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Interdisciplinary Summer Math Bridge Program for At-Risk Transition Students

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Introduction

This complete research paper details Lipscomb University's summer math bridge program designed to support at-risk students transitioning into engineering and computing programs. We present two years of longitudinal data on the outcomes of these students. Math bridge programs are becoming more common as higher education institutions are adapting to changing student demographics, including an increase in minority and non-traditional student enrollments and a persisting decline in math readiness. Math remediation can affect the graduation rate, particularly for these underrepresented populations. The current six-year graduation rates in engineering nationally hover around 60%, but dip below 40% when accounting for various underrepresented demographics [1], [2]. Notably, these figures often paint an overly optimistic picture, as universities typically exclude pre-engineering students or those facing initial obstacles to starting the engineering curriculum from graduation rate calculations.

At Lipscomb University, students are allowed to declare engineering upon admission. Anecdotally, we see that many of these students attrit (to another degree program or leave the university altogether) before beginning their engineering curriculum. This attrition is primarily attributed to challenges in math remediation and delayed graduation timelines. Consequently, the actual graduation rates for this at-risk population are markedly lower. As educators who strive to connect with these at-risk populations, we are presented with both promising opportunities and unique challenges.

One recent challenge is the declining math readiness of all students, and particularly for racial minorities. Data reported by ACT, Inc show declining ACT scores in their 5-year trends. Between 2018 and 2023 the national average composite ACT score declined from 20.7 to 19.5 and the national average math score declined from 20.4 to 19.0 [3]. In the 2020 incoming engineering freshman class of Lipscomb University, 42% required at least one math remediation course, of which 43% were Hispanic, 26% were Caucasian, 13% were African American, 13% were Asian, and 17% were female. Table 1, after a 2023 ACT, Inc, shows the national average math ACT score has a significant disparity between racial and ethnic demographics [3].

Table 1: National Average ACT Math Score by Race/Ethnicity. After Table 2.3, [3].

Student Race/Ethnicity	Average Mathematics ACT Score
White	20.3
Asian	24.2
Two or more races	19.1
Prefer not/no response	17.6
Hispanic/Latino	16.2
Native Hawaiian/Other Pacific Islander	16.4
American Indian/Alaska Native	16.0
Black/African American	15.8

For minority students, declining math-readiness is compounded with pandemic related effects and financial constraints. Lower ACT math scores can result in remedial math courses which often prolong graduation timelines (if they do not result in attrition). Increased graduation timelines for underrepresented groups, who oftentimes carry a larger debt burden, result in a high-risk of attrition or even withdrawal from attending University before their first engineering term. According to the Department of Education, Black or African American students, particularly Black or African American women, carry the largest debt burden of any demographic [4].

Various approaches have been implemented to address the challenges, either partially or comprehensively. Approaches include, math mentoring and tutoring [5], math curricular changes and course innovations [6], and math summer bridge programs [7]. Math summer bridge programs reported in previous work have varied in length, target demographics, and approach. However, most show that math performance can be improved through a summer program.

In this work, longitudinal math performance is presented for students at Lipscomb University who participated in the math bridge program described here. Accelerated Engineering Readiness Opportunity (AERO) is a 1-week math bridge program, with one session offered in 2021 and two consecutive sessions in 2022. While this program participation is open, the program targeted public high school transition students unable to start in Calculus 1, and non-traditional students (veterans and returning learners) with over a year gap in the last math course they have taken. This bridge program provides individualized math plans, rigorous math review, and hands-on, project-based learning (PBLs). Program participants showed improvement in math performance and math persistence as compared to the baseline data and showed a promising starting point for addressing the obstacles facing these at-risk student populations.

Baseline student population

The baseline student population includes any students at Lipscomb University with an intended major of Computer Science (CS), or Civil (CE), Electrical and Computer (ECE), Mechanical (ME), or Software Engineering (SE) beginning with cohorts starting at the University in Fall of 2012. All courses taken by these students, up until Spring of 2023, are considered in the dataset. Additionally, any student with a listed intended major from the aforementioned list of majors for even a single semester at the University is included in the group. (e.g. a student attending with an intended Mechanical Engineering major who changes majors to English has all their mathematics courses tracked in this dataset). For dual-enrollment, non-degree seeking students who later enroll at the University and are listed with one of the above intended majors, mathematics courses taken before an intended major is declared (usually with the student transitioning to full-time) are excluded. The aim is to compare AERO participants to other students coming to the University who are also targeting a 4-year degree. The dataset contains data from 884 students who met these conditions.

One other intricacy of the dataset should be noted. For Electrical and Computer, Civil, and Mechanical Engineering, the full standard Calculus sequence is required (Calculus 1-3 and Differential Equations). Computer Science only requires Calculus 1 and 2 in this sequence and Software Engineering only requires Calculus 1. Out of 929 total students, 238 were declared computer science majors and 76 were declared as software engineering at some point. There are 19 students who switched from the majors requiring the full Calculus sequence (CE, ECE, ME) to one of the two computing degrees under examination here. Additionally, students within the considered 5 majors attrit to other degree programs or leave the university. These courses have successively less mathematics demand in their curriculum. Engineering students who change majors typically change to a major whose only mathematics requirement for graduation is College Algebra. It should be noted that a passing grade in College Algebra is the baseline mathematics degree requirement at the University and allows for completion of most of the 4-year degrees at the institution.

Figure 1 shows data for five groups within the baseline group. These groups are formed based on which mathematics course a student attempted during the first semester they took a math course at the University. For this figure, passing is defined as a C or better in the course. Nearly all math courses in sequence, and various engineering and computing courses, require a C or better in a lower math course. The figure shows the percentage of the students in the population (starting with the first course in the respective grouping) that completed each of the listed math courses.

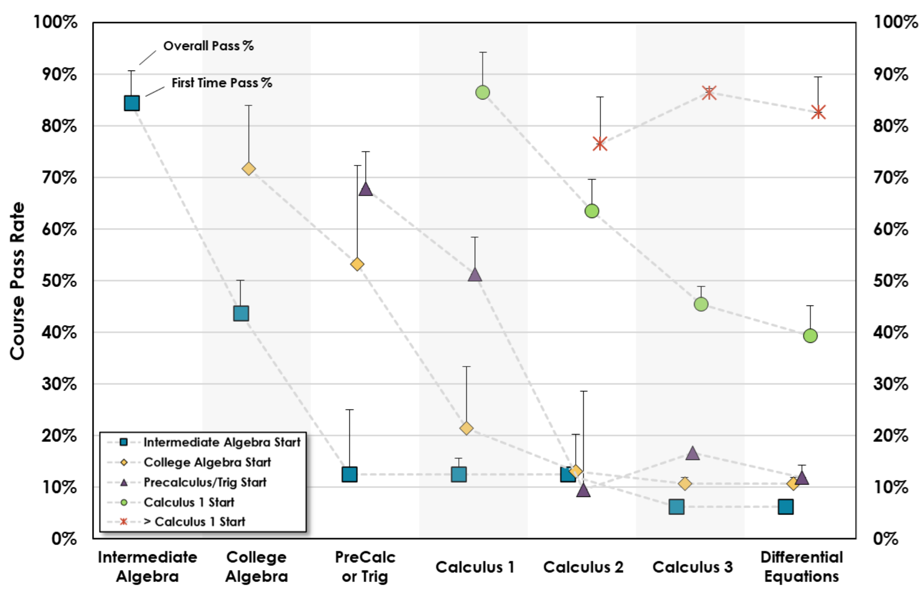


Figure 1: Pass rates for control group students grouped by first math course taken at the university. Rates are shown as a percentage of students taking the first course in their respective sequence to demonstrate the percentage of students in each group who pass and progress to subsequent math courses. Data points represent first time pass rates for each population with error bars indicating overall pass rate (inclusive of multiple attempts)

The upward error bar indicates the pass rate for that population after multiple (2 or more) attempts to pass the course. The plot is intended to show attrition from these programs relative to which course the students started in. For example, if there were 100 students in the group where the first mathematics course was College Algebra, 21 (21%) would have passed Calculus 1 on the first attempt and 34 (34%) would have passed it after multiple attempts.

Based on Figure 1, the data show half of baseline students beginning in Calculus 1 finish their Calculus sequence and 85% or more of the students starting in a mathematics course beyond Calculus 1 finish their Calculus sequence. These course pass rates represent a minimum value, as students who do not pass their mathematics courses often transfer credit in from other institutions after taking the course elsewhere in the summer. A much steeper decline is shown for groups starting Intermediate or College Algebra, with likely less than 40% able to meet requirements for SE (Calculus 1) and around 20% able to meet requirements for CS (Calculus 2). Around 10% in these groups meet requirements for CE, ECE, and ME degrees. For those starting in Pre-calculus or Trigonometry, more than 70% attempt Calculus 1 with around 60% of those students passing it. Around 50% of the Pre-calculus/Trigonometry starting group attempt Calculus 2 or beyond with less than 30% passing it or subsequent courses. Again, a very small percentage of these students continue to take courses required for CE, ECE, and ME degrees.

Figure 2 shows the pass rates for the same groupings of students, this time with percentages shown with the denominator being the number of students in each group taking each class. The trends that would be expected from examination of the previous figure mostly continue here. Plotting the data in this manner shows how the students in each group who do progress to the next course fare. One interesting observation is that the students starting in College Algebra who do progress to Calculus 2 or later outperform the students starting in Pre-calculus/Trig in those courses, albeit with a smaller percentage of the original starting group.

While it may seem anomalous to see the Intermediate Algebra group performing so well in later courses, the data points for the last three courses in the sequence represent only three out of around one hundred students in that group who progressed to the final courses in the sequence. Students who started in Calculus 1 that progressed past do not look significantly different from students who had AP credit or transferred Calculus 1 credit into the University.

The summary of the baseline data serves two purposes for this work. First, it provides a backdrop for comparison to the AERO Program participants. It is a concern of those involved with the program to make sure students are not boosted into a more demanding mathematics course only to see them struggle and regress to the mathematics performance exhibited upon entry to the AERO program (or worse). If the program participants perform similarly, or better than, the baseline groupings when accelerated ahead by a course (or two) in the curriculum, we can be assured that we are not having only a short-term effect. Second, the data presented in Figures 1 and 2 indicate that the starting point in the mathematics curriculum is strongly correlated with future completion of the Calculus sequence. If the program participants are moved forward a course in mathematics and their performance is similar or better than the baseline group

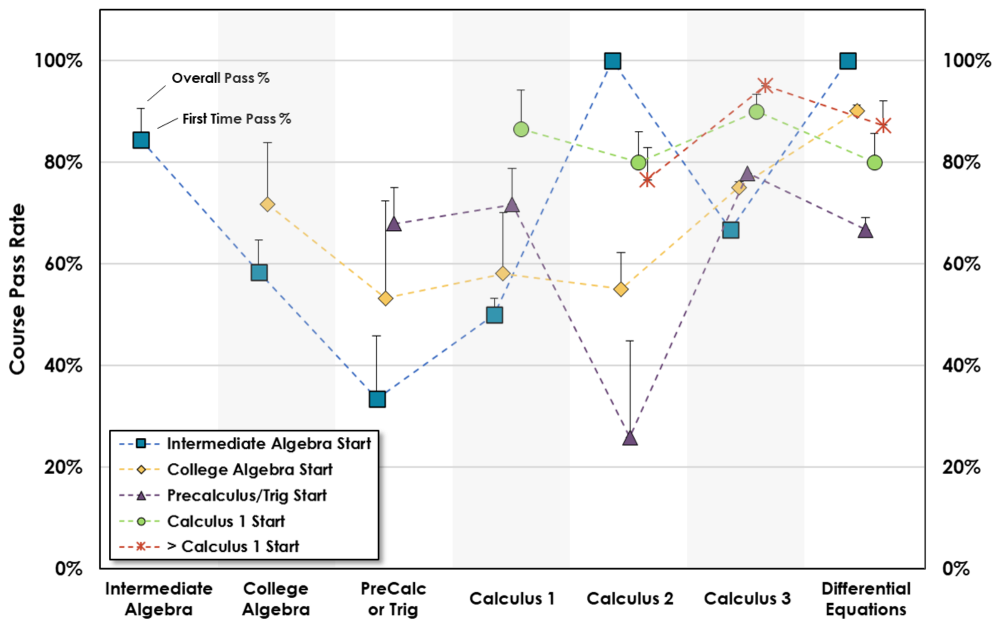


Figure 2: Pass rates for control group students grouped by first math course taken at the university. Rates are shown as a percentage of students taking each specific course to demonstrate the selected performance of students who have progressed to each course. Data points represent first time pass rates for each population with error bars indicating overall pass rate (inclusive of multiple attempts)

performance, we can be assured that the AERO program is increasing the success rates of the students involved.

Program description

The AERO program is designed to bolster student's math skills while engaging them in hands-on engineering through a humanitarian lens. During this 1-week bridge program students spent half of their time working directly with a math faculty, two math tutors with advanced degrees in math/engineering, and near-peer tutors who are current engineering students (some also previous math bridge participants). The second half of their time student participants engaged with engineering faculty in hands-on engineering PBLs designed around a central focus of humanitarian engineering. The PBLs were designed in an interdisciplinary approach leveraging the unique Lipscomb University engineering missions' program and they include humanitarian engineering activities in Electrical, Civil, and Mechanical engineering. Humanitarian engineering has been shown to engage a larger percentage of underrepresented students in engineering and provide unique opportunities to engage students with engineering [8].

The PBLs are centered around providing clean water access and involve students addressing the needs of a fictional global partner with a remote clinic. Students explore technical and social challenges and work on solutions while learning fundamental concepts in Electrical, Civil, and Mechanical engineering, including Algebra, Trigonometry, and Pre-calculus. At the end of the week, a final pump prototype system culminates the design experience.

The AERO math bridge program is sponsored by the NISSAN foundation which allows us to offer this at a low participant cost of $50. Participation fees for students who request financial assistance are waived. Future years the participation cost has increased to $150 as we have seen a high percentage of students who sign up but do not make full attendance a priority. Students are provided with a light breakfast, lunch and snacks throughout the week. Additionally, access to the math software as well as bus transportation and tours are provided in this participation fee. Students are requested to bring a laptop in order to access the math software. However, loaner laptops are provided courtesy of Lipscomb University for students who demonstrate need.

Math program

The main math review component of the program is built around a MyMathTest Pearson course created by Lipscomb University mathematics professor. The intent is to try to identify each student's weaknesses by having them take a series of increasingly difficult tests with the goal of a pass rate of 80%. If the pass rate is not achieved, the program allows students to practice specifically on the objectives they missed. When ready, the student can retest. Students are not allowed to ask for help while testing, but help is readily available from math faculty and tutors with engineering or math post-secondary degrees while reviewing for mastery. An emphasis is placed on students taking responsibility for their own learning, so they can practice objectives as much or little as they think necessary before retesting. As the week progresses, the faculty supervising the program will open the harder tests for students who want to see that content. However, students are encouraged to remember that the goal is not to complete the program, but to improve their personal abilities. At the end of the week every student takes Lipscomb University's math placement test. That placement is compared to the math placement the student would receive on the basis of their reported ACT/SAT score.

Objectives covered in the series of tests progress as follows: Geometry and Measurement, Exponents and Polynomials, Factoring, Rational Expressions, Equations and Inequalities, Functions and Graphs, Polynomial and Rational Functions, Exponential and Logarithmic Functions, Trigonometric Functions and Analytic Trigonometry. Each math session begins with a group problem to improve problem solving skills and as an opportunity to discuss the importance of resilience and working with others. Additionally, there is a hands-on activity during each half-day math session. These activities, after day one, are designed to introduce later topics that many students will never reach in the Pearson program.

The day one activity begins with a basic review of factoring and the relationship between the factors of a polynomial and their x-intercepts. Pairs of students create parabolic arches on graph paper using a wet tennis ball. Each pair is then told to draw an x- and y-axis on the graph paper making the vertex of the parabola within a specified quadrant. They are then tasked with writing an equation for the parabola [9].

On another day pairs of students will be given sets of similar right triangles and asked to measure all three sides and find the ratios of those sides. After averaging the results of the ratios for all the triangles in their set, they record their averages in a chart for all to see. See sample work. Students then spend time as a group noticing that the ratios for sine and cosine of complementary angles are repeated but swapped and discuss why this happens. They then calculate the sum of the squares of the sine and cosine ratios and notice that this value is always approximately one, again discussing why this would happen. The terminology for sine, cosine and tangent is not introduced until the end of the activity when the cofunction identities and the Pythagorean theorem are summarized using traditional notation.

	opp/hyp	adj/opp	opp/adj	$\cos^2\theta+\sin^2\theta$
20°	0.35	0.93	0.37	0.99
30°	0.51	0.87	0.801	1.017
40°	0.638	0.771	0.819	1.001
45°	0.71	0.71	1	1.008
50°	0.77	0.65	1.19	1.02
60°	865	.495	1.74	0.993
70°	0.935	0.353	2.666	0.999

One of the longer hands-on activities involves students making graphs for the sine and cosine functions using spaghetti. Groups of three students are given butcher paper with a circle and an x-axis pre-drawn on it. Students use a protractor to make marks every 15around the circle. They then place a string on the circle starting at 0and wrap it counterclockwise around the circle. Students transfer the marks from the circle onto the string and then again from the string to the x-axis. This process always generates good discussions as many students are not familiar with how to use a protractor. Once their x-axis is ready, students use spaghetti to measure the perpendicular distance to the x-axis and later the y-axis from each 15mark around the circle and record that as their range value. These create nice graphs of the cosine and sine curves respectively [10].

Mission project alignment

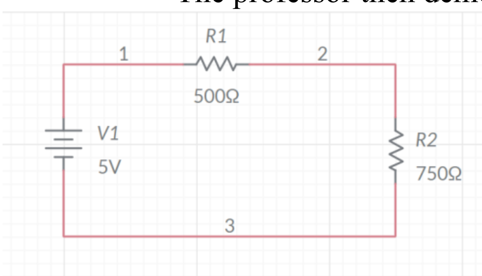
PBLs from all disciplines are tied together using the global partner proposal for a water tower to be built on their campus. The PBLs culminate in a prototype water tower. This tower ties together all three disciplines as it is controlled by a circuit using two mechanical float switches and mechanical relays which turn on and off a pump. The ECE faculty-led PBLs that prepare students to grasp the circuit design, the ME faculty presented lessons characterizing the pump and the CE faculty presented lessons on surveying, all of which connect together various math concepts.

Electrical engineering PBLs

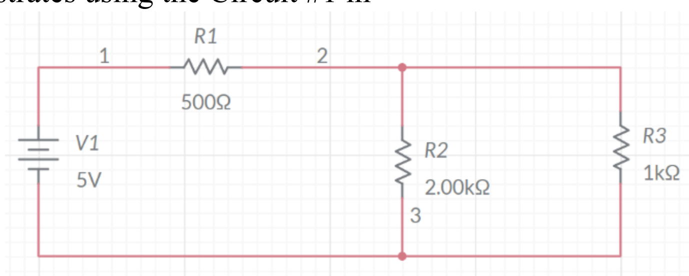
Electrical Engineering PBLs included a series of lessons to provide a foundation of electrical concepts, while connecting them to math concepts covered in the math intensive.

1. Current and Voltage
    a. Lecture: a short lecture was given on voltage, current, basic circuit elements and measurement tools like ohmmeters.

   b. Student exploration: students were tasked with using the ohmmeter to measure the resistance of various unknown resistors.
2. Basic Circuits
   a. Lecture: a short lecture was given to introduce the building blocks of making circuits. The ECE professor discussed what makes a circuit (closed loops) and what it means for elements to be in series and parallel. She also discussed how to use electrical measurement tools like the multimeter to measure voltage across elements in a circuit.
   b. Student explorations: between each concept students are presented with conductive dough [11], Snap Circuits, LEDs and resistors. They are tasked with building circuits to demonstrate the new concept. Students experimented by making circuits using conductive dough, and Snap Circuits placing LEDs and resistors in series and parallel. Students were then tasked with measuring the voltage of elements in the series and parallel circuits.
3. Conservation Equations
   a. Lecture: a short lecture was given to introduce how we solve circuits by combining our three main math relationships (Kirchoff's laws and Ohm's law). The professor then demonstrates using the Circuit #1 in



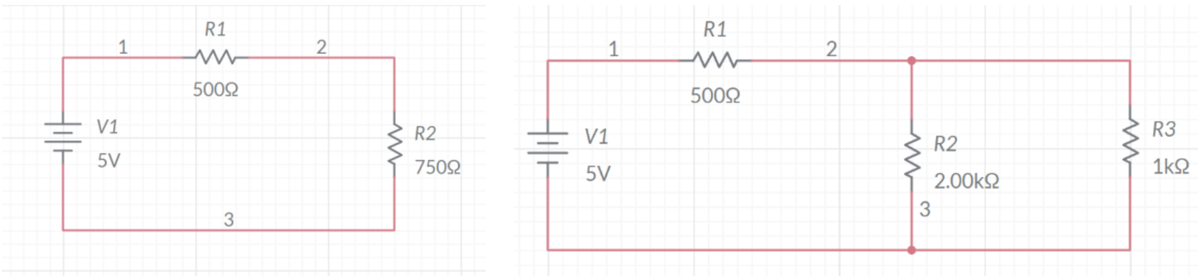
Circuit #1



Circuit #2

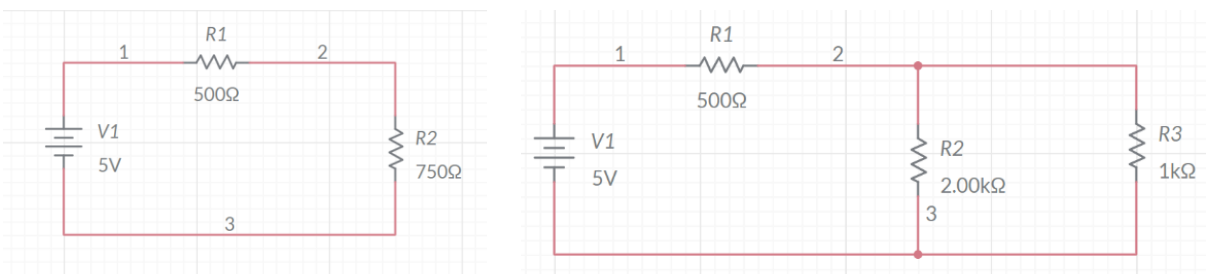
   b. **Figure 3**. Here the professor develops the three sets of equations for the circuit.

c. Student explorations: students were challenged to solve the system of linear equations for all unknown variables of Circuit 1. For Circuit #2 in



Circuit #1 Circuit #2

Figure 3: Circuit #1) simple series resistive circuit used as a demonstration for how circuits can be solved using a system of linear equations. Circuit #2) a slightly more complex resistive circuit used to challenge students to develop the system of linear equations, analyze the system of linear equations and experimentally verify



Circuit #1 Circuit #2

d. **Figure 3**, which is slightly more complex than the initial demonstration, the professor and students developed the set of equations together. The students were then challenged with finding the unknown circuit variables for the system of linear equations. Once students found the system of equations, they were tasked with building the circuit using their Snap Circuit board and measuring all voltages in the system. Students then compared their experimental results with their expected results.

Civil engineering PBLs

The civil engineering activity began with a brief review of geometry Trigonometry principles, including law of sines and cosines. Following this review, basic measurement techniques such as rulers, scales, tape measures, and protractors were discussed as tools for developing or measuring paper drawings or small objects. Expanding the discussion to gravity fed water distribution systems, common in small, rural developing communities, the question "How would you measure the height of a or distance to a water tower?" was prompted with a myriad of ideas, some built on previous experiences and the use of simple instruments such as inclinometers while others would be clear violations of health and safety protocols. This discussion segues into a brief introduction to surveying as the science of making two- and three-dimensional measurements in the environment wherein angle and distance measurements are demonstrated using a surveying total station.

For the group activity, student teams are tasked with developing a plan to measure the height of an antenna mounted on the top of the university campus bell tower as a surrogate for a water tower, which they cannot stand directly under (nor can they climb the tower), using only indirect measurements from a total station. Once teams have presented their plans, the field exercise is introduced. The exercise utilizes a total station to measure angles and distances of three triangles, one horizontal and two verticals. Two points, A and B, marked with nails are used for total station setups and form two corners of the horizontal triangle with the third corner, C, found directly under the antenna. However, point C cannot be occupied due to the tower construction. Using the total station, the horizontal distance between points A and B, AB, is measured as well as the horizontal angles ∠BAC and ∠ABC. At points A and B, the vertical angle from C to the antenna is also measured, however, only one vertical triangle is needed to solve for the antenna height. Using geometry and Trigonometry, students can solve for the remaining angle of the horizontal triangle, ∠ACB. Using the law of sines and Trigonometry, an additional horizontal distance, AC or BC, can be calculated and used in conjunction with the vertical angle to calculate the height relative to the elevation of the total station.

Mechanical engineering PBLs

The goal of this activity was to teach students about water pump performance by creating pump curves experimentally. In doing so, students get exposed to the concepts of volume flow rate, flow energy, and pressure head. Teams of three to four students assembled a system consisting of an electric bird-bath fountain water pump, an adjustable power supply, a 5 ft long vinyl hose and two 5-gallon buckets. The pump is connected to the power supply (connections are waterproof), the vinyl hose is attached to the pump's water outlet, and the pump is submerged in one of the buckets filled with water and placed on the floor. Next, students choose a low power level to drive the pump and record on a spreadsheet software the time it takes to fill the other bucket with the free end of the hose being held at a certain height. They refill the bucket five times at heights ranging from 1ft to 5ft, each time increasing the height by 1ft. At the end of this cycle students compute volume flow rates at different heights (pressure heads), create a scatter plot of head vs flow-rate data, and create a performance curve for the selected power level by fitting a 2nddegree polynomial curve through the points. This process is repeated a few more times at different power levels resulting in a pump performance map created experimentally by students.

Pump system prototype

The AERO program week is culminated by students assembling the pump system prototype. This prototype uses readily available commercial off the shelf parts. The tank system is prototyped with two heavy-duty 5-gallon plastic containers (one simulating the well and one simulating the storage tank). The pumps are purchased through Amazon and are standard small-scale water feature pumps. The pump system is controlled mechanically by a float switch and mechanical relay. With the guidance of a mechanical and electrical engineering professor, students wire the relay, pump and float switch and then analyze the system.

Enrichment activities

In addition to the math intensive and engineering PBLs, students are provided with various enrichment activities. Student participants went on a half-day tour of the program sponsor's facility, NISSAN foundation. Here students interacted with practicing engineers as well as engineering student interns at the facility and learned about the various opportunities and challenges engineers face. Anecdotally, this has always been a highlight of the program. "Lunch and Learns" were also provided throughout the week. Past engineering students of Lipscomb University and various engineering professionals were invited to join students for lunch and provide a short talk about one of the following topics: how you use math in your engineering profession and/or how you overcame a challenging math course in your degree.

Student participants

There was a total of 46 student participants in the 2021 and 2022 summer programs. While there is data showing the math improvement of these participants during the AERO program, longitudinal data for students not attending Lipscomb University would rely on self-reporting. As such, this paper only tracks the longitudinal data for 28 of these 46 total participants who continued onto Lipscomb University through the math archival data. Unless otherwise stated, the remainder of the paper refers to the 28 students continuing onto Lipscomb University as "student participants". Eleven of the 28 participants are Federal Pell-grant recipients, which is typically awarded to students demonstrating significant financial need at the undergraduate level. Demographics of the student participants include 39% who identified as White/Caucasian, 7% as Asian/Pacific Islander, 3.5% as American Indian/Alaskan Native, 25% as Black/African American, 14% as Hispanic and 10.7% chose to not respond; additionally, 36% of student participants were female and 64% were male and 7% of the participants identified as a veteran.

Results

Results show that over 80% of the total 46 students placed at least one math course higher after the program. For student participants who continued to Lipscomb University, Table 2 shows the breakdown of pre-program math placement (based on archival ACT math scores) and their post-program math placement based on Lipscomb University's internal math placement test. Results show that, of the students who ended up in Pre-calculus/Trigonometry, approximately 64% were students who improved their math placement, 2 of which had a pre-placement of Intermediate Algebra. Of the student participants who had a post-program math placement of College Algebra, 88% improved from Intermediate Algebra. It should be noted that 3 student participants who had a pre-program math placement of Calculus 1, due to ACT scores, were allowed to participate in the program if they still felt unprepared. These students are presented in Table 2. However, since they did not technically require remediation, their math progress and math improvement are beyond the scope of this work. For the 25 student participants needing remediation, we see that only 68% tested at least one math course higher.

Table 2: Pre- and post-program improvements by participant starting math placement (determined by archival ACT Math scores)

Pre-program Placement (28)	Post-program Placement		
Intermediate Algebra (13)	Intermediate Algebra (3)	College Algebra (8)	Pre-calculus/Trig (2)
College Algebra (6)	College Algebra (1)	Pre-calculus/Trig (5)	Calculus 1 (0)
Pre-calculus/Trig (6)	Pre-calculus/Trig (4)	Calculus 1 (2)	———
Calculus 1 (3)	Calculus 1 (3)	———	———
Total	39.3% no course improvement	53.6% improved by one course	7.1% increased by two courses
Total who needed remediation (excluding Calculus 1 pre-placement)	32%	60%	8%

We also compare retention rates and math performance with their baseline peers. At-risk students in the program show significant persistence and better math performance. The data reveals a substantial increase in first-semester math course success for program participants. Students placed into College Algebra, Pre-calculus, or Trigonometry through the program outperform historical data for engineering students in their first semester math courses. Those students who continue onto Calculus 1 earn about 0.8 higher letter grades than the control group. Ongoing data collection will help assess progress in higher-level math courses like Calculus 3 and Differential Equations.

Out of 28 students from the Program who went on to attend the University, 20 of them either placed into Pre-calculus/Trigonometry or College Algebra. Those two groups will be examined in detail here.

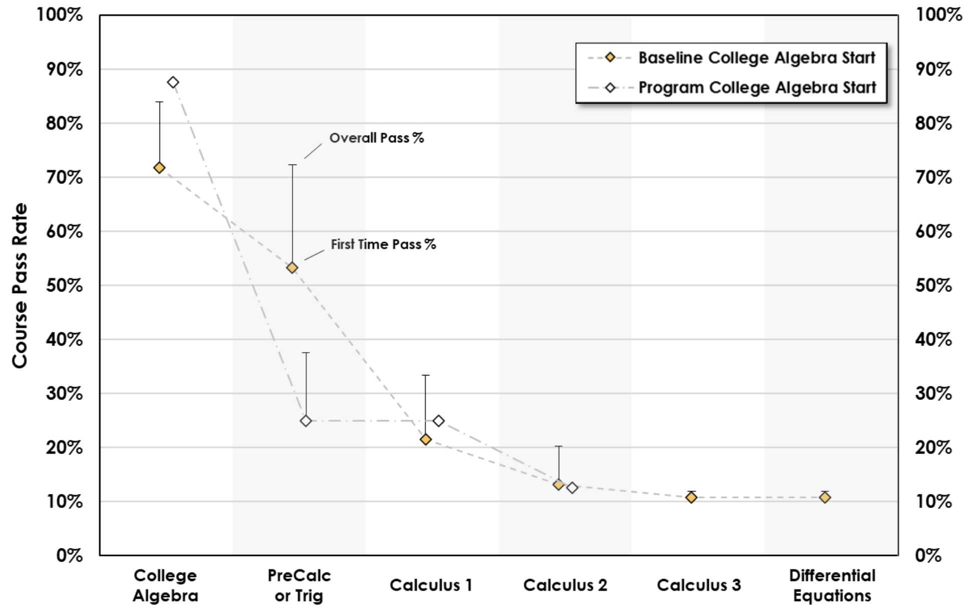


Figure 4: Pass rates for control group students and Program students who started in College Algebra. Rates are shown as a percentage of students taking the first course in their respective sequence to demonstrate the percentage of students in each group

Figure 4 shows the cohort pass-rate of Program participants whose first class at the University was College Algebra compared to the previously shown Baseline historical data. There is some increase in the initial course pass rate and around a 15% increase in the first-time pass rate of the course. There is a sizeable dip in cohort pass-rate for Pre-calculus/Trigonometry, but overall performance across all the courses tracks reasonably closely to the baseline data. For interpretation of these results, it should be noted that around half of the student participants (specifically, Summer 2022 participants) only have two semesters of coursework in the data set shown here. Therefore, cohort pass-rates in the third and fourth semester math courses should be treated as the conservative benchmark.

Figure 5 shows the pass rates for the students in the College Algebra groups in each individual class and Figure 6 shows the course grade average for those groups. Given 8 students in the Program data set, the results do not seem to be consistently better or worse than the baseline data.

Whereas the data for Program students starting in College Algebra shows mixed results, the Program data for students starting in Pre-calculus/Trigonometry shows a noticeable improvement across all metrics. Figure 7 shows the pass rates for the courses as a percentage of the students in the starting grouping. The persistence of these students is higher across the entire Calculus sequence. First time pass rate is around 15% higher in Pre-calculus/Trigonometry and more than 30% greater for Calculus 1. For Calculus 2, the first-time pass rate is 20% larger and around 3x

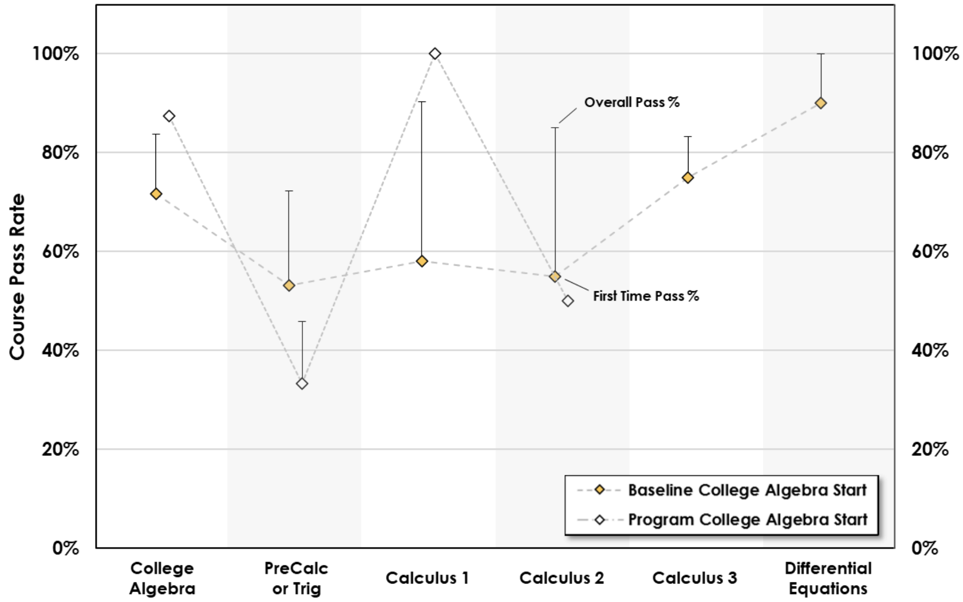


Figure 5: Pass rates for control group students and Program students who started in College Algebra. Rates are shown as a percentage of students taking each specific course to demonstrate the selected performance of students who have progressed to each course.

the Baseline group. For pass rates specific to populations who progressed to those courses, a similar separation in results is shown. Figure 8 shows 100% of Program participants starting in this group who progressed past Pre-calculus/Trigonometry passed Calculus 1 on the first attempt.

Figure 9 shows course grade results for these same groups. As might be expected given the results in Figure 7 and Figure 8, average grades for Program participants are improved across the Calculus sequence. Figure 9 shows around half a letter grade improvement for Pre-calculus/Trigonometry. Unlike the Program participants starting in College Algebra, the students in this group increase their performance in the following class, performing almost a full letter grade better in Calculus.

Discussion

One key result, the percentage improvement, shows that 80% of the total 46 participants improved. Whereas only 68% of student participants who continued to Lipscomb University showed improvement. The origin of the disparity between these results is unclear. However, one possibility could be the source of the pre-program math placement data. Pre-program math placement for the participants not continuing to Lipscomb University were based on self-reported ACT math scores, whereas for student participants who continued to Lipscomb University the PIs used archival data for officially reported ACT math scores.

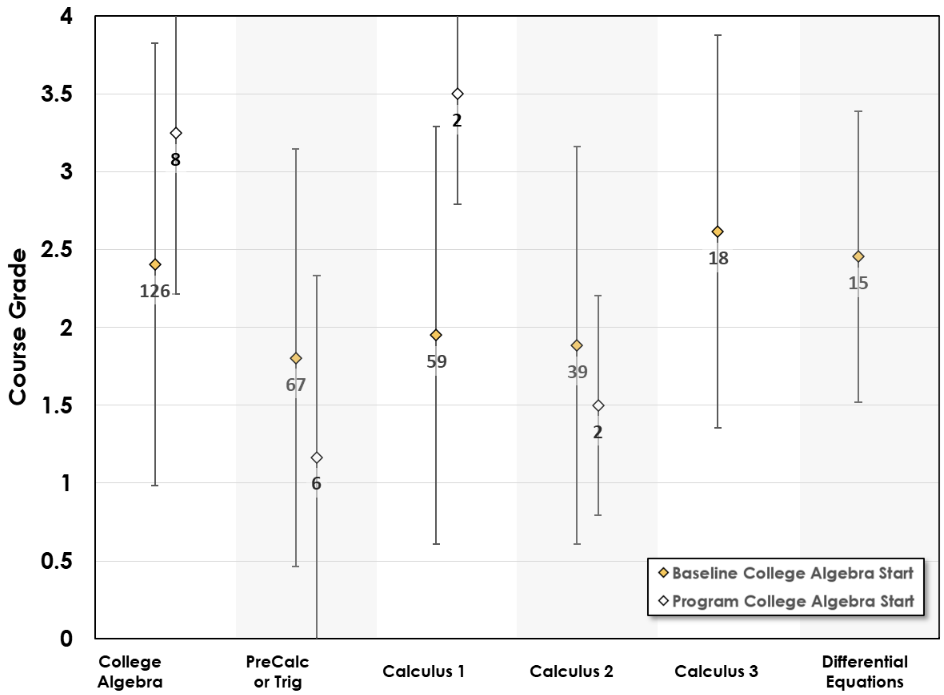


Figure 6: Course GPA for mathematics course sequence for students who started in College Algebra. Historical baseline data is compared to Program participants. Number of course attempts for each course is labeled. Error bars are one standard deviation.

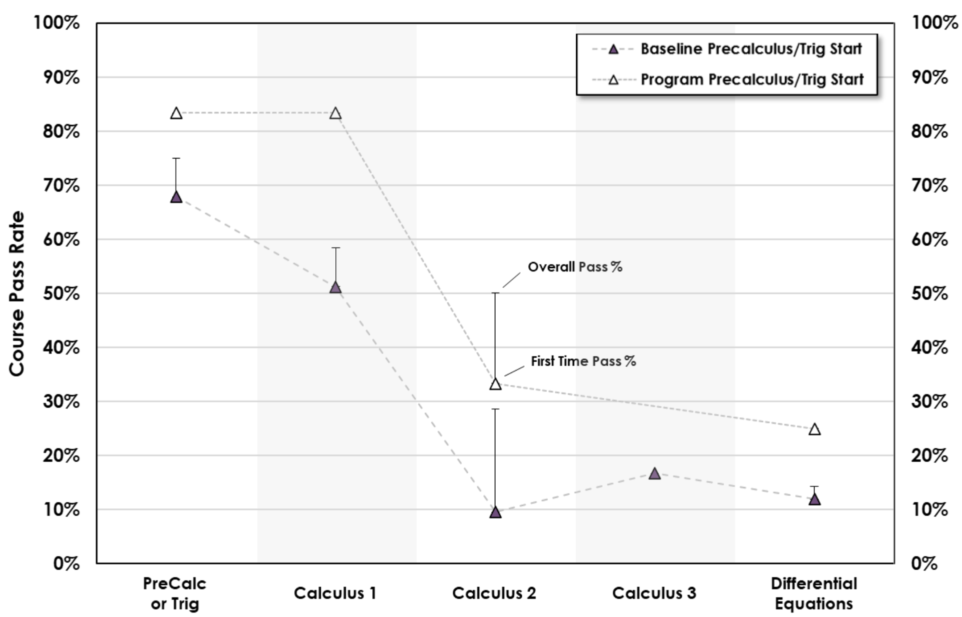


Figure 7: Pass rates for control group students and Program students who started in College Algebra. Rates are shown as a percentage of students taking the first course in their respective sequence to demonstrate the pass-rate in each group.

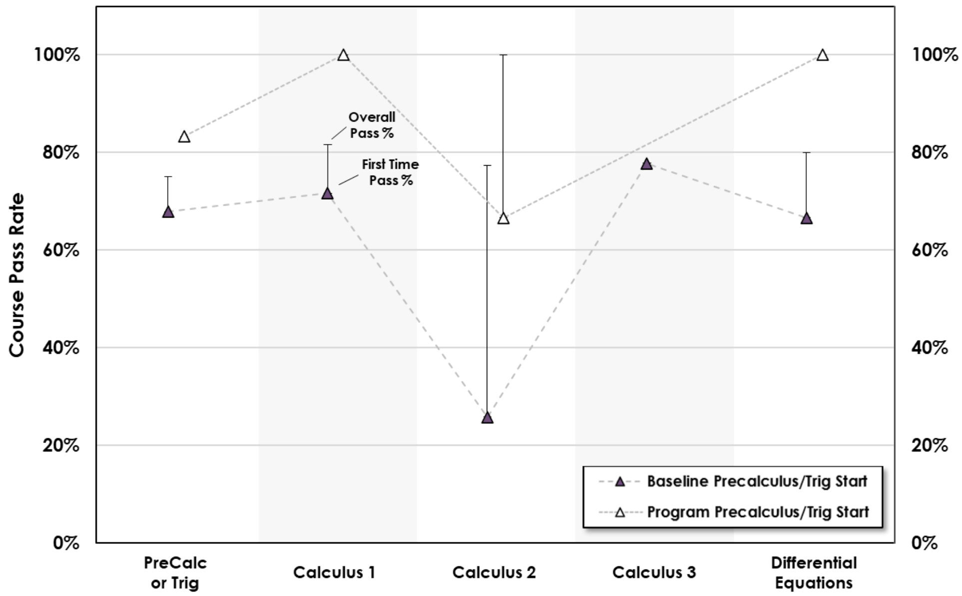


Figure 8: Pass rates for control group students and Program students who started in Pre-calculus/Trigonometry. Rates are shown as a percentage of students taking each specific course to demonstrate the selected performance of students who have progressed to each course.

Unsurprisingly, data from the baseline population show that math readiness can have a significant determination in a student's ability to finish an Engineering degree. One math course difference of Pre-calculus/Trigonometry as compared to Calculus 1 is the difference between approximately 15% to 45% completion of Differential Equations. Results show that student participants in this program are not immune to the attrition seen in the baseline population from College Algebra to Differential Equations, mainly for students starting below Calculus 1. AERO program participants match or outperform the baseline groups. While AERO participants in College Algebra, on average, look identical to the baseline student who starts in College Algebra, it should be noted that 88% of these AERO participants improved into College Algebra from Intermediate Algebra. Additionally, just under 90% of these AERO participants starting in College Algebra can pass College Algebra. While these students admittedly have a low completion rate of the Calculus sequence required to earn an Engineering degree, it can be argued that this program improved the lives of these students as a significant portion of them were able to complete the University math general education requirement of College Algebra allowing them to complete a university degree.

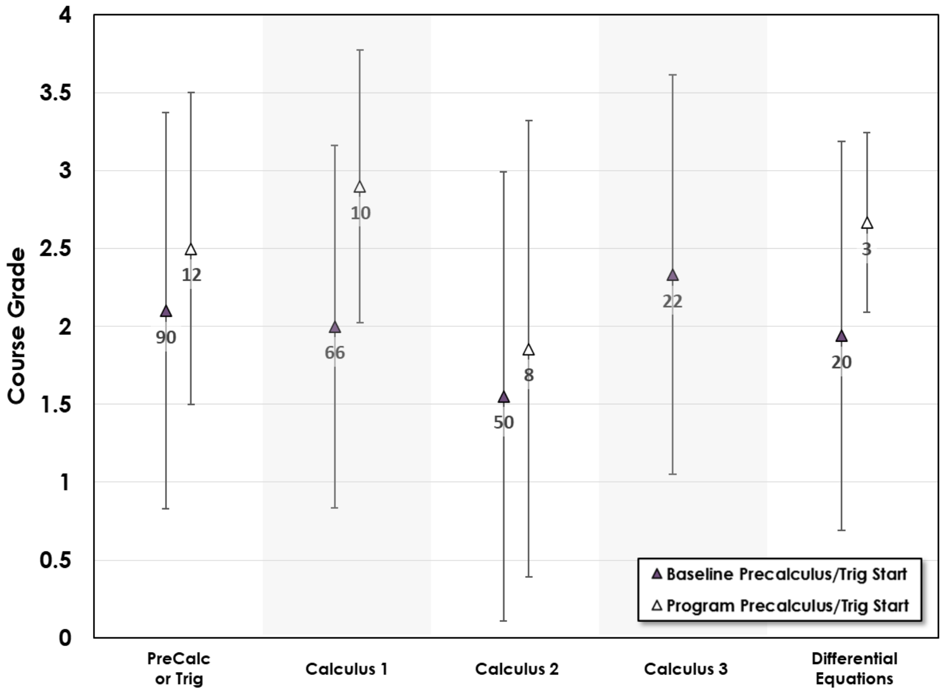


Figure 9: Course GPA for mathematics course sequence for students who started in Pre-calculus/Trigonometry. Historical baseline data is compared to Program participants. Number of course attempts for each course is labeled. Error bars are one standard deviation.

Notably, the outcome for student participants starting in Pre-calculus/Trigonometry is shown to be significantly better than the baseline populations with a completion rate over 67% after Calculus 2 as compared to 30% for the baseline students. It is unclear what factor of the AERO program has resulted in this marked outcome. However, it is unlikely that math preparation (amounting to approximately 20 hours total) alone is attributed to the increased completion rates. This is likely from a combination of math preparation, improved math confidence, increased awareness of and potentially willingness to access support systems.

Conclusion

The AERO summer math bridge program was designed to support at-risk students transitioning into computing or engineering degree programs. This program provides an individualized math preparation software tool, along with high student to faculty/tutor ratios to assess and bolster students' algebra and Trigonometry skills. The math curriculum is supported by engineering PBLs that are tied together using a humanitarian lens. These lessons focus on using various math skills, such as systems of linear equations, Trigonometry and polynomials. In addition to the math and engineering curriculum, students are provided with near-peer experiences through "Lunch and Learns" and during the sponsored field trip where they get the opportunity to hear from students and recent graduates.

Baseline data presents a bleak prospect for many students who are unable to start with Calculus 1 in their computing and engineering degrees. However, the AERO program has shown promising results for students through increased math placement and improved math completion rates for student participants who start in Pre-calculus/Trigonometry. It is unclear what aspect(s) of this program has resulted in such outcomes, and if these outcomes will persist for future AERO participants. Further studies will be required to isolate various components of the program to understand their impact on these students' math performance. Future studies are also needed to understand other factors (beyond math starting point) that can impact students' ability to complete their intended degrees so that other interventions can be designed. Overall, the outcomes of this program show an exciting start to supporting these at-risk students in our community.

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