Significance of Proper Math Placement for First Year Minority Engineering Students

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Abstract

Underrepresented minority (URM) students with limited math proficiency are among those less likely to consider engineering as a college major and career choice. According to ASHE, difficulty in remedial courses during K-12 are among the eight factors that contribute to inadequate preparation of URM students in engineering[7]. For those who pursue engineering, the ability to comprehend and perform upper level mathematical computations is vital. It is critical for engineering students as early as the first year of studies, to establish a strong mathematical foundation. For many years college and universities have addressed URM student under preparedness through the use of summer bridge programs. To aid in the successful transition of incoming URM engineering students, a Summer Bridge Program held at a 4-year predominantly white land-grant institution (PWI) in the Southeastern portion of the United States, uses a four-fold approach to determine math placement for URM engineering students. Research has shown that it is critical for students to begin their engineering studies in the proper math course to increase the likelihood of developing strong math competences needed throughout their engineering matriculation. This paper investigates how the Summer Bridge Program math placement and scores correlate with the success of first year math coursework of participants from 2014 -2018.

Keywords

STEM, Summer Bridge Program, URM students, Math Placement

Introduction

Over the last decade and a half, the U.S. has struggled to produce adequate numbers of qualified workers to meet the demands for science, technology, engineering and mathematics (STEM), related jobs. The U.S. must identify ways to increase participation across a diverse spectrum of citizens to help meet the growing needs for the technological demands of the 21st century. According to the U.S. Department of Labor[1], only 5% of U.S. workers are employed in fields related to science and engineering, yet they are responsible for more than 50% of our sustained economic expansion. Furthermore, minorities make-up 0.0025% (1/400) of that STEM workforce. Figure 1 illustrates the U.S. workforce breakdown including STEM jobs.

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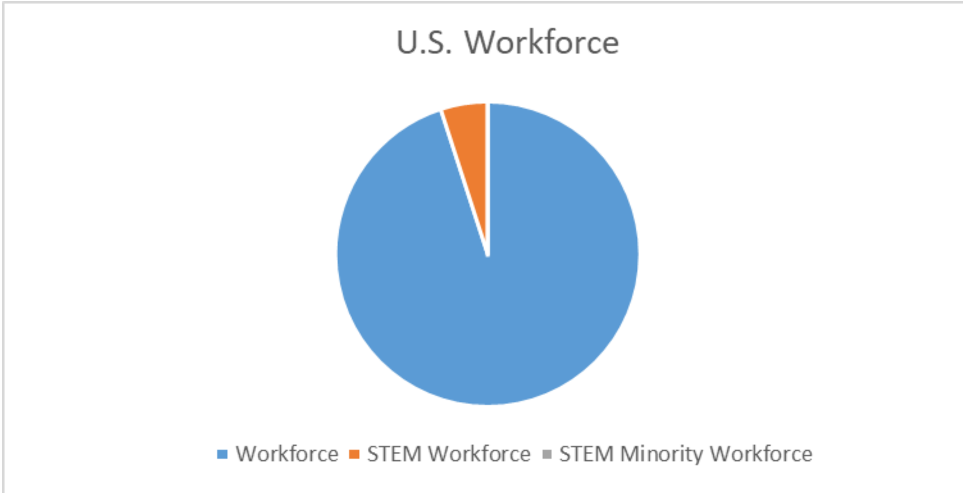

Figure 1. U.S. Workforce Breakdown (U.S. Department of Labor, 2007)

As the United States competes to remain a global leader in technology and innovation, it will require a STEM workforce inclusive of those from underrepresented populations to help meet the challenges of a robust knowledge-based economy. As early as the 2nd year of matriculation, African American, Hispanic American, American Indian or Pacific Islander students, which are more commonly referred to as underrepresented minority (URMs) in STEM, experience high levels of drop-out or change their major to a non-STEM major. These outcomes have been contributed to constraints including course rigor, institutional barriers and academic barriers. In many URM students contend with marginal financial resources, poor access to exceptional teachers and volunteers and chilly college campus climates. These are all factors prohibiting persistence and student success [2,3,4].

Historically those from underrepresented groups have not participated in STEM related college majors equal to or near the rate of those from majority groups. The U.S. Census Bureau[5] projects that racial minorities will become the majority demographic within the US as early as the year 2045. The Bureau contends during that year, Whites will comprise less than half of the U.S. population[6]. These statistics, coupled with the insistent demand for a highly skilled STEM related workforce, confirm the need for more inclusion of members from unrepresented minority groups in STEM college majors. It is imperative that U.S. policies, institutional structure and educational best practices be representative and inclusive of those from underrepresented minority groups to aid in the academic success of those pursuing STEM college majors and subsequently STEM careers. This growing gap in the availability of qualified STEM workers when compared to the demand for a STEM workforce continues to be a concern for national and state-level policy makers.

Factors Impacting Student Mathematical Foundation

Students considering engineering as a college major are expected to perform well in foundational courses such as mathematics. This can be difficult for students coming from K-12 backgrounds where STEM teacher shortages are prevalent. Noted as one of the eight factors impacting URM student preparedness for engineering, STEM teacher shortages across the U.S. continues to persist[7]. Additionally, it has been widely recognized that teacher shortages are especially a concern for schools with high rates of poverty and where lower pupil budgets exist. Furthermore, schools with high poverty are disproportionately affected when compared to schools in more affluent areas[8]. The researcher further contends on average high-poverty schools experience teacher attrition twice as much as affluent schools. As a primarily rural state located in the Southeastern portion of the United States, the University is home to many residents who live below the national poverty level. The state is educationally ranked 45th nationally in education overall and 49th in college readiness[9]. Some of the greatest teacher shortages occur in both rural and urban communities[10].

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Factors impacting low minority student representation in engineering college majors go beyond socioeconomic status, funding disparities, and unavailability of qualified STEM teachers. Minority students also experience low representation in Advanced Placement (AP) courses, diminished teacher expectations, oppositional culture and high rates of premature departure from high school[11]. As STEM jobs continue to be on the rise, the need to effectively prepare a pipeline of minority students who are well positioned to contribute technical professions is imperative.

First Year Math Challenges

For students who pursue engineering college majors, the ability to comprehend and perform upper level mathematical computation is vital. It is not uncommon for incoming first year URM students to express a dislike for math or a feeling of under preparedness due to their high school experiences. Establishing a strong mathematical foundation is fundamental and critical to the future success of engineering students. Studies have shown that many students fail to successfully complete gateway math courses needed for engineering such as the calculus sequence. Specifically, the outcomes of student performance in Calculus I has been used as a predictor of persistence in engineering majors[12].

Student outcomes in college mathematics can also be attributed to a lack of studying required in high school. Nite, Capraro, Bicer and Morgan[13] state that mathematics can be much more challenging to those students who were successful in high school without the need to study. Their findings posit engineering mathematics college courses tend to cover twice the volume of materials in 60% of the time allotted for high school mathematics courses. The rigor of college mathematics requires engineering students to enter college with sufficient mathematical competence. Incoming URM students have stated memorization as a common approach to studying[14]. Consequently, memorization as an approach to studying mathematics does not allow for depth of knowledge of the subject. Although prominently proclaimed across all educational ranks, the findings from Nite et al.[13] continues to stress the importance of students developing improved study skills to aid in improved college retention. This research further states that although a background of content knowledge is needed, good study habits are critical. Because the demand of college mathematics outpaces that of high school, students must determine how best to prepare themselves to learn material.

It is essential during first year college math courses students are able to successfully demonstrate conceptual mathematic ability and to draw from prior mathematical knowledge[15]. The inability of students to make these connections decreases the likelihood of success in later mathematic courses. Proper first year math placement allows students to improve math foundational competencies. This growth enables potential success in first year math courses and further serves as a motivation for additional college success[16]. Interventions by colleges and universities are needed to provide strategies for success in college mathematics[13]. Social equity initiatives such as summer bridge programs aid in the graduation rates of URM students at PWI southeast land-grant colleges and universities[17].

Summer Bridge Intervention

To aid in the high school to college mathematics transition, a Summer Bridge Program located at a 4-year land-grant PWI in the Southeastern portion of the U.S. has designed a four-fold approach to determining proper math placement for URM engineering students. The program accepts students with ranging ACT/SAT scores. Not all students enter the program ready to meet engineering mathematics requirements. Accordingly, Summer Bridge is committed to assisting students in minimizing or resolving academic learning gaps. Although Calculus I is the first math course for engineering degree credit, the Bridge Program focuses on preparing to meet individual student math needs to improve first year math outcomes and to assist students in developing a proper foundation.

The literature on URM STEM student retention is prevalent with discussions regarding the purpose and intent of Summer Bridge Programs; however, there remains much to learn about program design and overall program effectiveness. This 5-week residential academic program is held during the summer session prior to fall enrollment. Participants engage in an intensive schedule of foundational engineering courses, professional and personal development strategies and real-world engineering problem solving. To minimize the negative potential of learning material that some may not have been exposed to in high school, academic credit is not given for courses completed. However, students receive graded assignments and tests from each course taken. Participants attend the program at no cost as financial support is provided through corporate sponsorship. An online application, high school transcript and two letters of recommendation are required from students.

For some participants, the program rigor is unexpected and unlike their high school experiences. Over the years students have shared statements with program staff such as “we never had to study in high school” or “my high school didn’t offer Trigonometry”. In addition to academic course instruction, much effort is placed on helping students to establish effective study skills and proper time management strategies. The program offers instruction in both College Algebra and Trigonometry/Pre-Calculus for the 5-week session.

Math Course Determination

Prior to assigning students to either College Algebra or Trigonometry/Pre-Calculus during the Summer Bridge Program, an overall assessment is conducted for each student as illustrated in Figure 2. Student Math ACT sub-score, along with high school math coursework, and the University Math Placement assessment are all considered when determining math placement for Summer Bridge. Historically in engineering Math ACT sub-scores are used to determine whether a student is eligible to enroll in Calculus I. For instance, the 4 -year institution in this study, requires a Math ACT sub-score of 26 to enroll in Calculus I, the first course required in the math series for engineering majors. Students with less than a 26 sub-score are required to take a lower level math course instead.

Summer Bridge Mathematics

For the purpose of Summer Bridge math placement, a Math ACT sub-score of 23 is used to determine which university math placement test a student will complete. Those students with a score less than 23 complete the placement test for College Algebra while those students with a sub-score of 23 or above complete the Trigonometry/Pre-Calculus placement. A combination of these assessments and past performance in high school math courses as well as the ACT math score, enable students to be assigned to an appropriate math class. The use of multiple methods to capture data on student math abilities result in the creation of student math profiles. These math profiles allow for a more comprehensive understanding of each students’ math abilities. The input of these three unique data points allows for a “quasi” data triangulation approach to determining an appropriate start for student Summer Bridge math enrollment.

During the program orientation to parents and students, the Program Director shares the importance of students starting out in the proper math course. This prompting result in signed “contractual” agreements from students and parents to take the recommended math course in both the program and the fall. The motto of “Start Strong Finish Strong” is used as a reminder to both participants and parents that students excel at different rates. One of the program fundamental concepts emphasized is engineering coursework is less about where you start but more importantly to work to establish a solid math foundation.

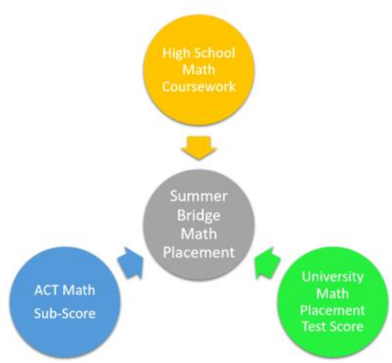

Figure 2. Summer Bridge Math Placement Diagram

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First Year Mathematics

Similar to the process used to determine Summer Bridge math placement, first year math course placement also uses multiple data inputs. At the completion of the Summer Bridge Program students receive final grades in each of the foundational engineering classes taken. Student fall math placement is based on the combination of four data points, 1). High school math transcript 2). Math ACT sub-score 3). University Math Placement Assessment 4) Summer Bridge Math Outcome. The creation of student math profiles increases the opportunity for more accurate fall math placement.

Specifically, Summer Bridge math instructors provide a recommendation for fall math courses as indicated by each student profile. In some cases, students are approved to by-pass the initial math course indicated by their Math ACT sub-score. Through an agreement with the University math department, students are granted a course override to take a higher-level math course. Additionally, there are students who receive recommendations to enroll in a lower level math course than is indicated by their Math ACT sub-score.

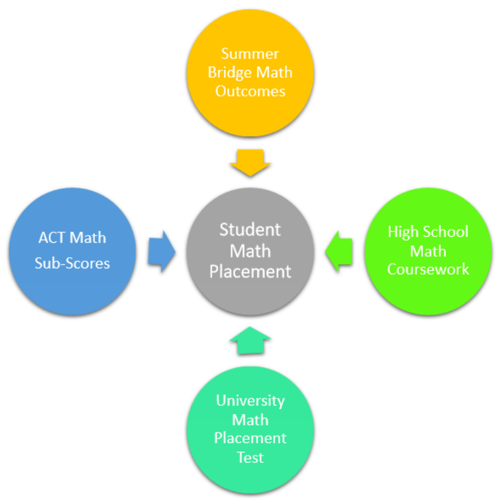

Figure 3. First Year Math Placement Diagram

Data Methodology

To analyze the effectiveness of fall math placement for the fall semester, final grades for each fall semester for the period 2014-2018 were compiled. of each participant and their proficiency of scores, we compiled the final grades from the College Algebra and Pre-Calculus courses offered in the Summer Bridge program from 2014 to 2018. In addition to fall math outcomes, Summer Bridge math outcomes have been included as shown in Tables (1-3). This study used archived student data extracted from the University's student, faculty and staff web portal, and documented Summer Bridge reports from 2014-2018.

According to our observations over this five-year period, student math "success" is defined as earning a grade of A, B, or C on the first attempt of a course. Program "success" for this same period is established as a cohort achieving a minimum of 75% of students earning grades of A, B, or C on the first attempt of a course. Although there were students who earned grades less than A, B or C, they were not the focus of this research. It is important to note that this study defines "first year math" to be the initial math course taken by students during the student's first fall semester in college.

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Results

The total number of participants across all Summer Bridge cohorts is broken between College Algebra or Trigonometry/Pre-Calculus as shown in Table 1. For the year 2014 there were a total of 34 students with most students or 56%, were placed in the Summer Bridge Trigonometry/Pre-Calculus course. The 2015 cohort resulted in more than half of the make-up, or 57%, enrolled in the Trigonometry/Pre-Calculus as well. The cohorts for 2016 and 2017 resulted in the majority of students enrolled in College Algebra totaling 54% and 60% respectively. In 2018, the Trigonometry/Pre-Calculus course included14 students or 52% of the cohort for that year.

Summer Bridge	**2014**	**2015**	**2016**	**2017**	**2018**
College Algebra	15	18	19	27	13
Pre-Calculus	19	24	16	18	14
Total	**34**	**42**	**35**	**45**	**27**

Table 1. Summer Bridge Student 2014-2018 Cohorts (*Math Course Breakdown*)

Table 2 and Table 3 detail math courses taken during Summer Bridge across 2014-2018 cohorts. Data provided is broken down by the number of students earning a grade of A, B, C, D and F along with associated percentages. Table 2 includes grades for Trigonometry/Pre-Calculus and Table 3 provides grades for College Algebra.

Trigonometry Pre-Calculus	**Summer Bridge Cohorts (2014-2018)**									
Grades	**2014**		**2015**		**2016**		**2017**		**2018**	
A	4	21%	13	54%	10	63%	8	44%	6	43%
B	12	63%	7	29%	3	19%	8	44%	5	36%
C	2	11%	4	17%	3	19%	1	6%	2	14%
D	1	5%	0	0%	0	0%	0	0%	1	7%
F	0	0%	0	0%	0	0%	1	6%	0	0%
Total	19	100%	24	100%	16	100%	18	100%	14	100%

Table 2. Summer Bridge 2014-2018 Cohort (*Trigonometry/ Pre-Calculus Final Grades Breakdown*)

College Algebra	**Summer Bridge Cohorts (2014-2018)**									
Grades	**2014**		**2015**		**2016**		**2017**		**2018**	
A	8	53%	10	56%	3	16%	2	7%	4	31%
B	4	27%	5	28%	8	42%	7	26%	3	23%
C	2	13%	2	11%	2	11%	7	26%	0	0%
D	1	7%	1	6%	2	11%	10	37%	5	39%
F	0	0%	0	0%	4	21%	1	4%	1	8%
Total	15	100%	18	100%	19	100%	27	100%	13	100%

Table 3. Summer Bridge 2014-2018 Cohort (*College Algebra Final Grades Breakdown*)

Table 4 and Table5 provide summary data for fall semester. Within these two tables it is clear to see the rate of program "success" realized for each cohort. For example, in cohorts 2015, 2016 and 2018, 100% of all students making-up the cohorts for Trigonometry were successful in the fall math course.

Trigonometry	**Success**	
2014	76%	**89% Average Program Success Rate**
2015	100%	
2016	100%	
2017	71%	
2018	100%	

Table 4. Summary Fall Trigonometry Success by Cohort

Calculus I	**Success**	
2014	93%	**86% Average Program Success Rate**
2015	100%	
2016	92%	
2017	82%	
2018	63%	

Table 5: Summary Fall Calculus I Success by Cohort

Overall for Trigonometry taken during the years 2014-2018, it can be concluded that the Summer Bridge Program successfully placed students in the proper math course as determined by an average of 89% of all students receiving a successful grade in the course. Students taking Calculus I in the first year experienced an average program

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"success" rate of 86% across all cohorts. However, only 63% of the 2018 cohort for Calculus I were successful. For the 2017 cohort for Trigonometry, 71% of students successfully completed this course.

Table 6 shows those students who were considered outliers for this study. These students were either eligible to take a math class higher than Calculus I as determined by their incoming math transcript. Those students taking a class lower than Trigonometry either elected to do so or based on poor performance during Summer Bridge math, were instructed to do so.

Fall Math Course	2014	2015	2016	2017	2018
Intermediate Algebra	0	0	1	1	1
College Algebra	1	3	11	8	6
Linear Algebra	0	0	1	0	0
Pre-Calculus	1	1	1	0	0
Calculus II	0	1	0	3	2
Calculus III	0	0	0	1	0
Total	**2**	**5**	**14**	**13**	**9**
Percent	**6%**	**12%**	**40%**	**27%**	**33%**

Table 6: Fall Math Course Outliers

Conclusion

Based on the outcomes from both the Trigonometry and Calculus I course taken by all cohorts considered in this study, on average, the Summer Bridge Program achieved success in placing students in the proper first year math course. This determination is concluded by 89% and 86% of students on average, being successful in first year math courses. When observing each cohort, 8 out of 10 cohorts resulted in more than 75% of students being successful in first year math. There were two cohorts, or 20%, that did not achieve success based on our definition of program "success".

For the 2017 cohort, those taking Trigonometry as the first math course resulted in 71% of students receiving a grade of A, B, or C, which is less than the 75% program "success" rate established for this study. Additionally, the 2018 cohort of students taking Calculus 1 resulted in 63% of students receiving a grade of A, B, or C which also did not fail within the range for program "success".

While it is not uncommon and is acceptable that not all students who pursue STEM majors will be successful; it is the goal of the Summer Bridge Program to continue to identify interventions to reduce learning gaps and to increase student persistence. The use of multiple data inputs to create student math profiles for math placement has proven to beneficial when considering first-year math outcomes for incoming URM engineering students at the University.

Traditionally Math ACT sub-scores and math placement tests have been used in isolation to determine first year math placement for incoming engineering students. It is recommended that academic retention professionals at colleges and universities employ a summer bridge program where multiple student indicators are used. Such indicators as the four-fold approach discussed in this paper should be used when seeking to determine which math course is best suited for math placement.

Based on the positive outcomes of this study, 1). meeting URM engineering students where they are in their mathematical capability and 2). determining which math course they will need to build a stronger foundation is important to student success and overall retention efforts. Many URM students contend with STEM teacher shortages, K-12 funding disparities, low socio-economic status, and low representation in Advanced Placement courses. Although this was not the focus of this research, these impeding factors continue to warrant interventions by national and state policymakers. Through the use of Social Equity Initiatives (SEIs), such as Summer Bridge programs, institutions of higher learning demonstrate a commitment to increasing the experience and success of URM engineering students[2,17].

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Future works on URM engineering student math placement should consider 1). including outcomes from math courses taken during the spring semester of the first year 2). collecting data for additional years to establish longitudinal outcomes.

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Phenique Parker, a native of Hattiesburg, Mississippi, currently serves as the graduate assistant in the Office of Diversity Programs and Student Development for the Bagley College of Engineering at Mississippi State University. Presently, she is pursuing her Masters of Science degree in Kinesiology at Mississippi State University. She received her undergraduate degree in Biological Engineering with concentrations in Biomedical Engineering and Pre-Medicine from Mississippi State University (May 2017). Phenique is a 2017 Mississippi Idea Network of Biomedical Research Excellence (INBRE) research scholar. During the program, she presented her biomedical research as a finalist in the Mississippi Academy of Sciences Conference.

Angela C. Verdell, Mississippi State University

Angela C. Verdell is a native of Columbus, Mississippi and is currently the Director of Diversity Programs and Student Development in the Bagley College of Engineering at Mississippi State University. She is responsible for developing and implementing programming to create pathways for underrepresented student success in engineering. She received her Doctor of Philosophy in Public Policy and Administration from Mississippi State University. Her research area includes understanding the impact of institutional structure on the graduation rates of racially minoritized groups within engineering at predominantly white land grant institutions. She received her undergraduate degree in Finance from Jackson State University and a Master of

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Engineering in Industrial and Systems Engineering from Mississippi State University. Prior to joining the College of Engineering, Angela was an Adjunct Instructor in the College of Business where she taught courses in International Logistics, Physical Distribution, and Transportation Management. Angela has worked in industry for a number of years with the Johnson and Johnson Corporation, Shell Oil Company, and Entergy Nuclear Power. In addition to her technical roles, Angela was instrumental in promoting and advancing diversity and inclusion initiatives across these organizations.

Angela's contribution to broadening participation of underrepresented groups in engineering is evident in her advocacy work to increase Science, Technology, Engineering and Mathematics (STEM) education for minoritized students at all levels. She has written and been awarded grants for summer enrichment and Saturday programs to expose underrepresented minority students or learners and girls to the wonders of STEM. Her signature outreach program, I AM GIRL, has introduced engineering to hundreds of elementary and middle school girls where some have successfully entered college in a STEM discipline. In 2016 Angela published and presented her work at the national conference of the American Society of Engineering Education on the best practices for a summer bridge program for minority engineering students. She is the immediate past Region B Chair for the National Association for Multicultural Engineering Program Advocates (NAMEPA).

Angela has served as a trustee and Board Chair for the local school board in her hometown. She has held leadership positions within the Executive Board for the Boys and Girls Club of the Golden Triangle area. She is an active member of the Columbus-Lowndes Alumni Chapter of Delta Sigma Theta Sorority, Inc. Angela resides in Columbus with her husband Ron and they are the proud parents of two children, Jessica, a graduate of Jackson State University, and Aaron, a Columbus High School student.

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