Board 307: Improving STEM Student Fundamental Math Skills with Tailored Game-Based Instruction

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Improving STEM Student Fundamental Math Skills with Tailored Game-Based Instruction

This research focuses on an intervention for mathematics remediation for all engineering and computer sciences majors at University of Nevada Las Vegas (UNLV) and STEM students (pre-engineering and pre-science) at College of Southern Nevada (CSN). During the 2020-2021 academic year within a Southwest School District, out of the vast majority of undergraduate students entering UNLV and CSN, only 21% of high school students scored at the proficient level in math [1]. 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. All engineering degrees at UNLV require three calculus courses, differential equations, and statistics. Specifically, engineering and computer science majors require calculus I (Math 181) as the first math course in the curriculum. Unfortunately, very few incoming freshmen meet this requirement and students aspiring to engineering and sciences have to spend, on average, 1.5-2.0 years on math studies prior to enrolling in Calculus I. This fact implies longer wait times to enroll in courses specific to their major, higher attrition rates, longer time to graduation, and additional financial burden to students. To mitigate the math under-preparation issue, UNLV and CSN created math deficiency mitigation approaches as early as 1996 (Figure 1), requiring students to take and pass algebra and pre-calculus before enrolling in Math 181-Calculus I.

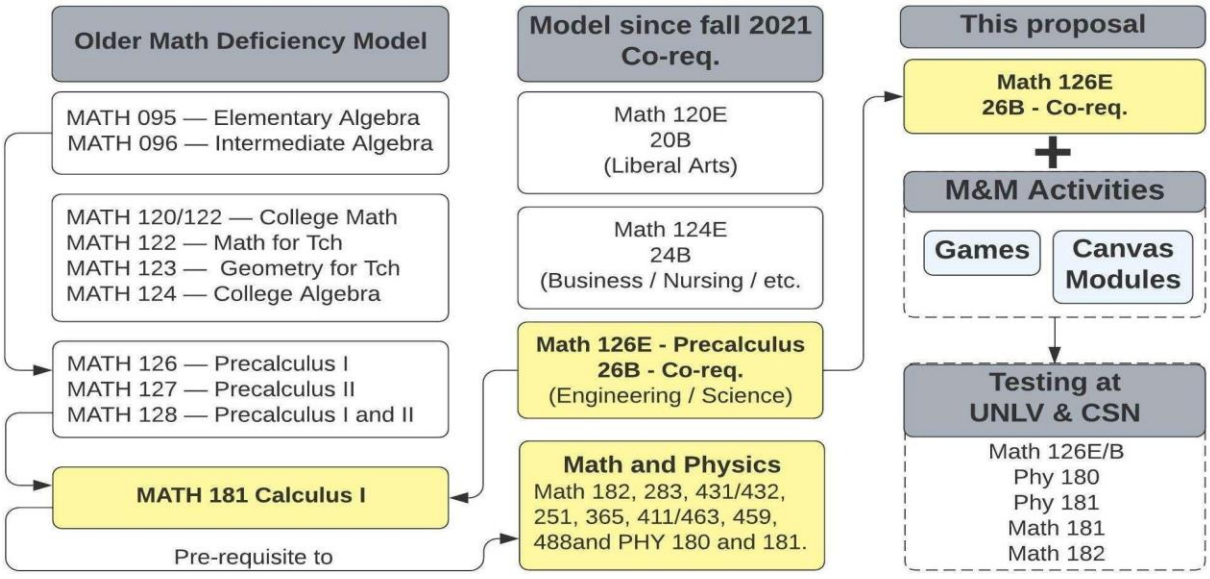

Figure 1: Math Deficiency Approaches at UNLV and CSN: Past, Current, and proposed Practices

The initial approach involved placement testing and practice exercises using the software ALEKS PPL [2]. ALEKS placement test has a 30+ year research base with adoptions by major

universities. It was initiated out of Columbia specifically to address placement issues in engineering and it assesses a broad slice of the gateway mathematics topics with a very large pool of objectives from which to draw. Figure 2 shows that more than 50% of students who took the ALEKS placement test are coming from Title I high schools from the Clark County school district that feeds UNLV and CSN. These high schools are geographically located in areas with a large Hispanic population.

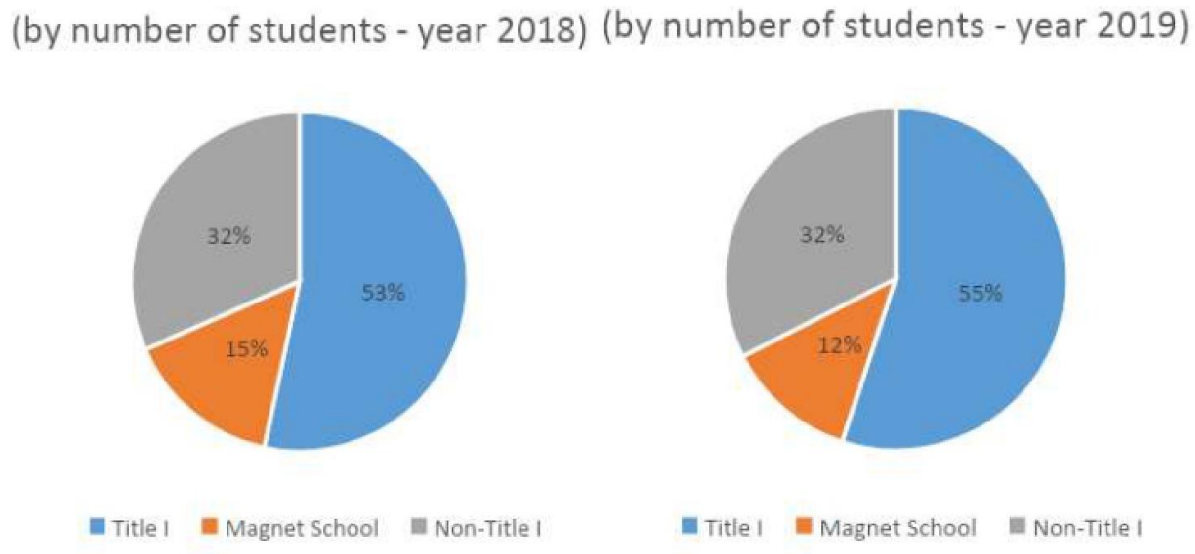

Figure 2: Distribution of students who took ALEKS based on Type of High School Attended

The ALEKS placement test data collected at UNLV for 2018 and 2019 shows that the largest number of students taking the test were Hispanic, followed by White, Asian, and Mixed-race students. The number of students from other underrepresented groups was small and proportionate to their representation of the total UNLV population. Over 60% of students taking the ALEKS test were from Title I schools followed by Non-Title I and then magnet schools. Over 61% of the students attended Clark County high school and about 40% were from out of state schools. More than 60% of the students who took the ALEKS placement test were not college ready and therefore needed to be placed in remedial math. More than 50% of the Hispanic population and first-generation Hispanic population needed additional math instruction, and females tended to score lower than males (Figure 3). About half of the Hispanic students identified as lacking math preparation are first-generation, and the number of female students lacking college-level math proficiency is approximately double those of male students. More than 70% of the female Hispanic students were placed in remedial math as compared to about 58% of the male students; independent of being first generation or not, the data show that Hispanic females are placed lower than males in both years. These data show the need to focus on meeting math deficiency needs of incoming freshmen, especially the needs of female Hispanic students who aspire to STEM majors. Currently the percentage of female engineering students at UNLV is only about 17%.

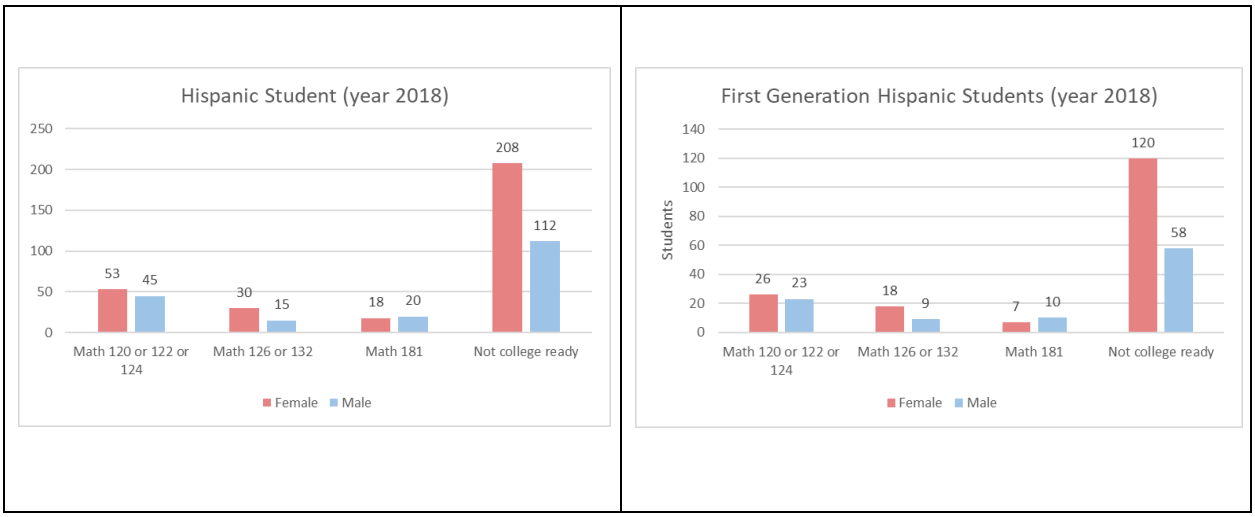

Figure 3: UNLV's Distribution of Hispanic population (left) and first-generation Hispanic population (right) in math courses based on gender in year 2018.

Since fall 2021, a co-requisite model for gateway math courses has been adopted at CSN and UNLV in an attempt to mitigate the math deficiency of incoming students (Figure 1). In the co-requisite model, students aspiring to engineering and science who have been identified as needing additional math instruction are placed in a co-requisite section of a pre-calculus course, Math 126E (3 credits) pre-calculus with the co-requisite component Math 26B (2 credits at UNLV and 3-credits at CSN). In 26B students are expected to study concepts that will help them catch up with the needed math to perform well in Math 126 E (Pre-calculus). Thus, in a co-requisite pre-calculus course, students spend an additional two hours with the instructor with the intent to remediate Algebra. Current literature review of 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 [3]. The literature also reveals that the most successful methods directly address real math skill deficits [4].

The research reported here focuses on developing Math Masters (M&M) games, in collaboration with the UNLV Center of Game Innovation. The game design process follows an iterative approach, with scholars in mathematics, STEM education, and educational psychology collaborating with gaming innovation designers to identify opportunities to combine critical math concepts with a complimentary game structure and design. The games supplement the current co-requisite model used by UNLV and CSN for pre-calculus math focusing on basic arithmetic operations, functions (such as linear, quadratic, square root, and inverse), log and exponential modeling and system of equations. The game developed to teach basic arithmetic operations will be presented in this paper. It was developed to decompose math concepts into individual knowledge components that can be intervened upon, as well as to promote student motivation and reduce psychosocial barriers through personally- and culturally-relevant pedagogy. These strategies are hypothesized to lead to increased engagement and math achievement. The game on basic arithmetic operations consists of four subgames: order of operations, exponents, radicals, and factoring subgames. Moreover, each subgame is associated

with a well-known scientist from underrepresented groups (such as the famous female African American Mathematician Dorothy Johnson Vaughan, Colombian planetary geologist Adriana Ocampo Uria, a Japanese American meteorologist Tetsuya Theodore Fujita, Mexican American astronaut Jose Hernandez). This is incorporated as a puzzle progression theme within the levels of the subgame. At the beginning level in the subgame, students are "solving" simpler problems or are guided through solving longer problems. Then, at the intermediate and advanced levels students are "solving" more complicated and longer problems with less guidance.

The research plan includes first testing the games in co-requisite pre-calculus Math 126E/26B at UNLV and CSN in Spring and Summer 2024, then refining the game and testing it again. The game on basic arithmetic operations was piloted in Summer 2023 to a smaller student audience. The research includes formative evaluation for the improvement of the games. We integrate a range of measurement strategies in our project to assess how M&M is able to reach satisfactory outcomes on students' math knowledge, math-related motivation, academic achievement, and engineering major persistence. These strategies include quantitative and qualitative approaches to inform the refinement of M&M and triangulate its efficacy.

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