Technology Enhanced Pre-Calculus Classrooms (Work in Progress)

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RESEARCH INTERESTS: Include teaching and learning cognition skills, informal learning environments and strategies, and science/technology curriculum design/implementation/evaluation.

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Abstract

At California State University, Bakersfield (CSUB), many incoming freshmen have poor mathematics preparation and place at the elementary algebra or pre-calculus level. This leads to issues in retention and graduation rates in the calculus-based STEM majors, particularly engineering. As part of grant activities, mathematics faculty at CSUB explored using technology enhancements in the classroom to improve student learning and progression through the pre-calculus sequence. Two different methods of technology enhancement were tested with tablet PCs in the 2016/17 academic year. Effectiveness was measured through passing rate and average GPA comparisons between control sections and test sections. One technique has promising results, but has several confounding factors. Additional testing is ongoing during the 2017/18 academic year to further study the promising technique.

Introduction

As part of the activities for its U.S. Department of Education Minority Science and Engineering Improvement Program (MSEIP) grant, California State University, Bakersfield (CSUB) is exploring the effectiveness of technology enhancements in the mathematics classroom. Southern San Joaquin Valley, the service region for CSUB, is an ethnically diverse, but socioeconomically challenged, area marked by low educational attainment. According to U.S. Census data, less than 75% of the residents in Kern County, the largest county in the service region, hold a high school degree (or equivalent) and less than 16% hold a bachelor's degree or higher [1]. In comparison, nationwide more than 85% of Americans hold a high school degree and more than 30% of Americans hold a bachelor's degree or higher [2].

CSUB is designated as both a Hispanic-Serving Institution (HSI) and Minority-Serving Institution (MSI). As of Fall 2016, there are over 9300 students at CSUB, and nearly 2800 are within the School of Natural Sciences, Mathematics, and Engineering (NSME). Approximately 60% of the students are female, although this drops to approximately 48% within NSME. Campus demographics and NSME demographics closely align with those of Kern County, as shown in Table 1.

Table 1: Demographic data for CSUB and Kern County, the largest county in the service region of CSUB.

	CSUB Fall 2016	**NSME Fall 2016**	**Kern County** [1]
Asian	7%	11%	5%
African American / Black	6%	5%	6%
Hispanic / Latino	55%	53%	51%
Native American	1%	1%	2%
Pacific Islander	0%	0%	0%
Two or More Races	3%	3%	3%
White	18%	19%	33%
Unknown / Non-resident	10%	8%	--

Only one-third of high school graduates in the region completed all of the college preparatory requirements for the state university system, compared to nearly half of graduates statewide [3]. This often manifests as poor mathematics preparation and many students place at the elementary algebra or pre-calculus I level when they enter CSUB. Poor mathematics preparation leads to issues with success and retention of STEM majors, particularly engineering majors.

The technology interventions from the MSEIP grant are aimed at the pre-calculus level to provide more support for the students who enter CSUB with weaker mathematics backgrounds. The success and retention in the pre-calculus sequence directly affects the success and retention in the mathematically intensive STEM majors. At CSUB, the pre-calculus sequence consists of the courses MATH 1050 Pre-Calculus I and MATH 1060 Pre-Calculus II. There is also a combined course, MATH 1040 Pre-Calculus I and II, that was not part of this study.

This paper is organized as follows. The Technology Enhancements section describes the two techniques that were tested in the pre-calculus classroom. The Analysis of Technology Enhancements section describes the composition of the control and test class sections, and then compares the passing rates and average GPAs between the control and test groups. The Conclusions and Future Work section discusses the promising trends and the additional testing that is ongoing during the 2017/18 academic year.

Technology Enhancements

Two different methods of using technology enhancement in the pre-calculus classroom are being tested under the MSEIP grant at CSUB. Both technology enhancements use Surface Pro 3 and Surface Pro 4 tablet PCs in the classroom to augment traditional teaching techniques. The two methodologies differ drastically in how the technology is used in the classroom.

Both methodologies build upon the prior works on how technology can enhance the mathematics classroom. The interventions outlined in the grant proposal, which form the foundation of both methodologies, came from previous works which showed that tablet PCs are effective instructional tools in undergraduate mathematics courses that can improve student success and retention [4] [5] [6] [7]. The second methodology builds upon the prior works showing the pedagogical benefits of using the Desmos [8] interactive mathematics website in mathematics courses [9] [10] [11].

The first enhancement ("Method 1") uses the tablet PCs as digital paper. Students are given PDF files with problems and they have to use the digital pen to write the answers into the PDF files, which can then be saved electronically. Essentially, the technology is used as a substitute for traditional paper-based problem sheets. This methodology was tested by two instructors in MATH 1050 Pre-Calculus I for the 2016/17 academic year.

The second enhancement ("Method 2") more extensively incorporated technology into the classroom using Desmos activities on the tablet PCs, with some supplemental activities using online videos, Excel, Maple, Khan Academy calculators, and the online free version of Wolfram Alpha. Students are provided a variety of interactive activities using those tools, depending on the specific pre-calculus course. The activities for MATH 1050 Pre-Calculus I are listed in Table

2. The activities for the MATH 1060 Pre-Calculus II course are listed in Table 3. For example, in Pre-Calculus II, the lesson on the unit circle is augmented with an activity on Desmos that visualizes the unit circle and allows a student to interactively change the point on the unit circle. This methodology was prototyped and tested by one instructor in both Pre-Calculus I and Pre-Calculus II during the 2016/17 academic year.

Table 2: List of interactive activities for the Pre-Calculus I course.

Course Requirement	**Supplemental Activities**
Coordinates, graphs, and inequalities	Desmos: • Linear Systems Bundle • Linear Equations Bundle
Functions – Definitions, operations, and inverse functions	Desmos: • Functions Bundle • Transformations Bundle • Quadratics Bundle
Optimization problems	Desmos: • Functions Bundle • Transformations Bundle • Quadratics Bundle
Compound interest and exponential growth and decay	Desmos: • Exponentials Bundle

Table 3: List of interactive activities for the Pre-Calculus II course.

Course Requirement	**Supplemental Activities**
Right angle and unit circle trigonometry	Desmos: • Trig and the Unit Circle Khan Academy: • Solve for a Side in Right Triangles (calculator tool) • Solve for an Angle in Right Triangles (calculator tool) • Right Triangle Word Problems (quiz tool)
Trigonometry equations and identities	Desmos: • Sine and Cosine Graphs with Multiple Transformations • Relationship Between Sine and Cosine • Match My Trig Function • Graphing Tangent • Tangent, Cotangent, Secant, and Cosecant • Graphs of Trig Functions
Polar coordinate systems	Desmos: • Polar Graph Exploration • Polar Coordinates (two activities) • Graphing Polar Coordinates • Polar Graphing Challenge

Conic sections and parametric equations	Desmos: • Learning Conics • Parametric Equations Video: • Conics in 3D

Analysis of Technology Enhancements

In order to analyze the impact of the technology enhancements, the pre-calculus sections offered in the 2016/17 academic year were designated as a "Control" section (no technology enhancement), a "Method 1" section (using the tablet PCs as digital paper), or a "Method 2" section (more extensive incorporation of technology in the classroom). All sections followed the same curriculum standards for MATH 1050 and 1060, as outlined by the Mathematics Department, and there were also common final exams for the courses during the 2016/17 academic year. This minimizes variations between instructors with respects to course topics and difficulty of the final exam.

Figure 1 shows the number of students in each category and breaks down the students by underrepresented minority (URM) status and gender. For Pre-Calculus II, there were no sections designated as a "Method 1" section in the 2016/17 academic year.

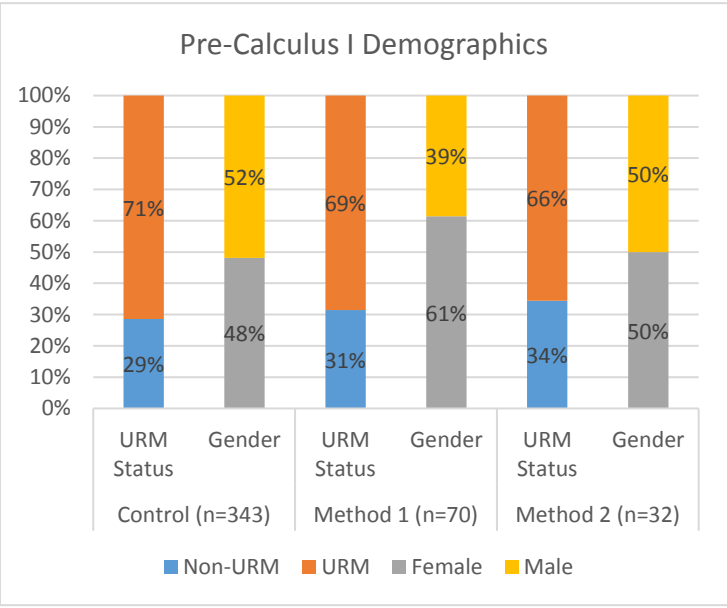

Figure 1a

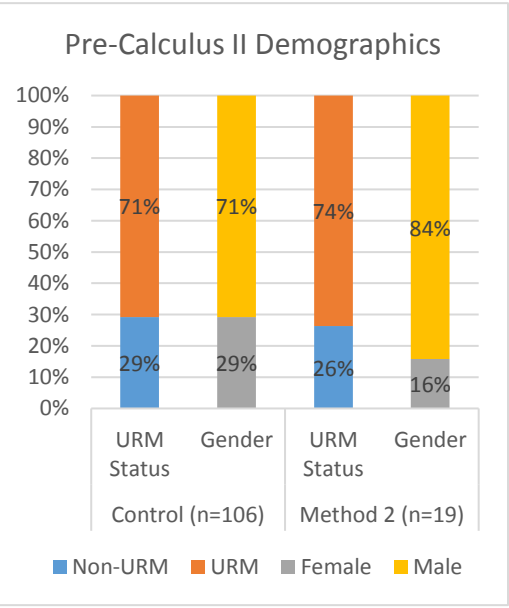

Figure 1b

Figure 1: Aggregated demographics of the pre-calculus courses for the 2016/17 academic year. Underrepresented minority (URM) status and gender breakdowns for the control group and the two experimental method groups are given. No pre-calculus II courses tried the "Method 1" experimental methodology in the 2016/17 academic year. Figure 1a is for pre-calculus I courses and Figure 1b is for pre-calculus II courses.

Two metrics were analyzed to determine student success: the average GPA for students in each course category and the passing rate in each course category. The average GPA showed no statistically significant differences for Pre-Calculus I between the control group and either technology method, as shown in Figure 2. The average GPA for the "Method 2" group in Pre-Calculus II is higher than the average GPA for the control group across all categories, as shown in Figure 3. However, as noted in Figure 1, there were only 19 students in the "Method 2" test group, which is too small of a sample size to derive significant results.

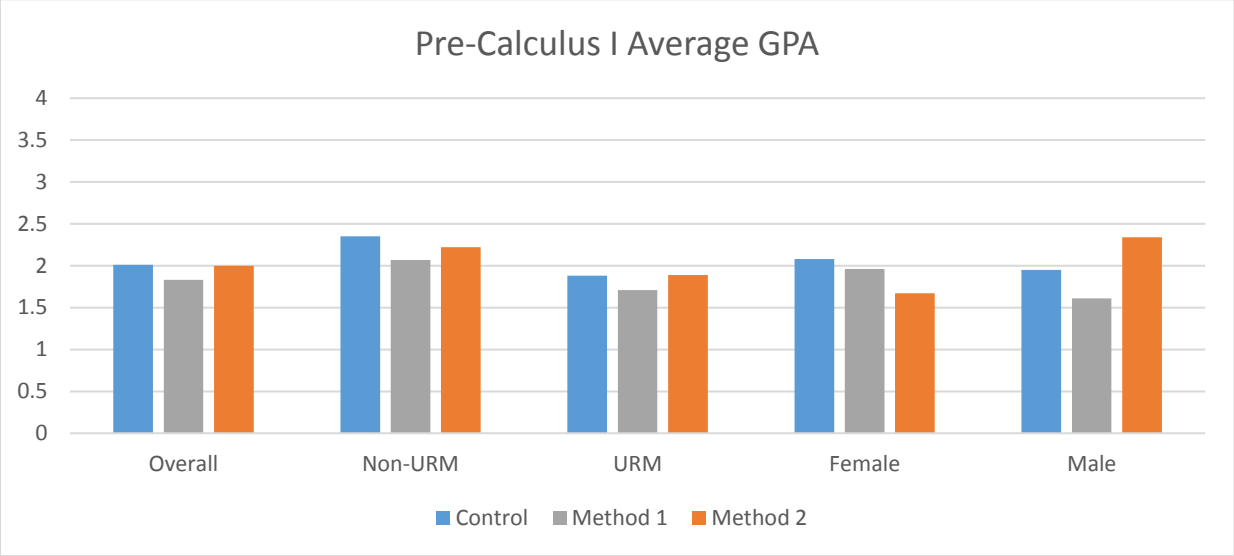

Figure 2: Average GPA for the pre-calculus I courses for the control group and both experimental method groups.

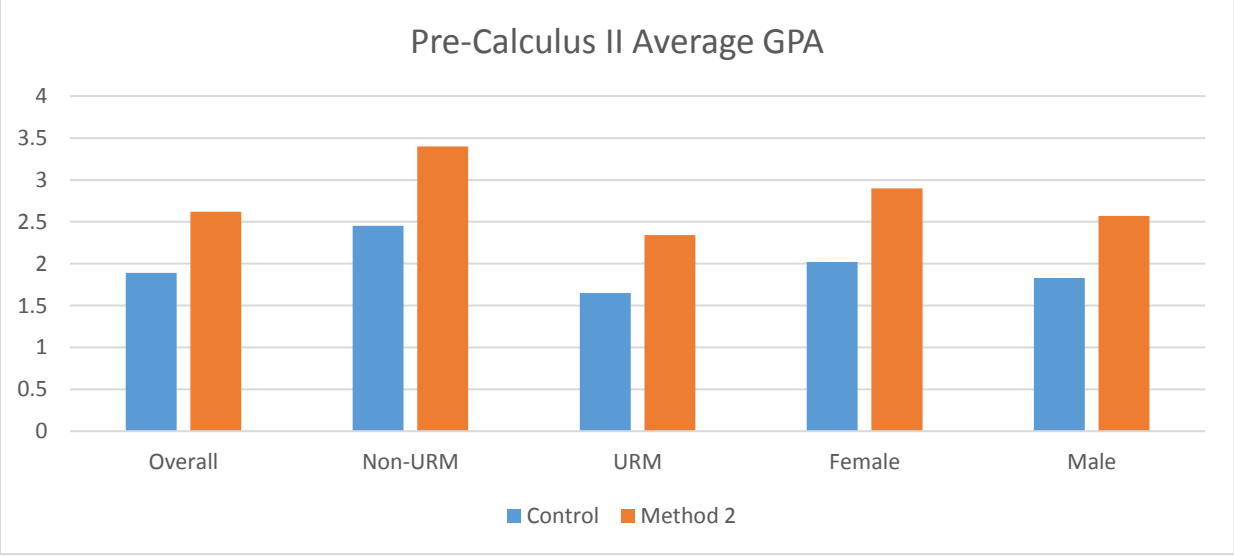

Figure 3: Average GPA for the pre-calculus II courses for the control group and "Method 2" experimental group.

When looking at the pass rates, a student is considered to have passed either pre-calculus course when they have achieved a grade of C- or higher on the graded course scale, or a grade of CR for

the credit/no-credit grading basis. This makes them eligible to go on to the next course in the pre-calculus and calculus course sequence. For Pre-Calculus I, the results for the "Method 1" group are essentially the same as the control group, as shown in Figure 4. There is a slightly higher pass rate for URM students and for female students, but it is not significant. However, the pass rates in Pre-Calculus I for the "Method 2" group are higher in all areas except for female students. And when looking at Pre-Calculus II pass rates, as shown in Figure 5, "Method 2" has a higher pass rate than the control group for all student groups.

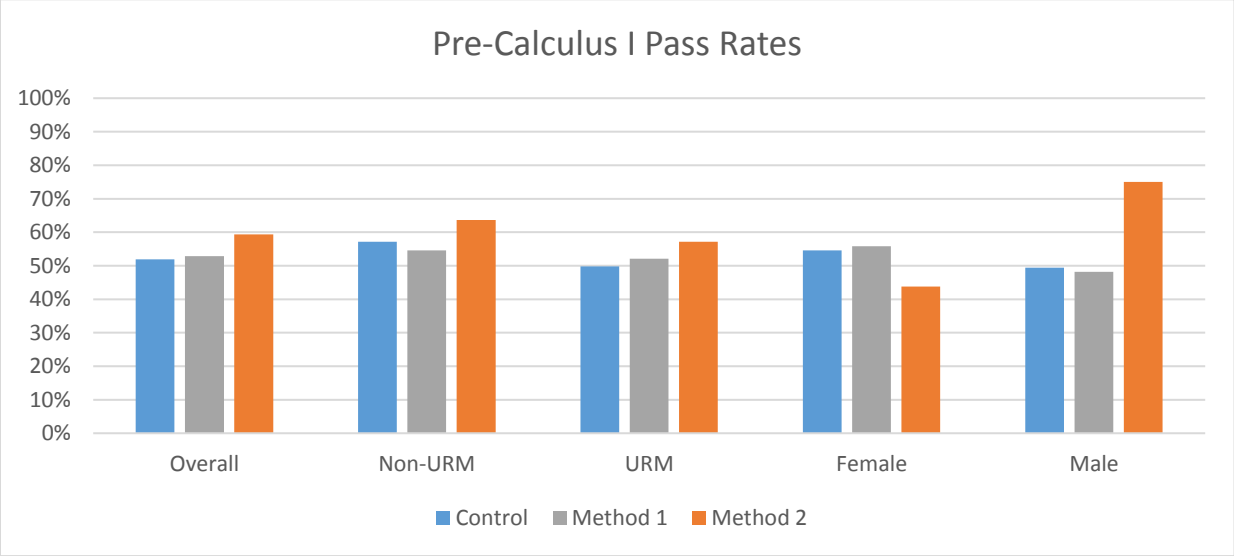

Figure 4: Passing rates for pre-calculus I courses for the control group and both experimental method groups. A grade of C- or better (or "CR" for credit/no-credit grading basis) is needed to pass the course.

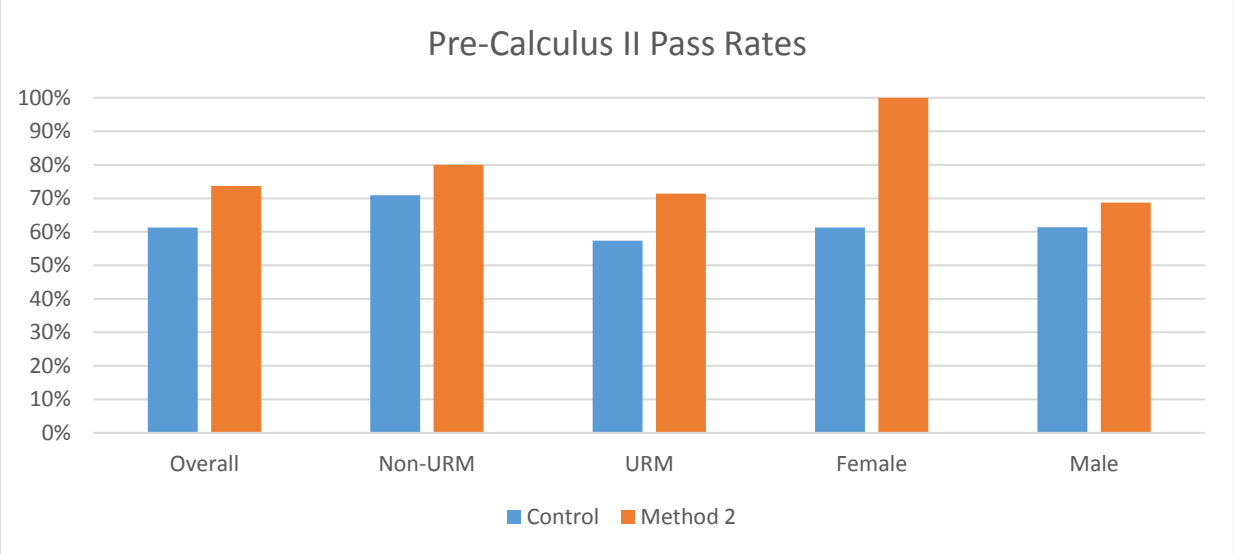

Figure 5: Passing rates for the pre-calculus II courses for the control group and "Method 2" experimental group. A grade of C- or better (or "CR" for credit/no-credit grading basis) is needed to pass the course.

Conclusion and Future Work

The preliminary results are very promising for the second method, particularly in Pre-Calculus II. However, the sample sizes are small and the same instructor taught both “Method 2” test courses, so there are confounding factors. Additionally, both test sections for “Method 2” were night courses. CSUB is extending the “Method 2” curriculum to additional instructors and sections in the 2017/18 academic year to see if the trend holds over a larger sample size and with different instructors.

The results for “Method 2” in Pre-Calculus I are not as strong as those in Pre-Calculus II. There are a variety of factors that could explain this difference. Biology majors at CSUB only take Pre-Calculus I and do not take Pre-Calculus II, so this changes the major distribution between the courses. In addition, although students can test in to either Pre-Calculus II or Calculus I, it is rare that a student actually tests into Pre-Calculus II. This means the pool of students in Pre-Calculus I contains a large number of freshmen who are still adjusting to the college experience, whereas the pool of students in Pre-Calculus II have taken at least one term of college. The leads for the MSEIP grant are working with the university research office to gather more granular data from the courses to see if these factors affect the results.

Acknowledgement

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