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Preparing Engineering Students for the Fall Semester through a Summer Math Bridge Program

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Mr. Brandon Crisel,

I am an 11 year veteran instructor at the University of Arkansas with a BS and MS in Mathematics with emphasis in Statistics and applied Math as well as a MS in Industrial Engineering. I began working in the Math Department, teaching service courses. While there, I taught College Algebra, Math for Elementary Teachers 1&2, Mathematical Reasoning, and Finite Mathematics. I also helped spearhead our department's online initiative to both flip classes while simultaneously creating an online program for our service courses. I was also the Testing Coordinator, where I managed the Testing and Tutoring Centers and their staff. I also created, maintained, supported, and administered the Online Math Placement Test and its related documentation. Through this job, I grew a relationship with the members of our Freshmen Engineering Program (FEP) as their students were one of the largest populations that interacted with the placement exam. Later, an opportunity arose to take a position that would be a 50/50 split between Math and FEP, where I taught sequences of Introduction to Engineering themed in Electronics, Robotics, and Structures. I have since moved entirely to a full time instructor for FEP, where I have helped redesign the Electronics and Robotics theme. I have also developed and implemented a common Computing theme.

Full Paper: Preparing Engineering Students for the Fall Semester through a Summer Math Bridge Program

Introduction

Summer bridge programs are one method used to aid students' transitions from high school to college. Bridge programs have been shown to provide not only academic skills but social resources to connect students to the university, as well as, to other students [1-3]. For engineering students, math can often be seen as the hurdle for degree progression. Students who begin their engineering curriculum in calculus II or higher math have higher graduation rates compared to unprepared students [4]. Thus, creating a successful bridge program that would not only promote the social resources of campus but also improve the mathematical readiness of under-prepared students is advantageous to this student population.

The eight semester degree plans for all engineering and computer science majors at the University of Arkansas assume students will begin their math study in calculus I. However, only 70% of our first-year engineering students qualify to enroll in a math course of calculus or higher, while 20% qualify for precalculus (one math class behind) and 10% for college algebra (two math classes behind). Students' math placements are determined based on their ACT or SAT math scores, through AP or college credit for a prerequisite course, or through a placement exam offered through the University.

In order to improve the math-readiness for a group of first year engineering students who had ACT scores below 28 (thus, did not qualify for calculus I), College of Engineering (CoE) and First-Year Engineering Program (FEP) offered Engineering Math Acceleration Program (EMAP) in Summer 2019. EMAP was a one-week bridge program with the objectives to help students improve their math preparedness, to connect students to the university life, to allow students to explore the College's opportunities and resources, and to help students make connections with their peers to form friendships early that could help them during their fall semester. The program was sponsored by CoE and was offered free to students. Students were also offered a scholarship at the end of the program if they fully participated in the program.

Students who participated in the program were encouraged to move into their fall housing room assignment early, before EMAP began, to replicate the fall college experience. The math-preparedness portion of the program used ALEKS Placement, Preparation and Learning Assessment or ALEKS PPL. The ALEKS PPL is a three-step process including 1) a practice exam 2) a minimum of three hours of ALEKS Prep & Learning Modules and 3) four additional attempts at the proctored exam to improve math placement. On the first day of the EMAP, students were required to take an initial proctored ALEKS exam to establish a baseline for study materials. The students then had time throughout the week to work on the Prep & Learning Modules in a typical engineering classroom with instructors and upper classmen mentors for guided help on content, before taking the proctored exam on the last day of the program. Participants were required to attend all classes, study halls and social activities. The purpose of this paper was to assess the performance of the students who participated in the EMAP program to determine the benefits of offering the program again in the future.

Methods

University of Arkansas is a land grant, public university currently serving approximately 23,000 undergraduate students with a freshmen class of approximately 5,000 students. The students considered in this paper were part of the College of Engineering. As of Fall 2019, the CoE had 3,344 undergraduate students of which 24% are female. Underrepresented students (including female, minority, and first-generation students) made up 51% of the first-year class. The class average ACT ranged from 28.4-28.8 and the class average high school GPA ranged from 3.82-3.85 from fall 2016 to fall 2020. First-year retention rates in the CoE ranged from 67%-72% and six-year graduation rates ranged from 48%-50% over the past five years.

At University of Arkansas, Department of Mathematical Sciences sets the criteria for math placement based on college credit for pre-requisite courses, ACT Math score, SAT Math score or ALEKS PPL Exam Score (Table 1). College algebra is offered as a three-credit hour to five credit hour course where the four credit and five credit courses are designed to incorporate additional remedial math material. Engineering Applications of Mathematics (E-Math) was developed to incorporate engineering labs to support mathematical topics covered in college algebra and precalculus math. The course was taught by engineering faculty in close coordination with the Department of Mathematical Sciences. Calculus I with Review covers the typical content of calculus I, but meets more frequently in smaller sized lectures to also review important college algebra and precalculus topics relevant to the calculus material.

Table 1. Math Courses Taken by EMAP students and Math Placement Criteria in Fall2019

Course	Course Title	Completed Course with a C or better	ACT Math Score	SAT Math Score	ALEKS Math Placement Score
MATH 1203 & 0002L	College Algebra w/2 Hour Lab	none	none	none	none
MATH 1203 & 0001L	College Algebra w/1 Hour Lab	none	19	510	30
MATH 1203	College Algebra	none	23	570	46
GNEG 1514	Engineering Applications of Mathematics (E-Math)	MATH 1203	23	570	46
MATH 1284C	Precalculus	MATH 1203	26	620	60
MATH 2445	Calculus I with Review	MATH 1284C	28	660	70
MATH 2554C	Calculus I	MATH 1284C	28	660	76

University of Arkansas monitors yearly retention and graduation rates for all students. The data analyzed in this study was limited to the freshman engineering cohort who started as a part of First Year Engineering Program in the first fall semester. Pass Rates, GPAs, and retention rates were determined for the 2019 cohort. The cohort was broken down into two groups: 1) EMAP – students who were enrolled in the summer bridge program and 2) Cohort – the rest of the students (not including the EMAP students) in 2019 Cohort. In distributions, we focused on the math courses that EMAP students were enrolled in; however, the grand totals for cohort include all students regardless of initial math course. Initial math placement for some EMAP students differed from their eligibility by Math ACT or ALEKS PPL score due to incoming college credits. Lastly, all types of college algebra classes were counted as “college algebra” in the cohort data.

Results and Discussion

EMAP Students' ALEKS Placement Results and Fall Math Placement

One of the goals of the bridge program was to help students increase their math placement through the ALEKS PPL. Students took a proctored exam day one to get a baseline score and again at the end of the program with the hope of improvement. Most (79%) of the students scored below their expected level on Day 1, where only nine students met or exceeded their placement based on ACT/SAT scores with their first exam (Table 2). As shown in Table 2, no student scored high enough on their initial ALEKS PPL to qualify for precalculus and only 8 qualified for college algebra with no lab. Working through the ALEKS Prep and Learning modules helped students recall some skills they had not utilized in years, reinforced some weaker concepts, and gave them more familiarity with the ALEKS system. Table 3 shows that average ALEKS PPL scores on the final day increased across all levels with the overall average rising 14.8 points. 79% (n=35) increased math placement from first ALEKS score placement to second ALEKS score placement. 23% (n=10) of students qualified to advance their math placements as a result of their ALEKS PPL score compared to their initial ACT/SAT math placement. Two students placed into calculus I with review based on their ALEKS PPL score putting them on pace with the engineering eight semester degree plans.

Table 2. Math Placement of EMAP Students based on ALEKS PPL exam scoring.

Course	Placement Based on ACT/SAT	Placement Based on ALEKS 1	Placement Based on ALEKS 2	Fall 2019 course
MATH 1203 & 0002L	2	11	1	
MATH 1203 & 0001L	10	24	13	
MATH 1203	19	8	17	9 (all 1203)
GNEG 1514*	Same as 1203	Same as 1203	Same as 1203	10
MATH 1284C	12	0	11	14
MATH 2445	Same as 2554c	0	2	8
MATH 2554C	2	0	0	4

* GNEG 1514 has the same placement requirements as MATH 1203; students meeting the criteria for these courses have the choice of which math to enroll in

Table 3. Comparison of Day 1 and Final Day ALEKS PPL scores by Fall math course for students who participated in the Summer 2019 EMAP Bridge Program

Fall Math	Number of EMAP Students*	Average of Day 1 ALEKS**	Average of Final ALEKS	Average of Difference
MATH 1203	9	26.1	44.8	18.7
GNEG 1514	10	34.6	47.6	13.0
MATH 1284C	13	40.8	52.4	11.5
MATH 2445	7	42.0	55.7	13.7
MATH 2554C	4	41.5	65.0	23.5
Total	43	36.6	51.4	14.8

*2 students eliminated because they lacked final scores

** 6 students did not take the exam day 1 but had taken the proctored test before day 1

First Fall Math Course Pass Rates

Another goal of the bridge program was to improve math readiness for underprepared students. By exemplifying study requirements, building confidence in math skills, and acclimating students to the collegiate experience, EMAP allowed students to be able to preemptively see and overcome the initial stumbling blocks that usually present themselves in the first few weeks for underprepared students transitioning to college in an engineering program. Figure 1 shows that EMAP students had higher overall pass rates for their math classes (84% vs. 79%). As well, EMAP students had higher pass rates in every individual class except calculus I.

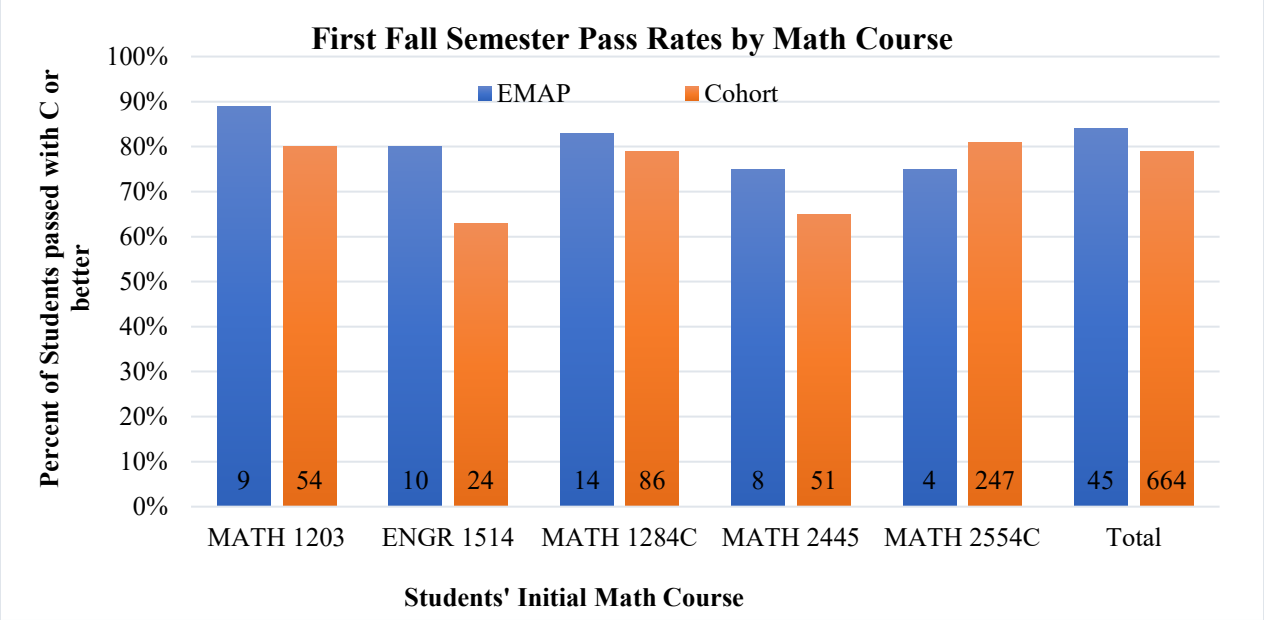

Figure 1. First Fall Semester Math Course Distribution and Pass Rates for EMAP and Cohort. The total number of students enrolled in each course is given inside the bars.

Fall Semester GPAs by Math Course

The first semester GPA of underprepared students that participated in EMAP was notably higher than their cohort counterparts. Table 4 shows that 67% (n=6) of EMAP college algebra students had a 3.0 or better GPA compared to only 36% (n=19) for the rest of the cohort. Similarly, 71% (n=10) of EMAP precalculus compared to only 48% (n=41) for the rest of the cohort and 60% (n=6) of EMAP E-Math students compared to 37% (n=9) for the rest of the cohort had a 3.0 or better GPA. However, EMAP students that were able to advance to a form of calculus I struggled in their first semester. Only 38% (n=3) of EMAP calculus I with review students compared to 52% (n=26) for the rest of the cohort and 50% (n=2) of the EMAP calculus I students compared to 68% (n=168) had a 3.0 or better GPA.

Table 4. Fall 2019 GPAs of students by first semester math course then by EMAP vs Cohort.

	College Algebra		**Precalculus**		**E-Math**	
GPA Range	EMAP	Cohort	EMAP	Cohort	EMAP	Cohort
Below 1.5	1 (11%)	11 (20%)	1 (7%)	13 (15%)	1 (10%)	6 (25%)
1.5 - 1.99		3 (6%)	1 (7%)	2 (2%)	1 (10%)	1 (4%)
2.0 - 2.49	1 (11%)	12 (22%)	1 (7%)	10 (12%)		2 (8%)
2.5 - 2.99	1 (11%)	9 (17%)	1 (7%)	20 (23%)	2 (20%)	6 (25%)
3.0 - 3.49	5 (56%)	12 (22%)	7 (50%)	17 (20%)	6 (60%)	5 (21%)
3.5 - 3.74		6 (11%)	3 (21%)	11 (13%)		2 (8%)
3.75 - 4.0	1 (11%)	1 (2%)		13 (15%)		2 (8%)
Total	9 (100%)	54 (100%)	14 (100%)	86 (100%)	10 (100%)	24 (100%)
	Calculus 1 with Review		**Calculus 1**		**All**	
GPA Range	EMAP	Cohort	EMAP	Cohort	EMAP	Cohort
Below 1.5		8 (16%)		15 (6%)	3 (7%)	57 (9%)
1.5 - 1.99		3 (6%)	1 (25%)	7 (3%)	3 (7%)	16 (2%)
2.0 - 2.49	4 (50%)	6 (12%)		24 (10%)	6 (13%)	69 (10%)
2.5 - 2.99	1 (13%)	8 (16%)	1 (25%)	34 (14%)	6 (13%)	88 (13%)
3.0 - 3.49	1 (13%)	11 (22%)	1 (25%)	51 (21%)	20 (44%)	134 (20%)
3.5 - 3.74		7 (14%)		37 (15%)	3 (7%)	100 (15%)
3.75 - 4.0	2 (25%)	8 (16%)	1 (25%)	80 (32%)	4 (9%)	197 (30%)
Total	8 (100%)	51 (100%)	4 (100%)	248 (100%)	45 (100%)	661 (100%)

Second Year Retention of 2019 Cohort

Second year retention for the COE has improved significantly (61% to 70%) after the implementation of FEP in 2007. In Fall 2019, there were 709 students enrolled in FEP. 84% of these students were enrolled at the University during the fall semester of their second year, and 72% were still enrolled in the COE. We see similar retention rates when we look at the 45 EMAP students separately; 82% of EMAP students were enrolled at the University during the fall semester of their second year, and 73% were still enrolled in the COE. To explore retention further, Figure 2 shows the second-year retention rate by students' initial math course they were enrolled in Fall 2019. We observe that the retention rate of EMAP students were higher than the rest of their cohort in all math courses with the most significant increase seen in college algebra.

We also explored the second-year retention rates by students' high school GPAs and by Math ACT scores. For high-school GPAs, we observed that the second-year retention rates for EMAP students were 10% higher than the rest of their cohort in high school GPA range 3.0 - 3.5. The difference was less than 5% in all other GPA ranges. For math ACT scores, we observed that the second-year retention rates for EMAP students were 24% higher than the rest of their cohort in Math ACT scores less than 23, and 20% higher than the rest of their cohort in Math ACT score range 23-25. The difference was less than 3% in Math ACT scores 26-27. The EMAP program has improved the second-year retention of students on the lower high school GPA and lower Math ACT score ranges.

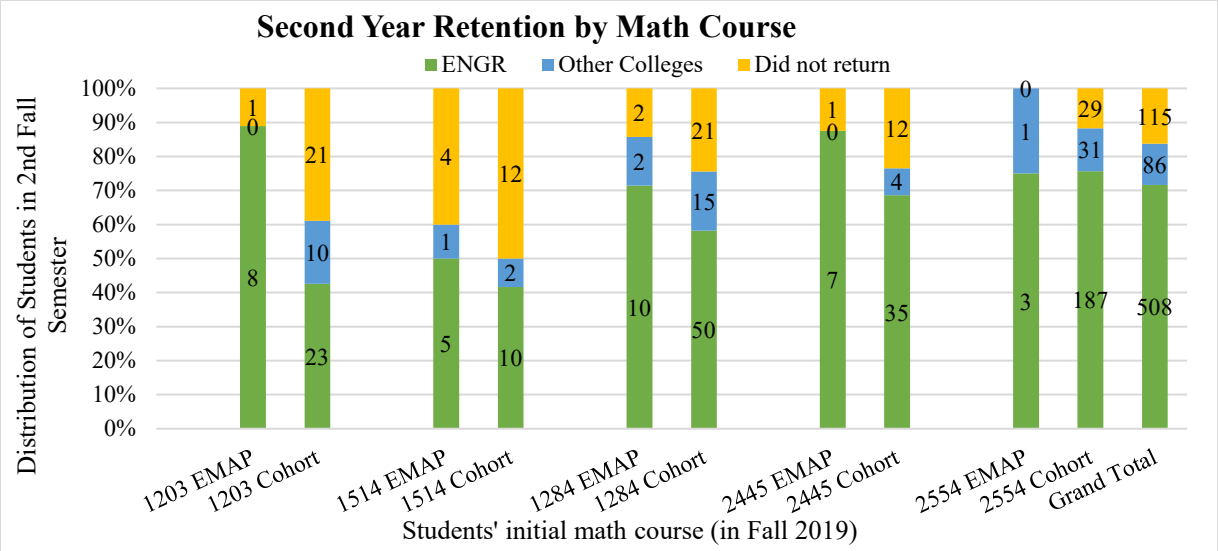

Figure 2. Second Year Retention Rates by Initial Math Class and divided into EMAP students and Cohort. The number of students in each category is given inside the bars.

Conclusion

The primary goals of the EMAP program were to increase the math placement and retention of underprepared students. Though the number of participants was small (n=45), we still observed notable success from this program where 23% of students advanced their math placement compared to their initial ACT/SAT placement. We also observed that the retention rate of EMAP students were higher than the rest of their cohort in all math courses with the most significant increase seen in college algebra. The EMAP program has improved the second-year retention of students on the lower high school GPA and lower Math ACT score ranges. EMAP students enrolled in college algebra and precalculus in the fall had higher GPAs than cohort students likely due to extra resources and study groups formed during the program. EMAP students who placed into calculus still struggled in the first semester. Though they had a similar pass rate as other cohort students, they still struggled with a difficult course load of calculus, physics, and chemistry. Additional analysis of spring semester success and second year retention was confounded by the effects of COVID-19 on course content delivery and grading policy.

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