Board 305: Improving Fundamental Mathematics Skills in Pre-Calculus Math Using Placed -Based Engineering Canvas Applications

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Recent studies have shown that the average retention rate at US engineering schools is 56%, and as much as 20% lower for underrepresented minorities [1]. More notably, about 40% of STEM students end-up switching their majors to non-science and non-technical majors, 50% drop out of physical and biological sciences, and 60% drop out of mathematics programs [2]. During the 2020-2021 academic year within a Southwest School District, the district from which a large R1 institution and a community college draw most of their undergraduate students, only 21% of high school students were proficient in math [3]. These numbers were exacerbated for Latinx students who are overrepresented at Title I schools with less access to experienced math teachers and advanced math course offerings. Among barriers to STEM degrees, deficiencies in mathematical skills have been considered the major contributing factor to STEM attrition [4], [5], [6], and [7]. Several models have been used at University of Nevada Las Vegas (UNLV) and College of Southern Nevada (CSN) in the past to bridge the math gap for students aspiring STEM fields (Figure 1). As early as 1996 students were required to pass courses on algebra and pre-calculus before enrolling in Math 181-Calculus I. Math 181 is the first calculus required from all engineering and computer science majors at UNLV followed by 3 or four more mathematics courses. Given the math-gap, students entering engineering and computer sciences at UNLV, typically had to spend two to three semesters before meeting the requirements to take Calculus I. This practice results in longer times to graduation, attrition, and additional financial burden to students.

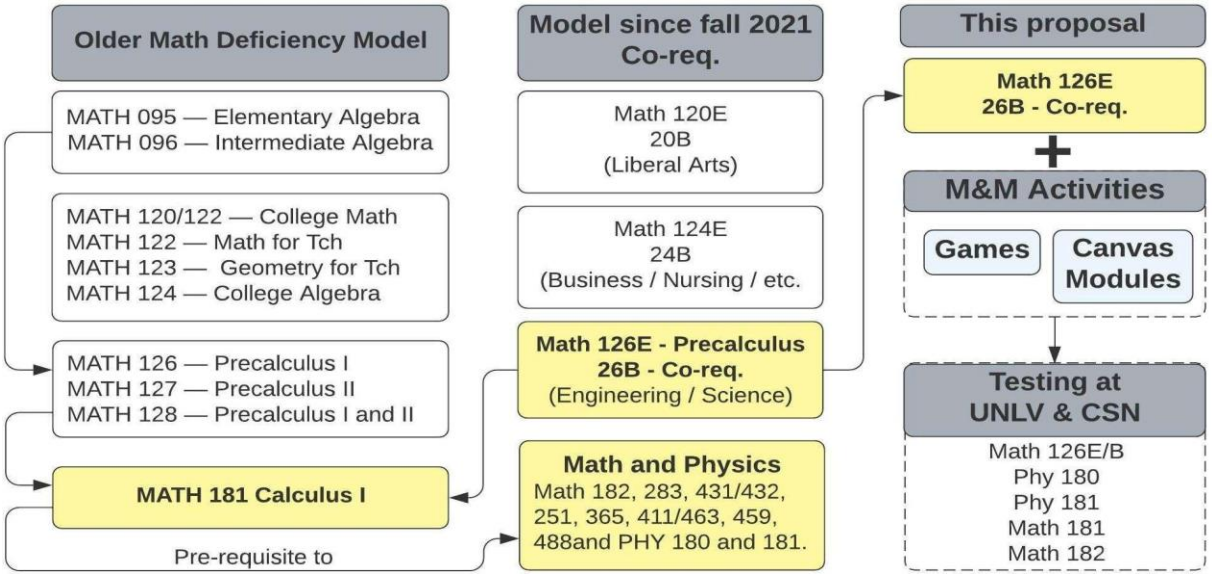


Figure 1: Math Deficiency Approaches at UNLV and CSN: Past, Current, and proposed Practices

Since fall 2021, a co-requisite model has been adopted at CSN and UNLV to attempt to improve incoming students' fundamental math skills and to mitigate the increased time to degree (Figure 1). In the co-requisite model, students who aspire to engineering and science degrees and require additional math instruction are placed in Math 126E (3 credits) pre-calculus with the co-requisite 26B (2 credits). In 26B students are expected to learn the needed math to perform well in Math 126 E (Pre-calculus). Figure 2 shows the math level of students entering the UNLV College of Engineering from 2010 to 2021. It shows that about 40% of students were enrolled in Math 181 and Math 182, i.e., Calculus I and II and over 60% enrolled at a lower math level. For the lower math classes, the largest number is for Math 126 and Math 127, pre-calculus I and II, respectively.

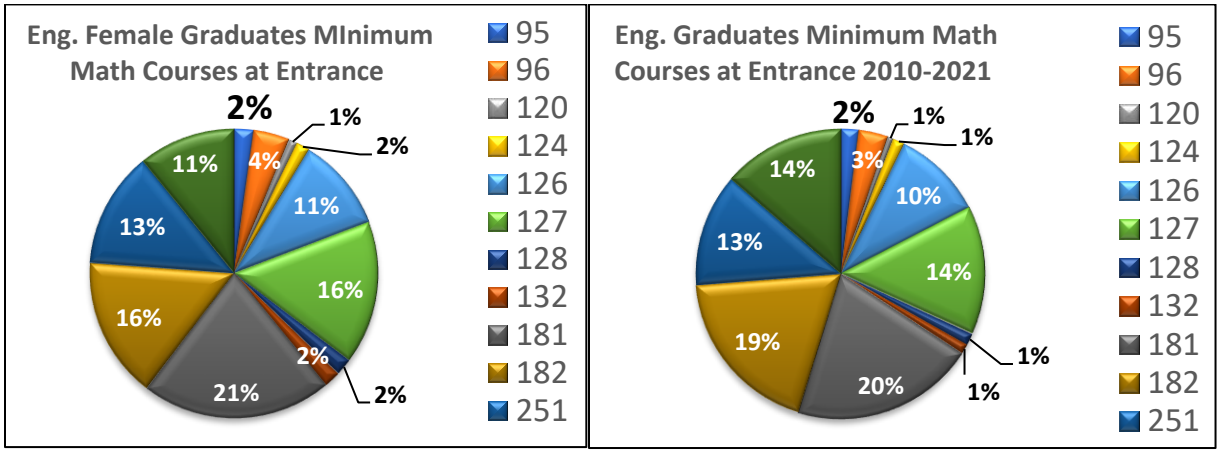
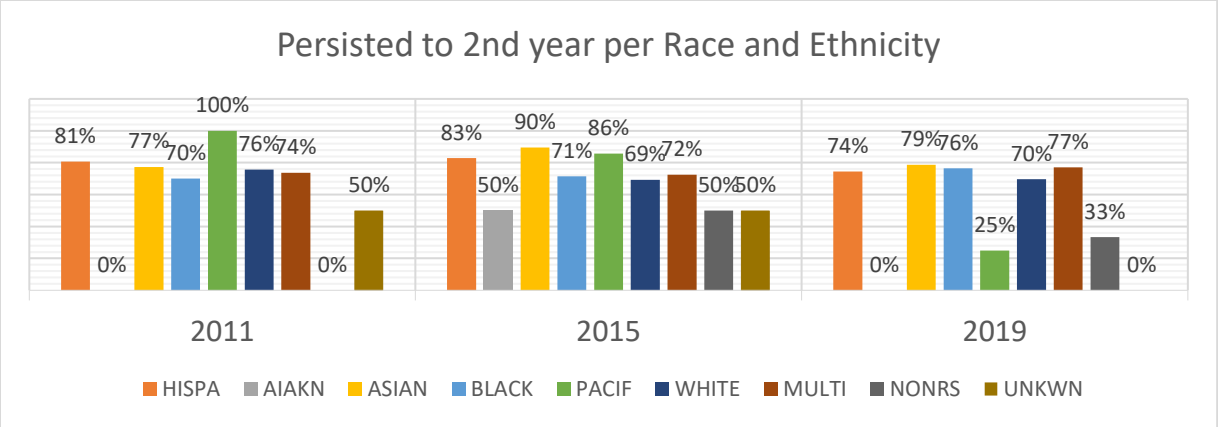
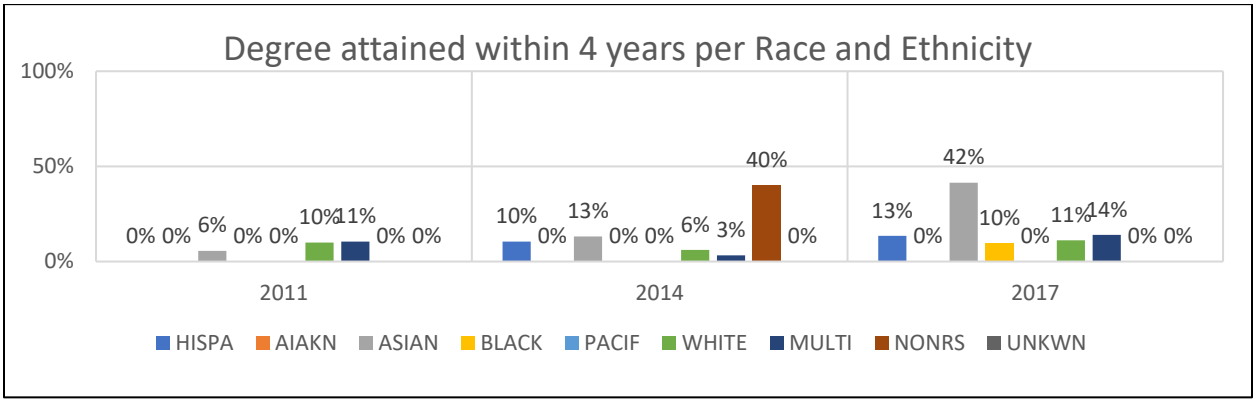


Figure 2- Math level entrance at UNLV for engineering and computer science graduates, 2010 to 2021.

Figure 3 shows persistence to 2nd year and graduation in 4 or 6 years. Persistence into the second year for female students and students overall seems relatively good. However, when it comes to 4th and 6th year graduation, the percentage of students graduating at 6th year is much higher, irrespective of ethnicity. Attainment by non-resident students is higher for both 4th and 6th year graduation. Together, these data point to the impact of math under-preparation has on delaying graduation of students majoring in engineering and computer sciences at UNLV.





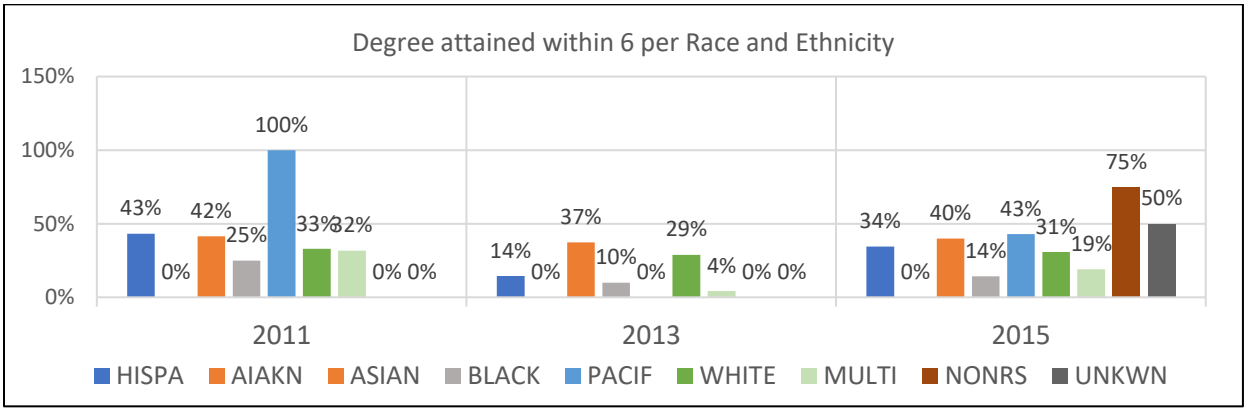


Figure 3: Persistence at year 2 and Graduation of Students within 4 and 6 Years by Ethnicity

Current literature reviews points to innovations and interventions that intend to improve the outcomes in mathematics points to active learning, hands-on projects, comic book-like interventions, mentoring programs, use of technology, one-to-one help, and peer study groups, as potential remediation tools [8]. The literature also reveals that the most successful methods directly address real math skill deficits [9]. The work reported here focuses on a National Science Foundation (NSF)-funded project aimed at improving fundamental math skills of pre-engineering students, at the large R1 institution UNLV and at the community college in the Southwest CSN. For UNLV and CSN STEM majors, addressing math proficiency gaps for high school graduates is critical. Therefore, there is a need to devise innovative math remediation

methods that are more engaging, effective, and less costly to students. UNLV and CSN faculty of mathematics, engineering, education, and computer sciences have joined forces to make a difference on this front. They have developed conceptually-rich applications and associated exercises to demonstrate the application of fundamental math concepts in engineering and computer sciences. Because students often perceive math as abstract and they do not see its application in science and engineering, the applications of the specific math concept in civil, mechanical, and electric engineering and computer sciences were developed to bridge this vacuum. The Canvas applications use placed-based pedagogy and focus on a large metropolitan city in the Southwest as the place where engineering is in action with its magnificent buildings and attractions and its beautiful surrounding arid environment. Herein, we present two Canvas applications, "Dig-it up" and "Ready-Set-Jump" that were developed to demonstrate the application of arithmetic operations in Civil and Mechanical engineering. In addition, a set of practice exercises were developed to accompany the applications.

The applications are being tested in the current co-requisite model used (Figure 1) by UNLV and CSN in spring and summer 2024 for pre-calculus I math. Data on students' motivation to learn math and knowledge gains will be collected to determine if these applications can assist students aspiring to STEM majors with mastering fundamental math principles. The design experiment approach is used in this research to test the Canvas applications. This research approach emphasizes an iterative cycle of data-driven decision-making through three critical processes: development, refinement, and evaluation. The research plan fulfills two goals: 1) to provide *formative evaluation* for the improvement of the game and associated Canvas applications, and 2) to *understand the mechanism* for how the games may work to improve students' STEM outcomes.

This research was funded by the National Science Foundation, Grant #2225226

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