Design and Implementation of a Two-Day Undergraduate Math Boot Camp during Regular Semesters

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Abstract

According to national data, less than half the freshman who start in STEM majors graduate with a STEM degree, and at least half of this attrition occurs during the freshman and sophomore year. Clearly, the first two years are critical for both academic success and retention of STEM students. The retention rates of freshman and sophomore students in STEM majors are the lowest in all levels. One of the major reasons is that STEM students failed in the gateway math courses in the first two years, which negatively impacts students' confidence in STEM and significantly increased their financial burden and pressure. There are different interventions and student support services to help increase STEM students' success in the gateway math courses, most of which rely on peer tutoring and mentoring during regular semesters. With the support from the U.S. Department of Education, Texas A&M University-Kingsville designed and implemented a two-day math boot camp program at beginning of each long semester in the last two years to provide critical help to students who have poor performance in selected math courses. The boot camp program did not teach the contents of the math courses that are currently taken by the students. Instead, it prepared the students to be ready for taking their currently math courses by building a solid background needed to pass the courses. The boot camp was open to students who either received poor grade in a prerequisite course of their current math class or failed their current math class in previous semester. During the boot camp, the faculty instructors used adaptive learning methods to help students learn basic knowledge and combined live instruction with after-class practices to ensure a smooth and successful learning process. Each selected course consists of 5-10 different learning modules. The faculty instructor taught these different learning modules, while a student mentor helped with the after-class practices. In the last two years, a total of 67 students participated in the boot camps. Each student participant was tested before and after the boot camp to evaluate the immediate impact of the boot camp. In addition, the authors tracked the students' academic performance before and after the boot camp to analyze both short-term and long-term impacts. This paper discusses the detailed design and implementation of the boot camp and the impacts on the student participants.

Project Background

Low-income, first-generation and other aspects of socioeconomic status enhanced the problems of educational attainment in the regions Texas A&M University-Kingsville (TAMUK) serves. To further clarify the target population, the financial characteristics of the undergraduate student population at TAMUK have been assessed, which include more than 50% of the undergraduate population at TAMUK received Pell Grants and more than 55% of undergraduate population at TAMUK received Federal Student Loans. Furthermore, more than 70% of TAMUK undergraduates received need-based grants or scholarships. TAMUK's need-based financial aid for undergraduate students is alarmingly high when compared to national trends. According to the College Board's Trends in College Pricing and Student Aid Report, total national undergraduate student aid resulted in the distribution of 15% Federal Pell Grants, 27% Federal Student Loans and 44% Grants or Scholarships [1]. The TAMUK undergraduate student financial aid profile suggests significantly higher trends in student need.

Not only the TAMUK students are facing a lot of financial pressure and difficulties, the students in those school districts near TAMUK have issues in their academic preparation before joining the university. About 20% of the Hispanic students in South Texas region were at Masters Grade Level for all grades in Mathematics [2]. Masters Grade Level refers to those students who are expected to succeed in the next grade or course with little or no academic intervention as they demonstrate the ability to think critically and apply the knowledge and skills gained [2]. Only about 30% of recent high school graduates in the South Texas region were at or above SAT/ACT criterion (lower than the state average of 36.1%). Therefore, the academic achievements in STEM disciplines of the majority of the students in this region are much lower than the state average. According to national data, less than half the freshman who start in STEM majors graduate with a STEM degree, and at least half of this attrition occurs during the freshman and sophomore year [3],[4].

In the rural four-year university, different mentoring and tutoring services are offered to students taking gateway math courses to help them during the regular semesters. For example, JavALab in Department of Mathematics provides tutoring help for courses like College Algebra, Trigonometry. PAAC (Pathways Academic Assistance Center) provides tutoring to all math courses students. And an NSF-funded project supports peer mentors in Math during regular semesters. Despite the current available services and programs that are designed to help STEM students during regular semesters, the DFW (grade D, Fail, and Withdraw/Quit) rates of these gateway math courses do not show significant improvements. Through campus-wide need assessment and identification processes, it was found out that the number of students using the available services are low compared to the class enrollment in most cases, while most of the students used the services only tried to ask help right before the exams. Many students were not able to use these available services outside their class schedule due to the needs of part-time jobs, children care, etc. In addition, the relationship and trust between peer mentors and students are not established before the beginning of these classes.

Table 1 shows that selected gateway courses have extremely high DFW rates, while the average DFW rate of all other courses in STEM curriculum at TAMUK is about 10%.

Table 1: DFW rates of Selected Gateway Math Courses at XXX University

Course	Total Enrollment/D/F/W/DFW Percentage Rate*			
	Fall 2022	Spring 2022	Fall 2021	Spring 2021
MATH 1314-College algebra	433/35/78/73/43	213/18/53/42/53	496/246/41/105/79	327/26/68/41/41
MATH 1316-Trigonometry	164/12/28/6/28	179/28/38/17/46	169/20/36/14/41	159/15/31/11/36
MATH 1348-Analytic geometry	89/13/1/4/20	84/10/8/6/29	76/11/13/3/36	106/8/23/5/34
MATH 2413-Calculus I	116/8/6/3/15	83/5/7/2/17	122/5/6/1/10	105/4/7/3/13
MATH 2414-Calculus II	63/2/7/5/22	98/11/14/3/29	87/6/6/1/15	83/13/9/2/29

*Note: Total Enrollment, D, F, W are shown in headcounts while DFW Percentage Rate is shown in percentage in the table.

Program Design

There is a strong need to develop and implement an innovative intervention program to tackle the high DFW rate in these gateway courses, which further causes the low retention rates at all levels of undergraduate STEM programs at TAMUK. With the support from the U.S. Department of Education, a STEM Boot Camp program was developed and implemented in the last several years, which provided stipend support to attract students to participate in a two-day boot camp at the beginning of each semester to strengthen their fundamental knowledge needed to succeed in these gateway courses and provide peer mentoring services during the regular semesters with established relationship and trust between the peer mentors and students.

The purpose of the math boot camp is to review fundamental knowledge needed for students to pass the gateway courses. The boot camp did not teach the contents of the gateway courses that the students are taking or will take. Instead, the boot camp prepared the students to be ready for taking these gateway courses by building solid fundamental knowledge needed. The boot camp provided intensive instruction using adaptive learning methods to help students learn basic knowledge and combine live instruction with after class practices and group activities to ensure a smooth and successful learning process.

The two-day boot camp was always offered in the first weekend after the first class day of each long semester (spring and fall). The boot camp was optional and open to all the students who either received poor grade in a prerequisite course of their current math class or failed their current math class in previous semester. Selected students completed a pre-assessment before the boot camp and a post-assessment after the boot camp. About five-hour instructional lectures were offered under each course every day (2-3 hours in the morning and 2-3 hours in the afternoon). The topics covered in each course were well-designed and planned, so that the students had enough background to be successful in the courses they were assigned to take.

Each course in the boot camp were taught by one faculty mentor with the help of a student mentor. TAMUK students in their first two years of STEM majors who received poor grades in the pre-requisite of the gateway courses or failed the gateway courses were encouraged and qualified to participate in the boot camp. Students received A or B grades in the pre-requisite of the gateway courses were not recruited to the boot camp. The boot camp student mentors also provided continuous peer mentoring and tutoring to students in the gateway courses after the boot camp. Through the boot camp, it was expected that the student mentors have established close relationships and trust with the student participants, which would be much more effective and efficient for the student mentors to provide peer mentoring and tutoring to further help students in the gateway courses to successfully pass these courses.

The topics reviewed by each math course in the boot camps are listed below.
College Algebra reviewed 12 different topics: 1) Review Algebraic Expressions, 2) Linear functions and Lines, 3) Linear equations, 4) Linear inequalities, 5) Quadratic functions and Parabola, 6) Quadratic equations, 7) Quadratic inequalities, 8) Transformations of functions, 9) Combinations of functions; Inverse functions, 10) Polynomial functions and their graphs, 11) Exponential and logarithmic functions, and 12) Systems of linear equations in two variables.

Trigonometry reviewed nine different topics: 1) Angles and their measure, 2) Trigonometric Functions and Unit Circle, 3) Sine and Cosine Graphs, 4) Tangent, Cotangent, Cosecant, and Secant graphs, 5) Trigonometric equations, 6) Trigonometric Identities, 7) Right Triangle Trigonometry and Applications, 8) The laws of Sines and Cosines and Applications, and 9) Phase shift and Simple Harmonic Functions. Analytic Geometry reviewed 12 different topics: 1) Lines and Circles, 2) Functions: properties and transformations, 3) Properties of Linear Functions and Linear Models, 4) Quadratic Functions and their properties, 5) Polynomial Functions and their graphs, 6) Real and Complex Zeros of a Polynomial Function, 7) Rational Functions: properties and their graphs, 8) Polynomial and rational inequalities, 9) Polar equations and Graphs, 10) Complex Plane and De Moivre Theorem, 11) Vectors: the dot product, and 12) Conics: Parabola, Ellipse, and Hyperbola. Calculus I reviewed nine different topics: 1) Review of Basic Functions, 2) The Limit of a function; Limit Laws, Continuity, 3) Limits at infinity; Horizontal and Vertical Asymptotes, 4) The Derivative of a function: limit definition, 5) Derivative Laws; Product, Quotient, Chain Rules, and Implicit Differentiation, 6) Derivative Applications: Rates of change, Exponential Growth, Linear Approximations and differentials, 7) Maximum and Minimum Values; The Mean Value Theorem, 8) How derivatives affect the shape of a graph, and 9) Definite Integrals: Riemann Sum, The Fundamental Theorem, of Calculus, The Substitution Rule. Calculus II reviewed six different topics: 1) Applications of Integrations: Areas between curves: Volumes and Areas of Solids of Revolution; Arc Length, 2) Techniques of Integration: Integration by Parts, Trigonometric Integrals, Trigonometric Substitution, Integration by Partial Functions, Improper Integrals, 3) Parametric Equations and Polar Coordinates: Curves, arclengths, and areas under the curves, 4) Infinite Sequences and Series: Converge Tests: Divergence, Integral, Comparison, Limit Comparison, 5) Alternating Series: Absolute Convergence Test, Ratio and Root Tests, and 6) Power Series representation of a function; Taylor and Maclaurin Series.

Program Evaluation and Assessment Results

The boot camp has been offered four times (spring 2024, fall 2024, spring 2025, and fall 2025) covering College Algebra, Trigonometry, Analytic Geometry, Calculus I, and Calculus II with a total of 67 student participated. Table 2 shows the number of students participated in each course in the last two years. Since Calculus II was only offered in Fall 2025, there were only four students participated in Calculus II.

Table 2: The number of students participated in each boot camp course in the last two years

College Algebra	Trigonometry	Analytical Geometry	Calculus I	Calculus II
13	12	8	30	4

Table 3: Boot Camp students' pre- and post-assessment results (average scores in 100 scale)

	College Algebra	Trigonometry	Analytical Geometry	Calculus I	Calculus II
Pre	59	45	49	35	31
Post	78	73	83	62	85
Changes in percent	32%	62%	69%	77%	174%

Based on the pre- and post-assessment results, significant improvements were observed in all the courses. To further confirm the impact of the boot camp, students' performance in the selected courses have been tracked in the same semester as shown in Table 4. The overall performance of all boot camp students was much better than other university students. Although the number of boot camp students was relatively small compared to non-boot camp students, the impacts were extremely positive on students' course performance and overall performance.

Table 4: Students' performance in the math courses covered by the boot camp in the same semester

	Average course score (4.0 scale)		**DFW rate**		**Semester GPA**		**Retention Rate**	
	Camp student	All student	Camp student	All student	Camp student	All student	Camp student	All student
College Algebra	2.90	2.25	15%	40%	2.85	2.56	92%	67%
Trigonometry	2.85	2.40	17%	35%	2.75	2.60	92%	69%
Analytical Geometry	3.25	2.15	13%	30%	2.70	2.55	87.5%	70%
Calculus I	3.15	2.60	10%	15%	2.90	2.25	90%	80%
Calculus II	3.00	2.75	0%	25%	2.85	2.30	100%	85%

Note: GPA/Score calculation: A-4, B-3, C-2, D-1, E/F-0

Lessons Learned and Continuous Improvements

The boot camp was originally planned for one week before the semester starts. However, there were several unexpected factors affecting the plan, including

- Students' housing situation: The university residential halls were not open one week before the first class day, and
- The availability of faculty and student mentors: Most faculty and student mentors were not available one week before the first class day.

To address the two unexpected issue, the boot camp was modified from a one-week camp to a two-day weekend camp in the first weekend after the first class day. Based on the feedback from student participants, student mentors, and faculty mentors, the two-day weekend camp was much more preferrable compared to a possible one-week camp in term of scheduling and logistics. Most student participants also indicated that the boot camp was a big help in building their confidence in their STEM studies and college life, especially for freshman and sophomore students.

However, despite the stipend support and campus-wide recruitment efforts, only 60 students applied for and participated in the boot camps in the last two years, which was much less than expected. Although most student participants were very satisfied with the boot camp activities, the reason of lower-than-expected students participating in the boot camp is not clear year and should be further investigated. In addition, due to the small number of student participation, both short-term and long-term impacts of the two-day math boot camp should be further analyzed. Students who participated in the boot camp may already have higher

motivation in improving their learning and grades among all the students with poor performance in gateway math courses. More data need to be collected, such as interviews or focus groups of selected students, to further investigate the impacts of this boot camp program. Future work will also include checking students' performance in later courses and retention beyond one semester.

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