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Success in Engineering Study of Under-Prepared Students

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I am a 10 year veteran instructor at the University of Arkansas with a BS and MS in Mathematics with emphasis in Statistics and applied Math. I began working in the Math Department, teaching service courses. While there, I taught College Algebra, Math for Elementary Teachers 1 and 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 and develop a new common Computing theme.

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Full Paper: Success in Engineering Study of Under-Prepared Students

Introduction

Preparedness for college is an issue of concern for both students and institutions. For students, earning a college degree promises more job opportunity, greater job satisfaction, higher income, and better benefits. For institutions, graduation rates are a transparent measure of accountability and are used by potential students and donors as a measure of the quality of the school. With the national average college graduation rate hovering around 60% (NCES, 2020), institutions are looking for ways to increase this rate. Approximately one-third of all students entering colleges or universities in the United States need some form of remediation (Schak et al., 2017) and even more are considered unprepared to be successful in rigorous college level courses. Student preparedness may be an indicator of student persistence in higher education, since students who enroll in remedial courses are less likely to complete their degree (NCPPHE, 2010).

Scott-Clayton and Rodriguez (2015) found that while $4 billion is invested annually in courses to help underprepared students, little positive effect has been attributed to the effort. They proposed several possible reasons why efforts may have little success including that exam placement may not be an accurate method of placement, remedial courses may not actually be addressing or focusing on the needs of the student and that instructional approach used may not link the needed remedial skills with the relevant college level material. Thus, institutions need to take into account the needs of their students when considering ways to aid these students. Preparedness may not just be limited to course work but may also include social and professional skills such as time management, communication, problem solving, teamwork, and work ethic.

The purpose of this paper is to determine if retention rates of students who begin their math course of study in remedial math or college algebra increased after the implementation of a preparatory course called Fundamentals of Success in Engineering Study (SES) compared to the same population of students (i.e., qualified to take college algebra) prior to the implementation of this remedial course. We also compare the graduation rates of students based on their first math course and check whether they had completed Calculus I prior to the start of their second fall semester. This analysis will help us understand whether the implementation of SES was beneficial to under-prepared students, or if we need other ways of retaining this population of students.

Research Questions

1) Did second year retention increase in students who began their math course of study in college algebra after the implementation of SES?
2) Did the percent of students that completed Calculus I prior to the start of the second-year increase for students in college algebra after the implementation of SES?
3) How do graduation rates for students enrolled in college algebra during their first fall semester compare to students who enroll in a higher math course?
4) Did 4-year or 5-year graduation rates for students who began their course of study in college algebra increase after the implementation of SES compared to the historical rate?

University Studied

The University of Arkansas (UofA) is a land grant, public university currently serving approximately 23,000 undergraduate students. Minimum admission requirements for new freshman applicants is a high school GPA of 3.0 or higher on a 4.0 scale, and an ACT score of 20 or higher, or the SAT equivalent. The College of Engineering (COE) does not have separate admission standards. As of Fall 2019, the COE has 3,344 undergraduate students of which 24% are female. Underrepresented students (including female, minority and first-generation students) make up 51% of the first-year class. The first-year average ACT ranged from 27.8-28.8 and the first-year mean high school GPA ranged from 3.72-3.84 from fall 2015 to fall 2019. First-year retention rates in the COE ranged from 67%-71% over the past five years and six year graduation rates ranged from 46%-50% over the same time frame.

At the UofA, students are placed into a math course based on their ACT or SAT math scores or through AP or college credit for a prerequisite course. Prior to 2014, all students who wanted to major in engineering began their course of study in Introduction to Engineering I. This course covered unit conversions, dimensional analysis, and basics of programming; it was assumed that students enrolled in this course had sufficient skills in college algebra. Beginning in 2014, students who placed into a math course of pre-calculus or higher took the Introduction to Engineering Course, but students who did not have the math requisites were required to take a remedial engineering course called Fundamentals of Success in Engineering Study (SES) that focused on study skills and math skills development with the learning outcome of becoming successful engineering students. Approximately 85% of our first-year engineering students qualify to enroll in a math course of pre-calculus or higher, and 15% qualify for college algebra.

The Fundamentals of Success in Engineering (SES) Course Description

The primary goal of SES is to help students with lower placement develop study skills before they are pushed into mathematically rigorous courses. The course was initially developed around the *Studying Engineering: A Road Map to a Rewarding Career* (Landis, 2013). Using the text as a guide, students explored lessons that challenged them to think more about why they wanted to become an engineer, what would be required to become an engineer, and what professional skills they needed to be successful. The course culminated with the writing project "Design Your Process for Becoming a World-Class Engineering Student" in which students applied engineering design concepts to create a plan for becoming an engineer.

As with any course, SES evolved over the years to try to better serve our students. In the second year, the writings during the semester were modified to be incorporated as parts of the final project. Lessons were added which used engineering concepts to reinforce the skills they were learning in their College Algebra classes. A catapult competition was also added at the end of the semester to give students a hands-on team experience. In 2017, the math skills assignments were phased out in favor of some Microsoft Excel lessons. In 2018, the course was redesigned using *Teach Yourself How to Learn* (Yancy McGuire and McGuire, 2018). The course shifted focus to developing study skills that would be used in future engineering courses. The course returned to using the math skills lessons to have common example lectures and homework that would utilize the type of learning they would have in future engineering courses. The course continues to

evolve with the help of the full time Academic Coach hired by COE in 2019. While the content changes, the primary goal remains the same, which is to give first-year engineering students the best tools to succeed in their second year and beyond.

Methods

The UofA 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 (FEP) in the first fall semester from 2007-2018. Retention and graduation rates were determined for the cohort. The cohort was then broken down into two groups, those from 2007-2013, during which all freshman students took the same introductory course and 2014-2018, when students who qualified for college algebra took SES. Within these two groups, the data was limited to students who enrolled in remedial algebra and college algebra during their first fall semester.

Retention rates were calculated for each group (before SES was implemented and after SES was implemented) and graduation rates were calculated for four, five and six years where possible (e.g., six year is not available yet for the 2014-2019 data set). A two-sample t-test assuming equal variances was used to determine if there was a significant difference between the retention and graduation rates between each student grouping. We used an alpha of 0.05 for all analyses.

Results and Discussion

Second year retention for the COE has improved since the implementation of FEP in 2007. From 2007 to 2018, 7648 students were enrolled in the COE. 84% of these students were enrolled at the UofA during the fall semester of their second year, and 70% were still enrolled in the COE. However, that rate is lower for students who begin their math course of study in college algebra. During this same period, 930 students (of the 7648 total) were enrolled in remedial math or college algebra during the fall semester. Only 70% of these students remained at the UofA during their second year and only 52% stayed in the COE. To study the impact of SES course on second year retention, we looked at the years before and after the implementation of this course as two separate groups. Before the implementation of SES, from 2007 to 2013, there were 504 students enrolled in remedial math or college algebra of which 72% were enrolled in fall of their second year and 54% stayed in the COE. After the implementation of SES, fewer college algebra students were retained in the second year. From 2014 to 2018, there were 428 students enrolled in SES (and remedial math or college algebra) of which 65% were enrolled in fall of their second year and only 47% stayed in the COE. Table 1 summarizes these findings.

We observed that second year retention did not increase after the implementation of SES, in fact, there is a 7% drop in retention for the four years of data from 2014-2018. It is worth noting that the second-year retention gradually dropped over these years; with rates of 57%, 52%, 44%, 43% and 25% in the years 2014, 2015, 2016, 2017 and 2018, respectively. One possible explanation for this gradual drop is the recruitment of students for a new course we offered starting in 2016, GNEG 1514 Engineering Applications of Mathematics. This course was designed as an alternative to college algebra and precalculus courses offered by the math department. The

course combines math skills with engineering related applications and hands-on labs to provide engineering students with more relevant content and serves as an accelerated math course to help students in college algebra level math to get into Calculus I one semester earlier. There were 14, 38, and 42 students enrolled in GNEG 1514 in years 2016, 2017 and 2018, respectively, who would have otherwise been enrolled in SES. Pulling these students out of the SES class seemed to impact the second-year retention rates negatively for this cohort.

Table 1. Second year retention data for students enrolled in the College of Engineering at the University of Arkansas. Rates were calculated for the entire first year engineering cohort (FEP) and for students who qualified to take remedial math or college algebra (CA) during their fall semester. Data from 2014-2018 represents students who enrolled in SES if they were enrolled in remedial math or college algebra.

	Before SES: 2007-2013		After SES: 2014-2018	
2nd Year Retention	FEP (n=3769)	C.A. (n=504)	FEP (n=3879)	C.A. (n=426)
Engineering	70%	54%	70%	47%
University	84%	72%	83%	65%

Freshman engineering students in FEP declare their majors in the spring semester. Calculus I is a prerequisite to most introduction courses offered by the engineering majors; therefore, engineering students need to complete this math requirement before starting their second year to be able to move on to their departmental courses. We wanted to see if the percent of students that completed Calculus I prior to the start of the second year increased for students who started in college algebra after the implementation of SES. For years 2007-2013, 14.5% (76 students out of 504) of students who began their fall semester in college algebra completed Calculus I before the start of the 2nd fall semester. For years 2014-2018, 17.6% (75 students out of 426) of students who began their fall semester in college algebra completed calculus I before the start of the 2nd fall semester. This shows a 3.1 percentage point improvement in the calculus 1 completion rate. This improvement is substantial, but due to the sample size when comparing proportions, this change is not statistically significant with an alpha of 0.05 (although it is close with a p-value < 0.10).

The implementation of FEP in 2007 has increased the graduation rates for COE. The four-year graduation rate increased from 17.0% in 1998-2006 to 30.9% in 2007-2018, and 6-year graduation rate increased from 37.9% in 1998-2006 to 47.7% in 2007-2018. We wanted to know how graduation rates for students enrolled in college algebra compare to students who enrolled in a higher math course during the first fall semester (Table 2). It is not surprising that 4-year graduation rates are very low for students who start in college algebra since these students are two math classes behind the eight-semester degree plans of engineering majors. It is also important to note that some required science courses and most introduction level departmental courses have math prerequisites; therefore, these students also start behind in most required courses. These are all contributing factors for the overall low 5- and 6-year graduation rates for this group of students when compared with their peers who were able to follow the eight-semester degree plans more closely.

Table 2: Graduation data for College of Engineering students who started in FEP from 2007 to 2015. Rates were calculated for students who qualified to take remedial math or college algebra during their first fall semester (CA) and for all other students (FEP).

		Cohort Years								
		2007	2008	2009	2010	2011	2012	2013	2014	2015
4-Year Grad Rate	C.A.	0%	0%	0%	0%	1%	6%	3%	1%	4%
	FEP	30%	28%	28%	33%	36%	39%	37%	39%	41%
5-Year Grad Rate	C.A.	6%	4%	10%	8%	7%	18%	16%	16%	
	FEP	41%	49%	47%	48%	52%	52%	53%	54%	
6-Year Grad Rate	C.A.	11%	15%	13%	15%	12%	21%	19%		
	FEP	44%	53%	49%	51%	55%	55%	55%		

Table 3 organizes the graduation rates for COE students with the cohort separated into two groups in hopes to identify the impact of the implementation of SES course on graduation rates: Group 1 is students who started in FEP from 2007 to 2013, during which all freshman students took the same introductory course, and group 2 is students who started in FEP during 2014 and 2015, when students who qualified for college algebra took SES. Within each group, we also looked at the graduation rates of students who started in college algebra. Although the four-year graduation rates have consistently increased since the introduction of FEP, it is not possible to set a trend for the four-year graduation rates for students who started in college algebra because there are very few students with this accomplishment. There is an increase in the five-year graduation rates of FEP students who started in college algebra after the implementation of SES; the five-year graduation rate increased from 12% to 16% within the COE, and from 28% to 32% within the university. The data, unfortunately, is limited to only one year; we will continue to monitor the 5 and 6-year graduation rates for this group of students.

Table 3: Graduation data for College of Engineering students who started in FEP from 2007 to 2015. Rates were calculated for the entire first year engineering cohort (FEP) and for students who qualified to take remedial math or college algebra (CA) during their fall semester. Data from 2007-2013 was before the implementation of Success in Engineering Study (SES). Data for 2014 and 2015 represents students who were enrolled in SES.

	2007-2013		2014		2015	
Graduation Rate	FEP (n=3,777)	C.A. (n=504)	FEP (n=714)	C.A. (n=119)	FEP (n=802)	C.A. (n=117)
4-Year	30%	2%	32%	1%	36%	4%
5-Year	45%	12%	48%	16%		
6-Year	48%	16%				

Conclusions

Conclusions are constrained because of limited data (low n values) and some statistical analyses showed no significant improvement although meaningful positive trends were observed. Thus, we continue to look for significant changes in student success as more students participate in SES. Overall, we did not observe statistical differences in the retention and graduation rates of college algebra students after the implementation of SES. We continue to evolve the SES course based on qualitative feedback from students. This includes the need for more rigor in their first semester to better prepare them for second semester courses including pre-calculus math and chemistry. As instructors and academic advisors in the FEP, our observations are that engineering students need strong basic algebra skills to be successful in the abundance of STEM courses outlined in any engineering degree. SES should serve as a supplement to their math course, but the course content must spend significant time reinforcing math and study skills.

Although retention and graduation rates for the COE would improve by excluding under-prepared students from joining the college until mathematically prepared for rigorous STEM courses required for any engineering degree, the under-prepared population represents 15% of our student body and discounting them from the start would be unfair to these students. We will continue to search for ways to support these students as they in their academic careers.

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