Implementing an Engineering Applications of Mathematics Course at the University of Arkansas and Assessing Retention Impact

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One of the hindrances to retention at a public university engineering program with open enrollment is that many students are not prepared for the rigorous curriculum requirements of the first year. In fact, recent increases in enrollment coupled with changes in the math placement guidelines at the University of Arkansas (UofA) have resulted in a significant number of students that are not qualified to begin their course of study in Calculus I. The majority of these students are qualified to begin their course of study one math class behind Calculus I. Traditionally, these students have enrolled in Precalculus. However, in fall 2010, we implemented an Engineering Applications of Mathematics (E-Math) course as an alternative to the Precalculus course. E-Math is modeled after a similar course developed at Wright State University [1]. The course covers many of the topics from the Precalculus course (in the context of engineering applications) as well as topics heavily used in sophomore-level engineering courses (including derivatives and integrals). To date, over 370 students have taken the course, and an additional 66 students are enrolled this spring.

In this paper, we discuss the evolution of the E-Math course structure since its implementation including our work with the Department of Mathematical Sciences in having the course recognized as a prerequisite to the Calculus I course. We evaluate the retention rates and progression through the math sequence of students that took E-Math and compare those results with students that took the traditional Precalculus course to the cohort as a whole. We also discuss our attempts to address issues associated with students who enter our program two math classes behind Calculus I. Specifically, we discuss the implementation of a course developed to have the students calculus ready in a single semester.

Introduction

In fall 2007, the Freshman Engineering Program (FEP) was started at the UofA with the intent of increasing student retention and success. Students complete a common first year before selecting one of nine degree plans offered by the College of Engineering (CoE). The common core taken by freshman engineering students includes Calculus I in the first semester and Calculus II in the second semester along with a two semester Introduction to Engineering course sequence. However, an increasing number of students enter the CoE one math course behind (Precalculus) or even two math courses behind (College Algebra and Precalculus). In the first FEP cohort of 343 students, 248 (72%) students qualified for Calculus I or higher while only 72 (21%) students began in Precalculus and 18 (5%) started in College Algebra. Effective fall 2009, the Department of Mathematical Sciences (MASC) increased the prerequisites for Calculus I and created a College Algebra with Review for students with lower math placement scores. This resulted in a slight decrease in the number of calculus ready engineering students and slight increase in algebra students. Table 1 displays the math placement requirements for the first three years of the FEP program.

Table 1. Previous Math Placement requirements

	ACT/SAT MATH Scores		
Math Course	**2007**	**2008**	**2009**
Calculus I	26/600	26/600	27/610
Precalculus	23/540	23/540	23/540
College Algebra	19/460	20/470	22/520
College Algebra with Review	N/A	N/A	19/460
Beginning Algebra	Below 19/460	Below 20/470	Below 19/460

Major changes to math placement took effect in fall 2010. MASC raised the requirements for Calculus I and Precalculus and created an optional online Math Placement Test (MPT) to allow students to place into higher courses than their ACT/SAT scores permitted. The MPT consists of three sequential tests: the Preparedness for Algebra (PALG), the Mastery of Algebra (MALG), and the Preparedness for Calculus (PCALC). All students must begin with the PALG test and progress forward regardless of ACT or SAT MATH scores. Students are allotted 90 minutes for each test. They must achieve a score of 80% or better to continue to the next test in the sequence. If a student failed to earn at least an 80%, the online module created a study guide for the student to use before making another attempt. Students were allowed three attempts to pass each test. The new math placement requirements are summarized in Table 2.

Table 2. Current Math Placement requirements

Math Course	**ACT/SAT MATH Scores**	**Math Placement Test**
Calculus I	30/680	PALG 80% AND MALG 80% AND PCALC 80%
Precalculus	26/600	PALG 80% AND MALG 80%
College Algebra	23/540	PALG 80%
College Algebra with Review	19/460	PALG 70%
Beginning Algebra	Below 19/460	

As expected, the change in math placement requirements in fall 2010 significantly impacted the number of incoming FEP students who were starting in a math class below Calculus I. This number was also affected by the campus and CoE increase in enrollment.

In order to manage the large increase in students who qualified for Precalculus in 2010, FEP unveiled an Engineering Applications of Mathematics course similar to the Wright State model.[1]

Engineering Applications of Mathematics

In fall 2010, FEP offered the first section of E-Math. The goal was to provide students who qualify for Precalculus an alternate route to Calculus I which would foster their interest in engineering and better prepare them for sophomore level engineering courses. Because this was a new course, MASC was not willing to grant students who passed E-Math direct qualification into Calculus I as is given to Precalculus students. However, students did have the option of completing the MPT to qualify for Calculus I. Therefore, E-Math consisted of two interlaced sets of assignments. The first were Algebra and Trigonometry assignments designed to teach the skills covered by the MPT and were taken directly from the MPT study guide. The second set of assignments were Engineering Applications assignments where math skills were linked to engineering problems like those required in sophomore engineering courses. The structure of the course consisted of three hours per week of lecture with optional drill sessions. The course content included over twenty handwritten homework assignments and three out of class exams. Each exam lasted three hours and consisted of a math skills portion and an applications portion. The spring 2011 offering of E-Math was similar except the exams were changed to four two-hour exams and daily in class quizzes were added.

For the fall 2011 term, E-Math changed to a four credit hour course. This also coincided with changing the structure to include a mandatory drill session two hours per week along with the three hours of lecture. With the structure changes, exams were moved to in class while quizzes were normally done during the drill sessions. The structure of E-Math is now similar to structure of the Precalculus and Calculus courses. In light of these changes and along with the results discussed in the next section of this paper during, the MASC approved E-Math as a prerequisite for Calculus I during summer 2011. Following the same prerequisites as Precalculus students, E-Math students who earn a C or better may enroll in Calculus I in the following semester.

The subsequent offering in spring 2012 was similar to the fall format. There were minor changes to the topics which included more emphasis on limits based on feedback from students in Calculus I. The offering for fall 2012 was also similar to this model with minor changes to content.

Calculus success of E-Math versus Precalculus students

The primary goal of the E-Math course is to offer students an alternative path to the required Calculus sequence while cultivating their interest in engineering. To determine the success of the E-Math course the students' success in Calculus I and their retention within the CoE is compared to the success and retention of Precalculus students. Cohorts are defined as students who enter the CoE as new freshman in the fall semester, started in college algebra or higher, and began the Introduction to Engineering course sequence. Table 3 summarizes the first math placement of the students in the FEP cohorts.

Table 3. First Math Course of FEP Cohorts

First Math Course	2007	2008	2009	2010	2011	2012
Algebra	18	29	31	80	107	142
Precalculus	72	73	75	109	134	123
E-Math	N/A	N/A	N/A	51	85	113
Cal 1	193	233	197	179	223	235
Cal 2+	55	75	63	92	106	152
Other	5	11	19	7	11	6
Grand Total	343	421	385	518	666	771

As summarized in Table 4, while a higher percentage of 2010 cohort students passed E-Math than Precalculus, a smaller number were able to take Calculus I in the spring due to the MPT restriction for E-Math students mentioned previously. The 27 E-Math students who qualified to take Calculus I through the MPT did pass Calculus I in the following spring at a higher rate than the Precalculus students.

Table 4. 2010 Cohort Success Rate in Calculus I by Fall 2010 Enrollment

Math Course Fall 2010	**Total**	**Passed**	**% Passed**	**Calculus I Spring 2011**	**Passed**	**Calculus I % Passed**
E-Math	51	46	90%	27	18	67%
Precalculus	110	75	68%	68	42	62%

The spring offering of E-Math tends to be more populated with transfer students not part of the cohort and some students who either failed Precalculus or E-Math in the fall. We limit our discussion to students in the cohort. In spring 2011, 26 students from the 2010 cohort took E-Math and 51 students took Precalculus. Of the 51 Precalculus students, 12 were students who had passed E-Math in the fall but did not take or pass the required math placement tests to qualify for Calculus I. Table 5 summarizes the success of these students in each of the categories as it pertains to passing Calculus I.

Table 5. 2010 Cohort Success Rate in Calculus I by Spring 2011 enrollment

Math Course Spring 2011	**Total**	**Passed**	**% Passed**	**Took Calculus I Summer/Fall 2011**	**Passed**	**Calculus I % Passed**
E-Math	26	13	50%	4	3	75%
Precalculus only	39	24	61%	21	8	38%
Precalculus after E-Math	12	10	83%	8	4	50%

As mentioned in the previous section, E-Math became an approved prerequisite for Calculus I for fall 2011. This change made E-Math a much more attractive option to students. Enrollment in E-Math was increased but due to campus wide increases in enrollment Precalculus also grew. To respect the MASC prerequisite permission, the grading rigor in the E-Math course was increased. This resulted in a decrease in the percentage of students passing E-Math, but as shown in Table 6 their success rate in Calculus I in the subsequent semester was similar to the previous E-Math and Precalculus students.

Table 6. 2011 Cohort Success Rate in Calculus I by Fall 2011 Enrollment

Math Course Fall 2011	Total	Passed	% Passed	Took Calculus I Spring 2012	Passed	Calculus I % Passed
E-Math	85	56	66%	54	35	65%
Precalculus	134	79	59%	70	50	71%

The spring 2012 offering of E-Math again consisted of many transfer students but there were 46 students from the 2011 cohort including 36 who had started in College Algebra in the fall (two math classes behind). Likewise, 48 of the 2011 cohort students took Precalculus in spring 2012 of those 17 had College Algebra in the fall. The success rate for both courses was lower in the spring. One explanation is that there are a higher percentage of students who withdraw from the course, and many of these students begin looking towards other majors. No major outside the CoE recognizes E-Math and very few require Precalculus. Therefore, students in this situation find it easy to withdraw from their math course to focus on other courses.

Table 7. 2011 Cohort Success Rate by Spring 2012 Enrollment

Math Course Spring 2012	Total	Passed	% Passed	Took Calculus I Summer 2012	Passed	Calculus I % Passed
E-Math	46	21	46%	4	2	50%
Precalculus	48	25	52%	7	4	57%

One of the goals in FEP is to improve the retention in the CoE by helping students progress through the Calculus sequence which result in persistence in the CoE. Tables 8 and 9 below address student progression through the math sequence. While the numbers for the early offerings show slight favor towards Precalculus students, the fall 2011 change in E-Math shows marked improvement. Precalculus also has the advantage of being offered in the summer. Those who completed E-Math are also at a disadvantage for summer courses because many community colleges in the area do not recognize E-Math as a prerequisite. Despite this disadvantage, the overall Calculus I completion rates are similar for both courses (69% vs. 67%). From this we can conclude that E-Math does represent an equally successful path through the first step of the Calculus sequence.

Table 8. Calculus I Completion Rate for Cohort Students by E-Math Completion Term

E-Math Completion term	**Total**	**Cal I Completion Rate**			
		Within One Year	**% Within One Year**	**Total Finished**	**% Total Finished**
Fall 2010	46	27	59%	32	70%
Spring 2011	13	6	46%	10	77%
Fall 2011	56	42	75%	43	77%
Spring 2012	21	9	43%	9	43%
Total	**136**	**84**	**62%**	**94**	**69%**

Table 9. Calculus I Completion Rate for Cohort Students by Precalculus Completion Term

Precalculus Completion term	**Total**	**Cal I completion Rate**			
		Within One Year	**% Within One Year**	**Total Finished**	**% Total Finished**
Fall 2010	81	49	60%	58	72%
Spring 2011	35	19	54%	25	72%
Summer 2011	5	0	0%	1	20%
Fall 2011	87	60	69%	65	75%
Spring 2012	26	14	54%	14	54%
Summer 2012*	12	3	25%	3	25%
Total	**246**	**145**	**59%**	**166**	**67%**

* Summer 2012 students have not completed a year since passing Precalculus.

Retention Comparison of E-Math versus Precalculus

Fifteen diverse institutions that have implemented a course similar to Wright State's model under NSF grants. When those with unfunded collaborations are included, over two dozen have implemented some part of the E-Math concept. Most these institutions have noticed an increase in retention rates among students in E-Math courses.[2] Therefore, the second goal of the E-Math course was to improve the persistence of students in the CoE. Tables 10 and 11 summarize the second and third year retention results of the 2010 cohort. Table 12 summarizes the second year retention of the 2011 cohort. Data on the second year retention of the 2012 cohort is not yet available. CoE retention numbers are higher for E-Math than Precalculus for both cohorts at the 2nd year and at the 3rd year for the 2010 cohort. Comparisons for staying at the university show a mixed result from Precalculus vs. E-Math. The 3rd-year retention data available shows E-Math students retention being slightly higher than the cohort in general as opposed to Precalculus which is below. This further supports the idea that E-Math helps retain students.

Table 10. 2010 Cohort 2nd Year Retention Based on First Math Course

		2nd Year Retention			
First Math	**Cohort**	**CoE**	**% CoE**	**UofA**	**% UofA**
Beginning Algebra	3	3	100%	3	100%
College Algebra	77	51	66%	65	84%
Precalculus	109	62	57%	86	79%
E-Math	51	35	69%	43	84%
Calculus I	179	133	74%	155	87%
Calculus II and beyond	92	77	84%	85	92%
None	7	5	71%	6	86%
Total Students	**518**	**366**	**71%**	**443**	**86%**

Table 11. 2010 Cohort 3rd Year Retention Based on First Math Course

		3rd Year Retention			
First Math	**Cohort**	**CoE**	**% CoE**	**UofA**	**% UofA**
Beginning Algebra	3	0	0%	1	33%
College Algebra	77	26	34%	49	64%
Precalculus	109	50	46%	75	69%
E-Math	51	29	57%	41	80%
Calculus I	179	112	63%	145	81%
Calculus II and beyond	92	65	71%	79	86%
None	7	5	71%	6	86%
Total Students	**518**	**287**	**55%**	**396**	**76%**

Table 12. 2011 Cohort 2nd Year Retention Based on First Math Course

		2nd Year Retention			
First Math	**Total**	**CoE**	**% CoE**	**UofA**	**% UofA**
Beginning Algebra	5	1	20%	3	60%
College Algebra	102	44	43%	62	61%
Precalculus	134	79	59%	108	81%
E-Math	85	55	65%	65	76%
Calculus I	223	176	79%	203	91%
Calculus II and beyond	106	95	90%	100	94%
Other	3	2	67%	3	100%
None	8	5	63%	7	88%
Total Students	**666**	**457**	**69%**	**551**	**83%**

Accelerated Math

Referring back to Table 3, another interesting statistic about the cohort is the increasing number of students who begin their first fall semester two math classes behind (i.e. initial placement in College Algebra). This number changed from 18 in 2007 to 142 students in 2012. Even with successful completion of College Algebra in the fall and Precalculus or E-Math in the spring, these students find themselves unable to meet prerequisites for sophomore engineering courses. FEP along with MASC partnered to create a solution for this problem beginning fall 2012. Accelerated Math (A-Math) was created to allow a small group of students the opportunity to take College Algebra (MATH 1203) and E-Math (GNEG 1514) in the fall semester. The students were placed in a section of College Algebra taught by an instructor who with a dual appointment in FEP and MASC. They were also placed in a separate section of E-Math taught by the FEP Director. There were also two teaching assistants assigned to the course for grading and help during drill sessions. Students attended a 50 minute lecture Monday, Wednesday, and Friday immediately followed by 50 minute drill, and an 80 minute lecture which met on Tuesdays and Thursdays. The content included the topics covered by both the College Algebra course and the E-Math course. The structure of the course was such that early in the semester all lecture focused on College Algebra material. As the semester progressed, E-Math applications were added with the appropriate topics. Eventually, the lecture content was completely focused on E-Math topics. Students completed College Algebra homework assignments online using My Labs Plus software, similar to other College Algebra courses, and handwritten E-Math assignments according to the FEP assignment policy. Drill time was used to allow students to ask questions and reinforce concepts.

Since the A-math combination accounted for seven credit-hours, there was importance placed on students' opportunity to pass the College Algebra part of the class even if they struggled with E-Math concepts. The key to this was creating separate exams for College Algebra skills and E-Math skills. Additionally for prerequisite purposes, importance was placed on making sure only students who passed the College Algebra portion were allowed credit for E-Math. Thirty-seven students completed this pilot program in fall 2012. Of those 37 students, 34 (92%) received credit for College Algebra, and 31 (84%) received credit for E-Math. Pass rates cannot be directly compared to other courses because students self-select into courses thus more dedicated students would attempt this path. However, these initial results indicate A-math could be a viable path for College Algebra students to become Calculus I eligible in a single semester. Their success through the Calculus sequence will continue to be monitored.

Conclusion & Future Work

In this paper, we have discussed the implementation of an Engineering Applications of Mathematics course as an alternative to a traditional Precalculus course for students entering our program one math class behind the recommended curriculum. Initial results show that E-Math represents an equally successful path through the first step of the Calculus sequence and has improved retention of students at the college level but not necessarily at the university level. We also introduced a pilot program that would allow students entering the program two math classes behind and opportunity to be Calculus ready after one semester with reasonable success.

While the increases in second year retention are promising, the ultimate goal of the program is to increase graduation rates at both the college and university levels. We will continue to monitor student progression through the math sequence and persistence in the CoE. Future work will include an assessment of students' ability to successfully complete Calculus 2.

[1] Klingbeil, N.W. et. al. "Rethinking Engineering Mathematics Education: A Model for Increased Retention, Motivation and Success in Engineering." *Proceedings of the 2004 ASEE Annual Conference & Exposition*, Salt Lake City, Utah, June 2004.

[2] Klingbeil, N., High, K., Keller, M., White, I., Brummel, B., Daily, J., Cheville, A. and Wolk, J., "The Wright State Model for Engineering Mathematics Education: Highlights from a CCLI Phase 3 Initiative, Volume 3," *Proceedings 2012 ASEE Annual Conference & Exposition,* San Antonio, TX, June 2012.