new first-year engineering and exploration students who took a pilot version of the mathematics for engineering course in the AU14 and AU15 terms are to remain in engineering:

1. Students who enrolled in engineering, declared an engineering area of interest in their first academic term, and completed the mathematics for engineering course during AU14 were retained to AU15 at a rate of 83%, which is similar to the first-year retention rate for the overall engineering college at the university. Students who did not complete the course were retained at a rate of 29%. See Table VII.

2. During AU14, students were asked at the start and end of the term the extent to which they agreed with the following statement, "I am confident that I will keep my current major." At the start of the term, 25% of students agreed with the above statement. However, by the end of the term, 38% of students agreed that they were confident about remaining in their major.

3. During AU14, students were asked at the start and end of the term the extent to which they agreed with the following statement, "There's a 50% chance that I will change my major." At the start of the term, 21% of students agreed with the above statement. Yet, by the end of the term, only 14% of students still agreed there was a 50% chance they would change their major.

TABLE VII

ENGINEERING STUDENT RETENTION

Term	Completed Math for Eng. Course			
	No		Yes	
	One Year Retention Rate	N	One Year Retention Rate	N
AU14	N/A	7	N/A	18
AU15	29%	2	83%	15

RECOMMENDATIONS

The following recommendations are for other universities interested in piloting a math for engineering course. The list below may be especially helpful for other four-year universities that are large, more selective, public, and/or located in the Midwest.

1. Target potential participants during summer orientation sessions and provide students/parents with previous success stories and data from other universities.

2. In addition to engineering math, teach students college success strategies such as self-awareness and time management skills as well as study or test-taking tips, which may be unfamiliar to first-year undergraduates.

3. Hire undergraduate and graduate teaching assistants to assist with grading of lecture and lab assignments, testing/troubleshooting of lab equipment, and mentoring of students. If possible, hire a dedicated lab technician to purchase, assemble, and fix equipment.

4. Use existing university equipment and resources to modify and adapt lecture/lab assignments.
5. Encourage students to work in teams and enhance their written/oral communication skills through lab reports and presentations. Provide students with example files and guidelines for creating lab reports and presentations.

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AUTHOR INFORMATION

Leroy L. Long III Assistant Professor, Department of Engineering Fundamentals, Embry-Riddle Aeronautical University, LongL2@erau.edu

Lisa M. Abrams Associate Chair, Department of Engineering Education, The Ohio State University, Abrams.34@osu.edu

Lisa Barclay Senior Director, Diversity, Outreach & Inclusion Programs, The Ohio State University, Barclay.4@osu.edu

Jamie Paulson Graduation Coordinator & Data Specialist, College of Engineering Undergraduate Education & Student Services, The Ohio State University, Paulson.38@osu.edu