Closing the Achievement Gap for Underrepresented Minority Students in STEM: A Deep Look at a Comprehensive Intervention

Jenna Van Sickle Valparaiso University **Kristen R. Schuler** Saint Joseph Academy (Cleveland, Ohio) **Candice Quinn** Middle Tennessee State University
John P. Holcomb, Susan D. Carver, Andrew Resnick, Debbie K. Jackson, Stephen F. Duffy, Nigamanth Sridhar
Cleveland State University

	Precalculus I fall pass rate	Precalculus II spring pass rate
Control	57.53%	60.38%
SPT sessions only	70.33%	75.89%
OpSTEM Scholars	80.51%	84.21%

Note: this uses 4 years of data before and 4 years of data after OpSTEM's implementation.

Table 1. Precalculus pass rates before and after the implementation of OpSTEM

Abstract

Operation STEM (OpSTEM) is an NSF grant-funded program at Cleveland State University to improve retention and graduation among high-risk students seeking STEM degrees by supporting them through early mathematics. OpSTEM focuses on students from underrepresented minority (URM) groups, first-generation college students, and women. The OpSTEM program has two levels of treatment: supplemental instruction and a comprehensive program. This study considers URM students and their non-URM counterparts. For non-URM students, the majority of gains are seen in pass rates with supplemental instruction. The comprehensive program is associated with increases in pass rates such that URM students are indistinguishable from their non-URM counterparts. For URM students, a comprehensive program is associated with a narrowing of the achievement gap that is not found with supplemental instruction alone.

Keywords: Underrepresented minority, STEM, mathematics, achievement gap, summer bridge

Introduction

In 2012, Cleveland State University was awarded a National Science Foundation (NSF) STEP Grant, NSF-DUE[i]-STEP[ii]-1161152. The purpose of NSF-STEP, a congressionally-mandated program, is to increase the number of Science, Technology, Engineering, and Mathematics (STEM) graduates in US colleges and universities. Upon receiving the grant, the university developed the Operation STEM (OpSTEM) program with a goal to increase the pass rates of Precalculus and Calculus courses, which are major barriers to STEM and college success. The program was first implemented in the 2013–2014 academic year. In the 2014–2015 academic year, the program was dually funded through Louis Stokes Alliances for Minority Participation (LSAMP) program, with the Ohio LSAMP Alliance, NSF-HRD[iii]-LSAMP-1304371. This research represents the fourth year of implementation of the OpSTEM program.

The OpSTEM program has created a quasi-experimental design with three comparison groups. The most comprehensive level of intervention is given to OpSTEM Scholars. These students are selected for the program because their success in a STEM career is at the highest risk. They are members of underrepresented minority groups, first-generation college students, and women. Students who are selected for the OpSTEM program are provided assistance through Precalculus I, Precalculus II, Calculus I, and Calculus II. This begins with a two-week Summer Institute which takes place in August, two weeks prior to the first semester that they enroll in the university. Throughout the academic year, OpSTEM Scholars are provided mandatory supplemental instruction through STEM Peer Teacher (SPT) Sessions. Additionally, OpSTEM Scholars are provided a tuition-free summer Calculus I course that also includes SPT sessions. Upon completing the summer Calculus I course, OpSTEM Scholars are given continued support through additional advising and potential research opportunities throughout their university study. Concurrent to classes during the academic year, OpSTEM Scholars participate in cohort activities including STEM speakers, social activities, college success workshops, and career preparation. Scholars receive stipends through the first year for their participation in the Summer Institute, activities, mentorship, and for earning a passing grade (C or better) in their required mathematics courses.

Precalculus I and II students who are not OpSTEM Scholars also benefit from the creation of the program. They receive mandatory supplemental instruction through SPT sessions and have access to the additional support provided by SPTs.

There are two levels of intervention for the OpSTEM program. The first level was given to the OpSTEM Scholars; these students receive the Summer Institute, SPT sessions, advising, cohort activities, mentorship, and stipends. The second level is for the remaining students in the Precalculus I and Precalculus II courses; these students receive SPT sessions only. These two groups will be compared with a control group of 4 years of precalculus students from before the OpSTEM program took effect.

Carver, et al. (2017) examined the results of the OpSTEM program in great detail, and among its successes, it was associated with a rise in pass rates for both Precalculus I and II significantly over its implementation (see Table 1). Carver, et al. (2017) concluded that SPT sessions alone "are sufficient to increase the precalculus pass rates… [and] the additional services provided in the second level of treatment (OpSTEM Scholars) increases pass rates and retention over and above the gains made by the SPT sessions alone" (p. 26).

Since a main focus of OpSTEM is to increase the STEM participation and success among underrepresented minority (URM) students, this study seeks to determine the effect of OpSTEM on URM students in particular and to examine the relationship between the increasing pass rates and grades of URM and non-URM students.

Literature Review

In 2012 the President's Council of Advisors on Science and Technology (PCAST) reported a projected deficit of one million STEM graduates needed for U.S. jobs over the decade to follow. Even more, it was reported that "fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree" (PCAST 2012). Additionally, the racial and ethnic breakdown of

Race/Ethnicity	U.S. Population (age 18 – 24)	U.S. S&E Bachelor's Degrees
White	56.1%	62.7%
Asian/Pacific Islander	5.2%	9.7%
Black	14.9%	8.8%
Hispanic	20.5%	10.3%
American Indian/Native Alaskan	0.9%	0.6%

Table 2. Breakdown of U.S. Population and Science and Engineering Degrees by Race *

* Note: Obtained from National Science Foundation (http://www.nsf.gov/nsb/sei/edTool/data/college-11.html). Degree data reflect U.S. citizens and permanent residents only; they do not include foreign nationals with temporary visas. Population data include all U.S. residents, regardless of citizenship status. S&E = science and engineering. S&E includes biological/agricultural sciences, physical sciences, computer sciences, mathematics/statistics

the students who obtain a STEM degree is skewed from U.S. population dynamics. Black, Hispanic, and American Indian/Native Alaskan make up 36.3% of the U.S. population, yet obtain only 19.7% of undergraduate science and engineering degrees while White and Asian/Pacific Islanders make up 61.3% of the population and earn 72.4% of the science and engineering degrees (See Table 2).

To meet the demand of one million STEM graduates, the council suggests targeting the retention of students pursuing STEM degrees. PCAST (2012) reported that "increasing the retention of STEM majors from 40% to 50% would, alone, generate three-quarters of the targeted 1 million additional STEM degrees over the next decade." Additionally, it is recommended to provide further supports to underrepresented minority, as they are a source of untapped potential (PCAST 2012).

Data from the 2004 Freshman Survey and the 2010-2011 National Student Clearinghouse highlight this untapped potential. 56,499 students indicated they were STEM aspirants in 2004, and while 44.5% of white and Asian students completed a STEM degree within 6 years, only 25% of URM students completed a STEM degree in the same amount of time (Figueroa, T., Cobian, K., Hurtado, S., Eagan, K. 2017).

In order to increase the number of STEM graduates, a closer look at the source of the issue is needed. The council reported that "in 2005, 57% of the students enrolled in 4-year colleges and universities were enrolled in pre-college algebra, trigonometry, or other pre-calculus courses" (PCAST 2012 p. 28). These courses are below the required introductory courses necessary for a STEM degree. Additionally, these courses tend to be a review of high school mathematics and often rely on rote memorization and a procedural approach to understanding the mathematics. This leaves students "with the impression that the field is dull and unimaginative, and that they can extend this judgment to all STEM disciplines" (PCAST 2012). This may cause students who are deciding their major to dismiss the possibility of STEM as well as push students who are intending to major in a STEM discipline to consider a different major. For underrepresented minorities, the problem does not stop there. In addition to remedial or introductory STEM courses being uninteresting, many minority students "cite an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure" (PCAST 2012). Also, STEM courses tend to have competitive classroom environments. These types of environments typically hinder the opportunities of underrepresented minorities to participate equally (Springer & Stanne 1999).

To make remedial and introductory STEM courses relevant and interesting as well as establish learning communities within the classroom, drastic pedagogical changes need to be made. The traditional lecture-style approach to teaching must shift to that of a student-centered approach. Research suggests that "what students learn is greatly influenced by how they learn, and many students learn best through active, collaborative, small-group work" (Springer, Stanne, & Donovan, 1999, p. 21). This can be accomplished in part using Project-Based Learning (PBL) and other forms of active learning. This diversification of teaching methods is necessary to reach all students (PCAST 2012). Additionally, studies have shown that active learning can close learning gap between URM and non-URM students along with an increased structure (Haak, HilleRisLambers, Pitre, & Freeman 2011) and through an increase in self-efficacy (Ballen, Wieman, Salehi, Searle, & Zamudio 2017). Additionally, PBL in STEM infuses the curriculum with real-world applicability, connects coursework to what STEM professionals actually do in their jobs, and creates a learning community around a task where students must think critically, communicate, solve problems, learn in a self-directed way, and motivate themselves and each other (Capraro, R. M., & Slough, S. W. 2013).

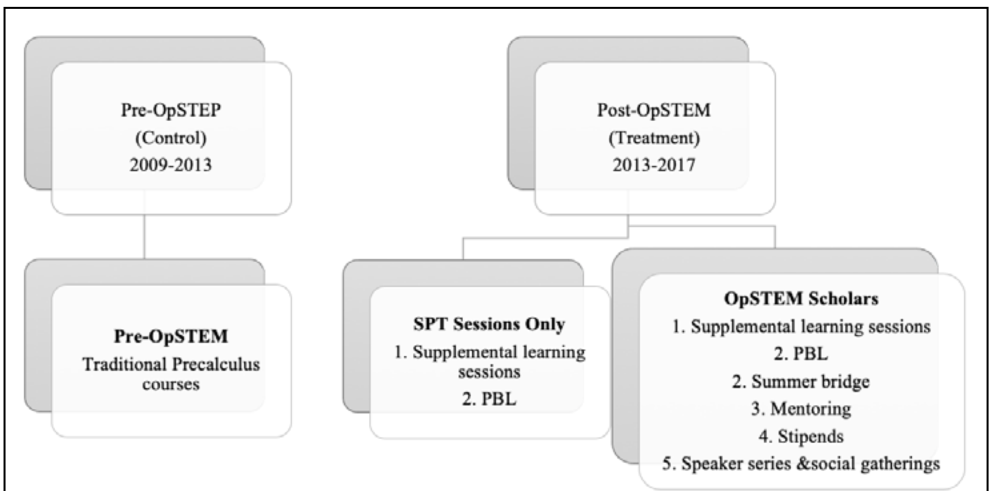

Diagram 1. Graphic of control and treatment groups outlined in this study

Peer teachers can also be used to promote retention and success in STEM (Dawson, vander Meer, Skalicky, & Cowley 2014). Peer teachers are undergraduate or graduate students that have already completed the course in which they teach. Typically, peer teachers do not introduce new content, rather they lead supplemental instruction that provides students with the opportunity to approach the content in using active learning pedagogy or apply the content to new real-world applications. Active learning is supported by educational research and learning theories. Vygotsky concluded that "learning is essentially social and that there is a gap between learning outcomes produced in isolation and those produced with careful guidance" (Gafney & Varma-Nelson, 2007 p. 535). Because peer teachers are also students, it is generally easier for them to relate and communicate with students. Additionally, the peer teacher can share their struggles and successes with the students in which they are teaching to help them find success. Thus, peer teachers are also able to act as mentors to the students they work with. Studies have shown that "undergraduate students who are mentored tend to have higher GPAs, higher retention rates, and more units completed per semester as compared to their un-mentored colleagues" (Wilson, et al., 2012, p. 149). In addition to qualitative measurements of success, mentoring "helps students to realize and envision their self-identity as STEM Scholars with the potential to offer meaningful contributions to their disciplines" (Wilson et. al. 2012, p. 154).

We have known for some time that student retention and pass rates are enhanced by learning communities (Tinto 1997; Tinto, V., Goodsell, A., & Russo, P. 1993), cohort groups that bond socially (Glimer 2007), and summer bridge programs (Raines 2012). Since mathematical proficiency is a predictor of success in STEM (Tai, R. H., Sadler, P. M., and Loehr, J. F. 2005; Sadler and Tai 2007; Wilson and Shrock 2001), we focus on the precalculus/calculus sequence. This is also a logical first area of focus, because these courses are prerequisite courses for many of the STEM courses students will be required to take in order to continue their studies.

OpSTEM was created to enhance student retention and pass rates by establishing a cohort group that functions as a learning community with PBL, through the summer bridge program, mentoring, and by using peer-led instruction in supplemental learning sessions in precalculus and calculus that employ student-centered learning.

In this study, we consider the effects of the OpSTEM program on URM and non-URM students, in comparison to a control group from prior to the implementation of OpSTEM. The OpSTEM participants consist of two groups—those who were OpSTEM Scholars and received all the interventions that the OpSTEM program offered, and those who received SPT sessions only.

Methodology

Research Questions

In this statistical analysis, the effects of the OpSTEM program are analyzed to address the following research questions:

1. How did precalculus pass rates differ for URM and non-URM students:
   a. in the control group?
   b. among students attending SPT sessions only?
   c. among OpSTEM Scholars?
2. How did mean grades in precalculus differ for URM and non-URM students†:
   a. in the control group?
   b. among students attending SPT sessions only?
   c. among OpSTEM Scholars?
3. How did grades in Precalculus I predict pass rates in Precalculus II, and does this differ among:
   a. URM and non-URM students?
   b. OpSTEM Scholars and others?

Treatment

Prior to the implementation of OpSTEM, the university possessed similar trends in STEM retention seen on the national level. In addition to low retention in STEM, the distribution of science and engineering degrees did not reflect the student population at this university. Similar to the U.S. as a whole, non-URM students were obtaining a larger percentage of STEM degrees in comparison to their population percentage, as seen in Table 3. The race/ethnicity categories are somewhat different for this university's enrollment data as compared with the NSF data in Table 2, but general trends were similar. As can be seen in Table 3, white and Asian students are overrepresented in University Science and Engineering Bachelor's Degrees, while Black/African American, Hispanic/Latino, Native Hawaiian or Other Pacific Islander, and students identifying with Two or more races are underrepresented. Additionally, while students in the "American Indian/Alaska Native" category do not seem to be underrepresented in University Science and Engineering Bachelor's Degrees, since the number in this group is very small and is historically an underrepresented minority group in the U.S., the decision was made to include these students as well. Because of the categories defined by university enrollment data and because of the trends of underrepresentation both in this university as well as in the U.S. more broadly, URM is defined as "Black/African American, Hispanic/Latino, Native Hawaiian or Other Pacific Islander, American Indian/Alaska Native, and Two or more races." Thus, OpSTEM was established with the goal to increase retention in STEM, especially of URM and first-generation college students, by providing support through the precalculus and calculus sequence, which is the first hurdle for STEM students.

Race/Ethnicity	University Undergraduate Enrollment	University S&E Bachelor's Degrees
White	61.5%	69.7%
Asian	2.6%	4.8%
Black/African American	20.1%	12.7%
Hispanic/Latino	4.1%	2.5%
American Indian/Alaska Native	0.3%	0.4%
Native Hawaiian or Other Pacific Islander	0.1%	0.0%
Two or more races	2.6%	1.5%
Non Resident Alien	4.5%	3.3%
Unknown	4.5%	5.2%

Table 3: Breakdown of university Enrollment and Science and Engineering Bachelor's Degrees by Race[iv]

Students selected to be OpSTEM Scholars attend an eight-day Summer Institute, two weeks prior to the start of the fall semester. During the Summer Institute, students are introduced to a cohort of their peers, and the social connections they make there often last throughout their time at this university. Students are also provided with a review of prerequisite mathematics and introduced to ALEKS (2016), the software program utilized in the Precalculus sequence. This allows students to feel prepared and confident for the first day of the semester. Additionally, the students are given the opportunity to listen to STEM guest speakers talk about their journey to receiving a STEM degree and their work in their field of study. OpSTEM Scholars also take part in activities that orient them to the university's campus, which is aimed to help students feel welcome on campus. Last, since most of the students are first-generation college students, they participate in academic success workshops to learn necessary study and time management skills as well as general tips to be successful in college.

Throughout the academic year, mandatory supplemental instruction is provided for both OpSTEM Scholars and all students enrolled in Precalculus I and Precalculus II. These sessions have varied in length somewhat over the course of OpSTEM. For the last two years and currently, they are 150 minutes per week, which is equal to the class time spent in the precalculus courses. The sessions are led by STEM Peer Teachers (SPTs), who are university students that have already completed Precalculus and Calculus courses. Most of the SPTs are STEM majors and many are aspiring high school teachers. During the sessions, students apply content learned in their mathematics courses through group work activities and PBL. In addition to leading the sessions, the SPTs also hold office hours and provide mentoring to all students enrolled in Precalculus I and Precalculus II. The students receiving SPT sessions alone are receiving a very significant benefit, as evidenced by their increased pass rates.

Beginning the Fall 2014 semester, each semester OpSTEM Scholars were required to attend two STEM speaker presentations, two college success workshops, one social event, one cohort meeting, and one or two meetings with their OpSTEM mentor depending on course grades (two if any course grade was below a C). During the prior two semesters, these supports were provided; however, they were not mandatory. The mandatory cohort meetings and social outings were designed to build stronger bonds within the groups of students while the academic advising, college success workshops, and STEM speakers were aimed to support and motivate the students to complete their STEM degree.

During the years studied in this analysis, the Precalculus I and Precalculus II courses saw other changes in addition to OpSTEM. Although these changes are not expected to drastically effect the statistical analysis, they are still noteworthy. First, the university underwent a 4 to 3 credit hour conversion within the timeframe being studied. Prior to the Fall 2014 semester, Precalculus I and Precalculus II were offered as 4 credit hour courses. How-

† Although pass rates and grades are related, they are being treated as different research questions in this study for two reasons. First, pass rates were the main focus of the STEP grant and the LSAMP grant that funded OpSTEM, as well as many similar grants at other universities. Second, early on, it was observed that pass rates alone give an incomplete picture; however, grades give more information.

ever, Precalculus I during the Fall 2014 and Precalculus II during the Spring 2015 semesters were offered as 3 credit hour courses. In addition, the mandatory SPT sessions resulted in an attendance and participation grade that was not present before the program was implemented. The attendance and participation component to the final grade changed throughout the program. For Precalculus I in the Fall 2013 semester, class attendance was counted as 4% of the Precalculus I grade while SPT session attendance and SPT session participation accounted for 4% each. For Fall 2014, each of the components was reduced to 2%. For Precalculus II, the Spring 2014 semester had a 0% class attendance grade, 5% SPT session attendance and participation grade combined. That semester, class attendance was 2% extra credit. Last, in the Spring 2015 semester, 2% was designated to class attendance, 2% was awarded for SPT session attendance, and 1% was awarded for SPT session participation.

Data Acquisition

Four years of demographic and course grade data were collected prior to the implementation of OpSTEM (from academic year 2009-2010 to 2012-2013), and four years of data were collected after the implementation of OpSTEM (from academic year 2013-2014 to 2016-2017). Students' Precalculus I and II grades, race, and status as an OpSTEM Scholar were analyzed.

Data used in this research were acquired from the university's Office of Institutional Research. Data were obtained for students enrolled in Precalculus I during the Fall semesters from 2009 to 2016 as well as students enrolled in Precalculus II during the Spring semesters from 2010 to 2017. Students' Precalculus I and II grades and race were analyzed. To these data was added students' status as an OpSTEM Scholar. These data came from the Director of OpSTEM.

Data were analyzed for the fall semesters for Precalculus I and the spring semesters for Precalculus II to reduce any confounding variables. Typically, students who complete the Precalculus sequence enroll in Precalculus I in the fall and Precalculus II in the spring. These are known as the "on-sequence" courses. Students complete courses "off-sequence" often do so because they have transferred from another school, failed a mathematics course within the sequence, or were placed in another course due to math placement scores, and pass rates are highly variable. Additionally, in the 2013–2014 and 2014–2015 academic years, SPT sessions only took place during the "on-sequence" semesters.

Letter Grade	Grade Points
A	4.0
A-	3.7
B+	3.3
B	3.0
B-	2.7
C+	2.3
C	2.0
D	1.0
F,W,X	0.0

Table 4. University's Grade Point System

Precalculus I				
Race/Ethnicity	Pre-OpSTEM N	Percentage	Post-OpSTEM N	Percentage
White	213	59.00%	349	57.03%
Asian	11	3.05%	30	4.90%
Black/African American	79	21.88%	123	20.10%
Hispanic/Latino	25	6.93%	34	5.56%
American Indian/Alaska Native	2	0.55%	1	0.16%
Native Hawaiian or Other Pacific Islander	0	0%	0	0%
Two or More Races	5	1.39%	27	4.41%
Non-Resident/Alien	26	7.20%	48	7.84%
Precalculus II				
Race/Ethnicity	Pre-OpSTEM N	Percentage	Post-OpSTEM N	Percentage
White	257	64.90%	308	60.75%
Asian	18	4.55%	33	6.51%
Black/African American	69	17.42%	85	16.77%
Hispanic/Latino	25	6.31%	21	4.14%
American Indian/Alaska Native	0	0%	1	0.20%
Native Hawaiian or Other Pacific Island	0	0%	1	0.20%
Two or More Races	11	2.78%	16	3.16%
Non-Resident/Alien	16	4.04%	42	8.28%

Table 5. Racial/Ethnic Background of Precalculus I & Precalculus II Students

The course grades were then assigned a conversion value consistent with the typical grade point value system, as outlined in Table 4. A grade of X is a designation no longer used, but in the past, it was used to designate a student who stopped attending and failed as a result. A few students had grades of NC, which indicated "no credit," meaning that they were auditing the course, and these students were not counted as either passing or failing.

Students who reported their race were studied to determine the effectiveness of OpSTEM among URM vs. non-URM students. The racial/ethnic background of the students studied can be found in Table 5. The students were divided into three categories, which were as follows: 1) White and Asian (non-URM), 2) Underrepresented Minority (URM), and 3) Non-Resident/Alien.

As noted above, Pre-OpSTEM refers to the control group, those students who took the course before the OpSTEM program. Post-OpSTEM refers to the treatment group, those students who took the course during the time that OpSTEM was being implemented.

This categorization of students is also justified by an analysis of Precalculus I grade points outlined in Chart 1. From the chart, it can be seen that all the students we identify as URM are scoring below the overall grade average of 2.17, while non-URM students (white and Asian) are scoring above the overall average.

For the purposes of this study, we are not considering Non-Resident/Alien/international students. Appendix 1 does an analysis of the results on this group alone and

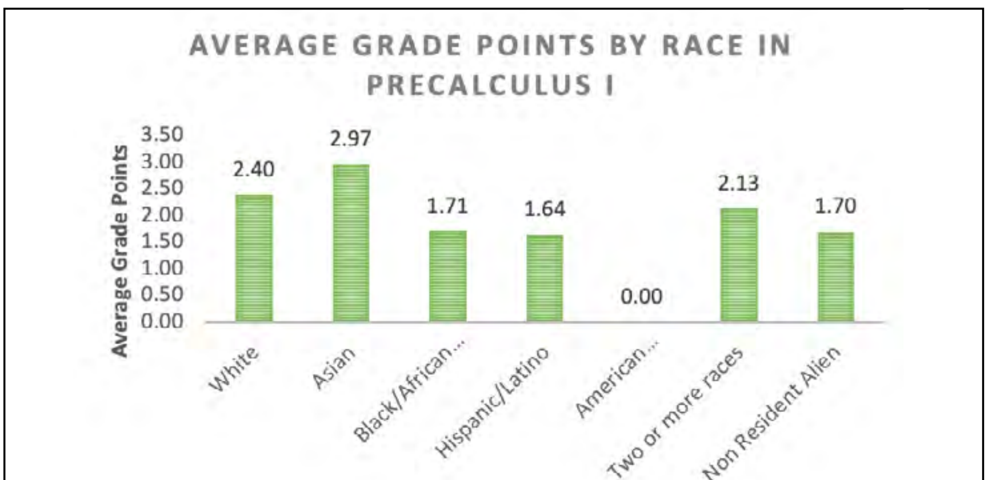

Chart 1. Precalculus I Scores from 2010-2017 by Race/Ethnicity. Note: Overall average: 2.17

Mean ACT	Fall Precalculus I			Spring Precalculus II		
Pre-OpSTEM	$\mu = 21.90$	$\sigma = 3.999$	N = 339	$\mu = 22.20$	$\sigma = 3.335$	N = 238
Post-OpSTEM	$\mu = 22.36$	$\sigma = 3.331$	N = 475	$\mu = 22.37$	$\sigma = 3.345$	N = 354

Table 6. Total Mean ACT scores for Fall Precalculus I and Spring Precalculus II students

gives more information about these students, the confounding factors they present, and the social and political factors that contributed to the make-up of the group. The university as a whole has a small group of international students, whose size and presence in the precalculus sequence changed substantially over the course of the study. Additionally, the purpose of the STEP grant, as set forth by NSF, is to increase the number of STEM degrees obtained among U.S. citizens, so they were ineligible for the OpSTEM Scholars program. Like all students in the precalculus program at the university, their precalculus courses had mandatory SPT sessions; however, international students could not become OpSTEM Scholars. See Appendix 1 for further results and discussion of Non-Resident/Alien/international students.

As a further piece of background information, and to establish context as to the student population, below are two tables that show the average ACT scores of the pre-OpSTEM control group and post-OpSTEM experimental groups. ACT data was available for 71% of Precalculus I students 79% of Precalculus II students because it is not required for transfer students. Although it is not complete, it provides helpful background information on the student population.

Since ACT scores are an indication of college readiness (Noble & Sawyer 2002; Robbins, et al., 2004), students in the pre- and post-OpSTEM groups have similar levels of college readiness as indicated by the ACT (see Table 7).

URM students have lower average ACT scores than their non-URM counterparts (see Table 7). Two-tailed z-tests indicate that the differences in mean ACT scores between URM and non-URM students in each of the four groups shown in the table above are statistically significant ($p < 0.0001$ for both Precalculus I groups and the post-OpSTEM Precalculus II group, and $p = 0.0026$ for pre-OpSTEM Precalculus II). The difference between the pre-OpSTEM group and the post-OpSTEM group was not found to be statistically significant when comparing URM to URM and non-URM to non-URM groups.

Table 8 indicates that OpSTEM Scholars are similar to their peers in the pre-OpSTEM control group (non-URM: $p = 0.1938$, URM: $p = 0.8838$).

Statistical Analysis

All analysis was conducted using Minitab. The first research question is as follows:

1. How did precalculus pass rates differ for URM and non-URM students:
   a. in the control group?
   b. among students attending SPT sessions only?
   c. among OpSTEM Scholars?

Across all the years analyzed in this study (2009-2017), the definition of passing for precalculus was consistent and entailed earning a grade of C or above. During all stages of analysis, the two treatment groups (OpSTEM Scholars and SPT sessions only) were considered separately and compared with the control group (students in precalculus courses in the four years prior to OpSTEM). The pass rates for Precalculus I and II for URM and non-URM groups were compared with their pre-OpSTEM URM and non-URM counterparts. These comparisons were analyzed using a binary logistic regression with factor A being OpSTEM status (three levels of treatment—control, SPT sessions only, and OpSTEM Scholars) and factor B being URM status (non-URM vs. URM). Additionally, certain population proportions were compared using a chi square test for significance.

When interpreting the results of the binary logistic regression, the factor A effect tells whether there is a significant difference between the control, SPT session only, and OpSTEM Scholar groups, the factor B effect tells whether there is a significant difference between the non-URM and URM groups, and the interaction effect tells whether the effect of the OpSTEM treatment is significantly different on the URM group versus the non-URM group.

The second research question is as follows:

2. How did mean grades in precalculus differ for URM and non-URM students:
   a. in the control group?
   b. among students attending SPT sessions only?
   c. among OpSTEM Scholars?

To test the difference in the mean grade points, two-factor ANOVA tests were used, with factor A being OpSTEM status (three levels of treatment—pre-OpSTEM Control, SPT sessions only, and OpSTEM scholars) and factor B being URM status (non-URM vs. URM).

When interpreting the results of these ANOVA tests, the factor A effect tells whether there is a significant difference between the control, SPT session only, and OpSTEM Scholar groups, the factor B effect tells whether there is a significant difference between the non-URM and URM groups, and the interaction effect tells whether the effect of OpSTEM is significantly different on the URM group versus the non-URM group.

The third research question is as follows:

3. How did grades in Precalculus I predict pass rates in Precalculus II, and does this differ among:
   a. URM and non-URM students?
   b. OpSTEM Scholars and others?

This question will be analyzed by considering those students who took both Precalculus I and II, and determining the pass rates in Precalculus II by grouping students by the grades they received in Precalculus I. We will do this for URM and non-URM students as well as OpSTEM Scholars, those in SPT sessions only, and the control group to determine any differences. The Spearman Rho correlation will be used to determine the correlation between the grade a student earns in Precalculus I and the grade that student earns in Precalculus II. The Spearman Rho correlation is used to evaluate relationships involving discrete ordinal variables, such as grade points.

For all tests in this study, $\alpha < 0.05$ will be considered statistically significant.

Mean ACT		Fall Precalculus I				Spring Precalculus II		
Pre-OpSTEM	Non-URM	$\mu = 22.71$	$\sigma = 3.892$	N =212	Non-URM	$\mu = 22.75$	$\sigma = 3.125$	N =162
	URM	$\mu = 20.74$	$\sigma = 3.979$	N =101	URM	$\mu = 21.15$	$\sigma = 3.654$	N = 60
Post-OpSTEM	Non-URM	$\mu = 23.07$	$\sigma = 3.155$	N =312	Non-URM	$\mu = 22.83$	$\sigma = 3.205$	N =254
	URM	$\mu = 20.93$	$\sigma = 3.309$	N =141	URM	$\mu = 21.16$	$\sigma = 3.368$	N =87

Note: Since Non-Resident/Alien students are not included in either non-URM or URM groups, and since some students did not report their race, the numbers in Table 7 do not total to the same numbers in Table 6.

Table 7. Mean ACT scores for Fall Precalculus I and Spring Precalculus II students, by URM/non-URM group

Mean ACT	Precalculus OpSTEM Scholars		
Non-URM	$\mu = 23.40$	$\sigma = 3.403$	N = 55
URM	$\mu = 20.634$	$\sigma = 3.411$	N = 41

Table 8. Mean ACT scores for Precalculus OpSTEM Scholars: non-URM and URM

Results

The first research question is as follows:

1. How did precalculus pass rates differ for URM and non-URM students:
   a. in the control group?
   b. among students attending SPT sessions only?
   c. among OpSTEM Scholars?

Non-URM	N	Pass Rate	Relative Increase
Pre-OpSTEM/Control	307	64.50%	
SPT sessions only	320	80.00%	24.03%
OpSTEM Scholars	59	81.36%	26.14%
URM	**N**	**Pass Rate**	**Relative Increase**
Pre-OpSTEM/Control	141	41.84%	
SPT sessions only	134	58.21%	39.13%
OpSTEM Scholars	51	80.39%	92.14%

Table 9. Precalculus I Pass Rates by URM Status

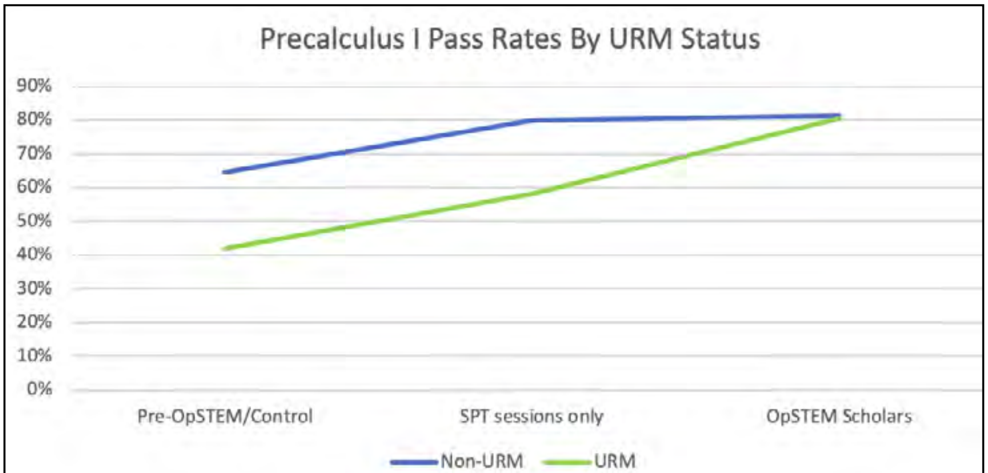

Chart 2. Precalculus I Pass Rates by URM Status

	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	5	80.03	16.007	80.03	<0.0001
OpSTEM status	2	21.36	10.679	21.36	<0.0001
URM status	1	20.19	20.185	20.19	<0.0001
Interaction	2	3.44	1.721	3.44	0.179

Table 10. Results of Binary Logistic Regression for Precalculus I Pass Rates

	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	3	76.59	25.530	76.59	<0.0001
OpSTEM status	2	42.77	21.384	42.77	<0.0001
URM status	1	38.76	38.759	38.76	<0.0001

Table 11. Results of Binary Logistic Regression for Precalculus I Pass Rates with Interaction Removed

	Chi-square	DF	P-Value
Pearson	7.92	1	0.0049
Likelihood Ratio	8.45	1	0.0037

Table 12. Chi-square test for URM SPT only vs. URM OpSTEM Scholars

	Chi-square	DF	P-Value
Pearson	0.06	1	0.8102
Likelihood Ratio	0.06	1	0.8090

Table 13. Chi-square test for non-URM SPT only vs. non- URM OpSTEM Scholars

	Chi-square	DF	P-Value
Pearson	0.02	1	0.8979
Likelihood Ratio	0.02	1	0.8980

Table 14. Chi-square test for non-URM OpSTEM scholars vs. URM OpSTEM Scholars

Table 9 shows the Precalculus I pass rates, differentiated by URM status as well as OpSTEM status. Chart 2 gives the same information as Table 9 in a graphical form. Both Table 9 and Chart 2 show that for Non-URM students, the vast majority of the benefit to pass rates was gained through SPT sessions, with little additional benefit for students who received the additional services that came with being OpSTEM Scholars. For URM students, on the other hand, while a large benefit was gained from SPT sessions alone, a large additional benefit was also gained for OpSTEM Scholars, and URM OpSTEM Scholars passed at nearly the same rate as their non-URM counterparts.

Table 10 shows the results of a binary logistic regression that analyzed the Precalculus I pass rate data that is summarized in Table 9, and Table 11 shows the results of a binary logistic regression on the same data, with the interaction term removed.

Table 12 gives the results of a Chi-square test on the significance of the pass rate of URM students who received SPT sessions only versus those URM students who received the OpSTEM Scholars treatment, and we find that this difference is statistically significant.

Table 13 gives the results of a Chi-square test on the significance of the pass rate of non-URM students who received SPT sessions only versus those non-URM students who received the OpSTEM Scholars treatment, and we find that this difference is not statistically significant.

Table 14 gives the results of a Chi-square test on the significance of the pass rate of non-URM students who received the OpSTEM scholars treatment versus those URM students who received the OpSTEM Scholars treatment, and we find that this difference is not statistically significant.

The binary logistic regression had significant main effects with $p < 0.0001$ for both main effects (Tables 10 and 11). This means that URM students passed Precalculus I differently from non-URM students, and that OpSTEM was associated with significantly different pass rates. The interaction effect was not significant, which says that the effect of OpSTEM was not significantly different on URM students as compared with non-URM students.

Chi-square tests show other interesting results. Chi square tests show that the level of OpSTEM treatment (SPT sessions only vs. OpSTEM Scholars) is significantly associated with higher pass rates for URM student (Table 12), although it is not associated with higher pass rates for non-URM students (Table 13). Additionally, URM status is not associated with a difference in pass rates among students in the OpSTEM Scholar group (Table 14).

Remarkably, before OpSTEM, URM students were passing at a rate of 41.84%, and with SPT sessions alone, URM students have increased their pass rate with a relative increase that outpaces their non-URM counterparts. Furthermore, those URM students who were OpSTEM Scholars have almost doubled their pass rate and have nearly made up the entire disparity with their non-URM counterparts

Turning to Precalculus II, we also see gains, but things look somewhat different. Table 15 shows the Precalculus II pass rates, differentiated by URM status as well as OpSTEM status. Chart 3 gives the same information as Table 15 in a graphical form.

Table 16 shows the results of a binary logistic regression that analyzed the Precalculus II pass rate data that is summarized in Table 15, and Table 17 shows the results of a binary logistic regression on the same data, with the interaction term removed.

In Precalculus II, it is important to note that binary logistic regression shows that URM status does not continue to be significantly associated with a difference in pass rates. It is important to note that there is little difference between the non-URM and URM groups before OpSTEM (control group), with non-URM students passing at a rate of 60.36% and URM students passing at a rate of 57.14%. This is a remarkable difference from Precalculus I.

Furthermore, in Precalculus II, rather than gaining more than their non-URM counterparts, URM students are gaining somewhat less. Each group (SPT sessions only and OpSTEM Scholars) is still making significant gains as compared with the pre-OpSTEM group; however, in order better to understand these results, it is important to turn to our second research question.

2. How did mean grades in precalculus differ for URM and non-URM students:
    a. in the control group?
    b. among students attending SPT sessions only?
    c. among OpSTEM Scholars?

Table 18 shows the Precalculus I mean grades, differentiated by URM status as well as OpSTEM status. Table 19 gives the results of an ANOVA on the Precalculus I grades that were summarized in Table 18. Chart 4 gives the same information as Table 18 in a graphical form.

Since the main effects of the ANOVA (Table 19) are significant, this tells us that OpSTEM treatment was associated with significantly higher pass rates and that URM status was associated with significantly lower pass rates. The interaction effect tells whether OpSTEM affects URM and non-URM students differently. This effect was not significant, which indicates that the level of OpSTEM treatment does not interact with the URM status to produce a different effect.

Chart 4 on the next page shows the linear model analyzed in the ANOVA. The two lines indicate the grades associated with the different levels of OpSTEM treatment. The gains students experience from SPT sessions only are proportional—URM and non-URM students gain at the same rate; however, when the additional support given to OpSTEM scholars is considered, non-URM students gain only incrementally more while URM students gain at an even greater rate. While the ANOVA fails to show a significant interaction effect between these two variables, there is an interesting pattern to consider. Since the samples are imbalanced and the sample size of the OpSTEM scholars group is smaller than the other groups (because of the nature of the program), the power of the ANOVA is decreased, since the power depends on the size of the smallest

Non-URM	N	Pass Rate	Relative Increase
Pre-OpSTEM/Control	275	60.36%	
SPT sessions only	289	77.85%	28.98%
OpSTEM Scholars	52	88.46%	46.55%
URM	**N**	**Pass Rate**	**Relative Increase**
Pre-OpSTEM/Control	105	57.14%	
SPT sessions only	83	68.67%	20.18%
OpSTEM Scholars	41	78.05%	36.59%

Table 15. Precalculus II Pass Rates by Race/Ethnicity

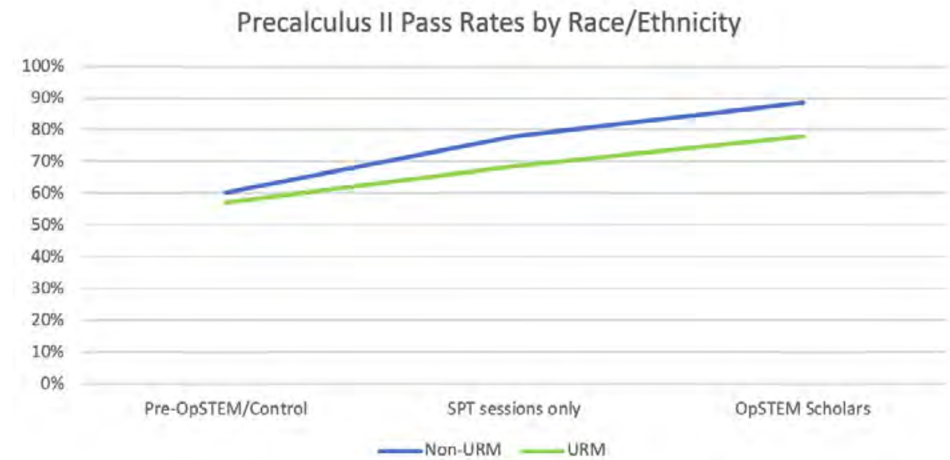

Chart 3. Precalculus II Pass Rates by URM Status

	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	5	39.67	7.9339	39.67	<0.000
OpSTEM status	2	30.36	15.1793	30.36	<0.000
URM status	1	0.33	0.3259	0.33	0.568
Interaction	2	1.72	0.8598	1.72	0.423

Table 16. Results of Binary Logistic Regression for Precalculus II Pass Rates

	DF	Adj Dev	Adj Mean	Chi-Square	P-Value
Regression	3	37.95	12.650	37.95	<0.000
OpSTEM status	2	35.02	17.508	35.02	<0.000
URM status	1	3.69	3.691	3.69	0.055

Table 17. Results of Binary Logistic Regression for Precalculus II Pass Rates with Interaction Removed

Non-URM	N	Mean Grade	Relative Increase
Pre-OpSTEM/Control	307	2.113	
SPT sessions only	320	2.693	27.45%
OpSTEM Scholars	59	2.749	30.10%
URM	**N**	**Mean Grade**	**Relative Increase**
Pre-OpSTEM/Control	141	1.442	
SPT sessions only	134	1.838	27.46%
OpSTEM Scholars	51	2.361	60.61%

Table 18. Precalculus I Mean Grades by URM status

	DF	Adj SS	Adj MS	F-Value	P-Value
OpSTEM status	2	73.01	36.503	16.28	0.000
URM status	1	63.72	63.717	28.43	0.000
Interaction	2	4.94	2.470	1.10	0.333

Table 19. Results of ANOVA for Precalculus I Mean Grades

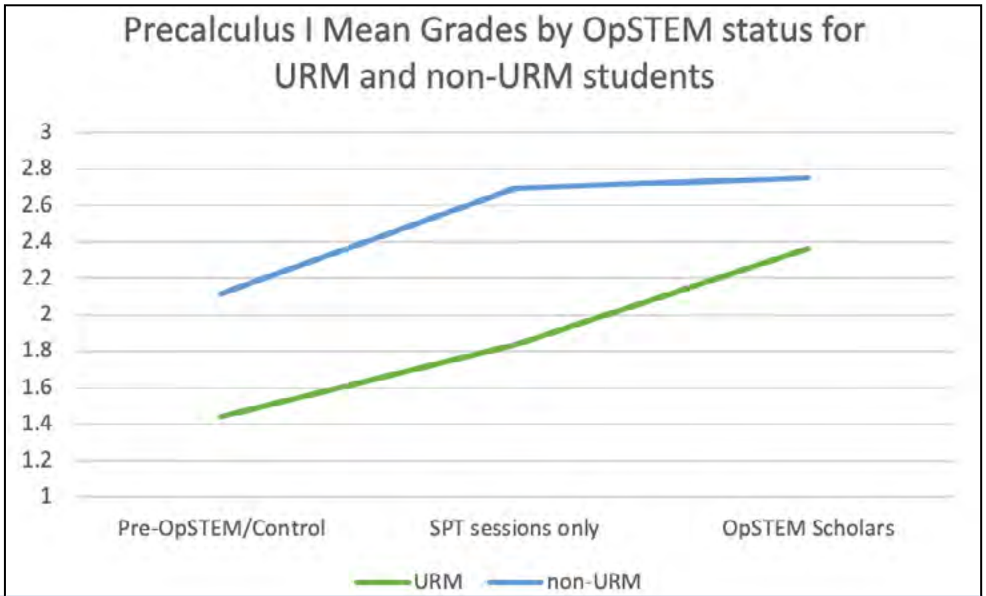

Chart 4. Precalculus I mean grades by OpSTEM status for URM and non-URM students.

Non-URM	N	Mean Grade	Relative Increase
Pre-OpSTEM/Control	275	2.057	
SPT sessions only	289	2.562	24.55%
OpSTEM Scholars	52	2.962	44.00%
URM	**N**	**Mean Grade**	**Relative Increase**
Pre-OpSTEM/Control	105	1.901	
SPT sessions only	83	2.099	10.42%
OpSTEM Scholars	41	2.546	33.93%

Table 20. Precalculus II Mean Grades by URM Status

	DF	Adj SS	Adj MS	F-Value	P-Value
OpSTEM status	2	45.87	22.935	10.25	0.000
URM status	1	15.87	15.866	7.09	0.008
Interaction	2	4.31	2.156	0.96	0.382

Table 21. Results of ANOVA for Precalculus II Mean Grades

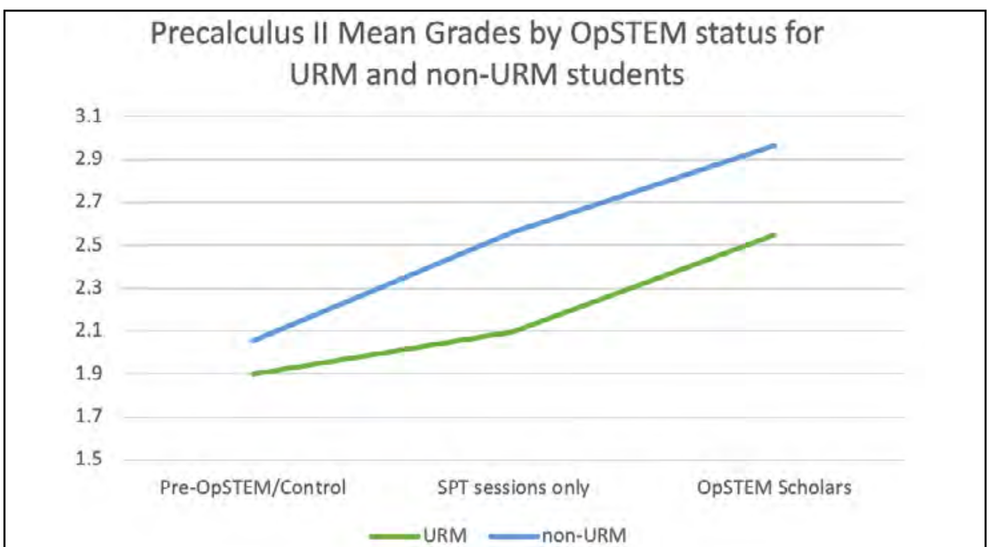

Chart 5. Precalculus II mean grades by OpSTEM status for URM and non-URM students.

group. The small number of students in the OpSTEM scholars group relative to the other groups may make it difficult to detect a difference.

When comparing the results of the mean grades with those of the pass rates, we can see that the pass rates tell only part of the story. When looking at Precalculus I pass rates only, it appears as though URM OpSTEM Scholars have entirely made up the deficit that they would have otherwise had; however, their mean grades show that while they passed Precalculus I at the same rate as their non-URM counterparts, their grades were not as high. This helps us understand why their Precalculus II pass rates experience a decline as compared with their non-URM counterparts. We will explore this relationship more when we discuss research question 3.

Table 20 shows the Precalculus II mean grades, differentiated by URM status as well as OpSTEM status. Table 21 gives the results of an ANOVA on the Precalculus II grades that were summarized in Table 20. Chart 5 gives the same information as Table 18 in a graphical form.

In Precalculus II, OpSTEM treatment was associated with significantly different grades, as was URM status, but the interaction between these effects was not significant.

Chart 5 on the bottom left shows the linear model analyzed in the ANOVA. We can see that the lines appear to be close to parallel—notably, however, URM students are falling farther behind non-URM students in both OpSTEM groups (SPT sessions only and OpSTEM scholars). In the control group, URM students had a smaller gap as compared with the non-URM group. OpSTEM (both SPT sessions only and OpSTEM Scholars) is associated with increased grades for all groups, but the gap is slightly increased in the Precalculus II group.

It is puzzling to see the remarkable gains URM students made in Precalculus I and then to see those trends reverse in Precalculus II. To help understand the reason for this trend, let us now turn our attention to question 3.

3. How did grades in Precalculus I predict pass rates in Precalculus II, and does this differ among:
   a. URM and non-URM students?
   b. OpSTEM Scholars and others?

In general, the trend we see is that grades in Precalculus I are highly predictive of students' grades in Precalculus II. Table 22 shows the correlation between Precalculus I and Precalculus II grades before OpSTEM (2010-2013), and Table 23 shows the correlation between Precalculus I and Precalculus II grades during OpSTEM's implementation (2014-2017),

The overall trend—the way in which Precalculus I grades predict pass rates in Precalculus II persists when we separate students by URM status and when we separate OpSTEM Scholars from students receiving SPT ses-

Spearman Rho	0.573
P-value	<0.0001

Table 22. Correlation between Precalculus I and Precalculus II grade, 2010-2013 (pre-OpSTEM)

Spearman Rho	0.781
P-value	<0.0001

Table 23. Correlation between Precalculus I and Precalculus II grade, 2014-2017 (post-OpSTEM)

sions only, as shown in Table 25.

However, there is a notable difference in the way that URM students' grades are distributed after OpSTEM. Chart 6 shows the distribution of passing grades for non-URM students in Precalculus I before and during Op-STEM's implementation. Both groups experienced a similar distribution of grades.

Non-URM students' passing grade distribution remained relatively consistent after OpSTEM; it improved somewhat, with more students earning A, A-, and B+ grades, and fewer students earning B, B-, C+, and C grades. This was not the case for URM students.

Chart 7 shows the distribution of passing grades for URM students in Precalculus I before and during Op-STEM's implementation. During the implementation of OpSTEM, while URM students experienced soaring pass rates in Precalculus I, the distribution of their passing grades changed for the worse.

URM students experienced a substantial change in the distribution of their grades post-OpSTEM, and this change helps to explain the disparity between the gains URM students make in Precalculus I and the lack thereof in Precalculus II.

It is essential to understand here that because of the *huge* increase in pass rates of URM students, the number of URM students passing Precalculus II has increased significantly from before OpSTEM. We are doing this investigation merely to try to understand why the amazing increase in pass rates in Precalculus I for URM students was not also matched in Precalculus II. In pure numbers of students, there are many more URM students passing the Precalculus I– Precalculus II sequence than before OpSTEM, largely because of how many additional URM students get a chance to make it from Precalculus I to Precalculus II.

Grades in Precalculus I predict pass rates in Precalculus II. This relationship can be seen in chart 8 below.

While pass rates were lower overall in 2010-2013, the overall trend is similar. We see fairly high pass rates for students in the A and B range in Precalculus I, with a significant drop-off once a student receives a grade in the C range in Precalculus I. (Note that there are no "C-" grades given at the university.)

Table 25 shows the Precalculus II pass rates based on

	Spearman Rho	P-value
non-URM students only, 2010-2013	0.565	<0.0001
URM students only, 2010-2013	0.609	<0.0001
non-URM students only 2014-2017	0.809	<0.0001
URM students only 2014-2017	0.743	<0.0001
OpSTEM scholars only 2014-2017	0.759	<0.0001
SPT sessions only, 2014-2017	0.788	<0.0001

Table 24. Correlation between Precalculus I and Precalculus II grades for various sub-groups

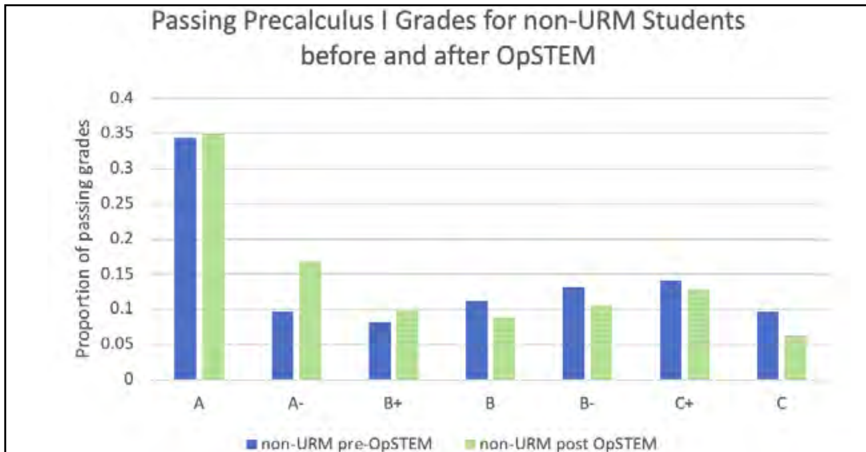

Chart 6. Passing Precalculus I grade for non-URM students before and after OpSTEM, given as a proportion of allthe passing grades. Note: post-OpSTEM includes both SPT sessions only and OpSTEM scholars' groups. The two groups experienced similar results.

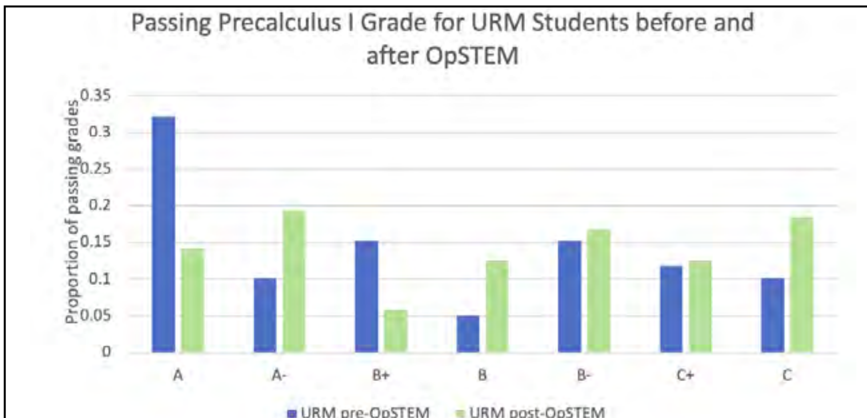

Chart 7. Passing Precalculus I grade for URM students before and after OpSTEM, given as a proportion of all the passing grades. Note: post-OpSTEM includes both SPT sessions only and OpSTEM scholars' groups. The two groups experienced similar results.

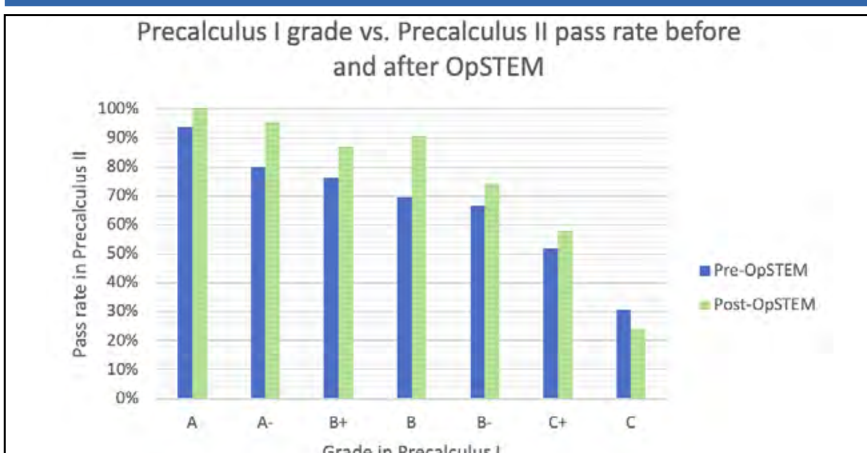

Chart 8. Precalculus I grade vs. Precalculus II pass rate for Spring 2010-2013 (Pre-OpSTEM) and Spring 2014-2017 (Post-OpSTEM) semesters of Precalculus II.

Precalculus I Grade	Precalculus II Pass Rate			
	Non-URM	**URM**	**SPT only**	**OpSTEM Scholars**
A/A-	99.21%	96.88%	98.40%	97.73%
B+/B/B-	79.10%	88.23%	81.33%	86.67%
C+/C	45.95%	45.45%	43.75%	46.67%

Table 25. Precalculus I grade vs. Precalculus II pass rate for Spring 2014-2017 semesters of Precalculus II showing different sub-groups.

	Chi-square	DF	P-Value
Pearson	1.28	1	0.2572
Likelihood Ratio	1.36	1	0.2437

Table 26. Chi-square test for URM vs. non-URM B+/B/B

	Chi-square	DF	P-Value
Pearson	0.43	1	0.5124

Table 27. Chi-square test for OpSTEM Scholars vs. SPT only B+/B/B

Precalculus I grade for different sub-groups of students. There are similar rates for all sub-groups, indicating that Precalculus I highly predictive of Precalculus II pass rate for all these sub-groups of students. Tables 26 and 27 are Chi-square tests on the groups that are most different, neither of which demonstrate statistical significance.

Chi square tests (Tables 26 and 27) indicate that none of the groups shown above experience significantly different pass rates in Precalculus II, when considering their Precalculus I grade. The data in Table 25 demonstrate that it is possible to explain the differences in the pass rates and grades in Precalculus II by using the pass rates and grades in Precalculus I. While the URM students make enormous gains in pass rate in Precalculus I, the gains in pass rate are not paralleled by their gains in average grade. Then, when they go into Precalculus II, where grades in Precalculus I is a strongly predictive factor in success, the URM students continue to be at a disadvantage because of their average grades in Precalculus I continue to lag behind. Of course, this is not to downplay the significant gains URM students made in both courses. It is especially significant when considering how many students were able to take Precalculus II as a result ofthe much higher Precalculus I pass rates.

Analysis and Implications

The purpose of this study was to examine the effect of the two levels of treatment provided by OpSTEM on Precalculus I and II grades and pass rates, and, in particular, to consider how these two levels of treatment affect URM and non-URM students. From previous research (Carver et al., 2017) we knew that in the post-OpSTEM years, pass rates in Precalculus I and II were significantly higher than they were in pre-OpSTEM years. We also knew that while students receiving SPT sessions alone received a significant benefit, OpSTEM Scholars received a significant gain over and above those students receiving SPT sessions alone.

This study considers the effect of SPT sessions and the OpSTEM Scholar treatment on URM students in particular. We found that in Precalculus I, URM students in the control group had considerably lower pass rates and mean grades than non-URM students. When considering the data holistically, using an ANOVA, we found that for Precalculus I, both main effects (URM status and OpSTEM status) were significant, but the interaction effect was not significant. This indicates that the OpSTEM program has a significant association with students' pass rates and grades in Precalculus I as does their status as a URM student. Since the interaction effect was not significant, it indicates that the increase associated with OpSTEM affected all students equally, notwithstanding race. When considering the particular result of OpSTEM Scholars' pass rates in Precalculus I, we found that URM OpSTEM Scholars almost entirely closed the gap in Precalculus I pass rates as compared with the non-URM OpSTEM Scholars (URM: 80.36%, non-URM: 81.39%), which was achieved when URM OpSTEM Scholars achieved pass rates 92.14% greater than the control group in comparison with a 39.13% gain in the non-URM OpSTEM Scholars group. This made the URM OpSTEM Scholars' pass rate indistinguishable from their non-URM peers.

These remarkable gains in Precalculus I pass rates were only partially matched by gains in average grades. The same OpSTEM Scholars who achieved almost the same pass rates did not achieve the same mean grade point (URM: 2.361, non-URM: 2.749).

We found that when we examine pass rates in Precalculus II, students' grades in Precalculus I are of utmost importance. With no significant differences among URM vs. non-URM groups, nor among OpSTEM Scholars vs. SPT sessions only, there are highly consistent data that show that students' grades in Precalculus I predict their pass rates in Precalculus II.

When looking at the effects of OpSTEM on Precalculus II pass rates and mean grades, we see that the URM group makes somewhat smaller relative increases than their non-URM counterparts. Importantly, these differences are not statistically significant. This indicates that there is not a statistically significant difference in the way that OpSTEM is affecting URM and non-URM pass rates and grades in Precalculus II. Since Precalculus I grades predict Precalculus II pass rates, and since URM students continue to lag behind non-URM students in Precalculus I mean grades, it follows that their Precalculus II pass rates will also lag behind non-URM students as well.

That being said, the gains that URM students have made in Precalculus I and II combined are remarkable. The OpSTEM Scholars program has an effect on URM students that helps them close the achievement gap between themselves and their non-URM peers. In Precalculus I, while white and Asian OpSTEM Scholars do similarly to those receiving SPT sessions alone, URM OpSTEM Scholars do so much better that they become statistically impossible to distinguish from their non-URM counterparts in pass rates. Furthermore, they nearly double their pass rates as compared with the control group, which means that twice as many students have the opportunity to move on to Precalculus II.

Turning our attention to the non-URM group, there is less of a difference between non-URM OpSTEM Scholars and those who receive SPT sessions only. In Precalculus I, the pass rate between non-URM students who are OpSTEM Scholars and those who receive SPT sessions only is virtually indistinguishable (OpSTEM Scholars: 81.36%, SPT sessions: 80.00%). OpSTEM Scholars seem to receive little additional benefit; looking at their average grades, we do see a difference, but that difference is not statistically significant (OpSTEM Scholars: 2.749, SPT sessions: 2.693, $p = 0.77$). Then, in Precalculus II, we do see a difference in pass rates between non-URM students who are OpSTEM Scholars versus those who are receiving SPT sessions only (OpSTEM Scholars: 88.46%, SPT sessions: 77.85%), but it is not statistically significant ($p = 0.081275$). It is possible that with larger numbers there would be a significant difference, and this warrants further study. Additionally, the OpSTEM Scholars recruitment process targets first-generation college students, and with a disproportionately large number of these students in our non-URM group, which also warrants additional research.

Conclusion

This study suggests that OpSTEM is associated with increased pass rates and mean grades among both URM and non-URM students in Precalculus I and II. SPT sessions are a major investment of time; however, for URM students, while they are associated with significant improvement, this improvement is not enough to narrow the achievement gap that exists between them and their white and Asian counterparts. In order to more successfully narrow that gap, a more comprehensive program, like the OpSTEM Scholars program, is associated with additional improvement. For non-URM students, the majority of the benefit is seen in SPT sessions alone.

The clear point suggested by these data is simple: in order to narrow the achievement gap between URM and non-URM students, a comprehensive program is associated with greater benefits than supplemental instruction alone. Supplemental instruction alone is not associated with the gains necessary for URM students to close the achievement gap they experience with their non-URM peers. While supplemental instruction by peer teachers was shown to be tremendously beneficial, as would be suggested by the literature from (Dawson, et. al. 2014; Wilson, Z., et. al. 2012), these data suggest that a more comprehensive program is associated with the types of gains necessary for URM students to narrow the achievement gap.

OpSTEM Scholars receive an 8-day summer-institute, mentoring, cohort activities including college success workshops and STEM speakers, SPT sessions, stipends, and free summer calculus. This level of involvement is necessary to narrow the achievement gap between URM students and their white and Asian peers. Ballen, et. al. 2017 showed that "for URM students, the increased science self-efficacy students experienced during the active-learning semester mediated the improved course performance," and they said that students self-reported an overall increase in social belonging as well. Since many of the interventions for the OpSTEM Scholars (the Summer Institute, social activities, college success workshops, STEM speakers, and other cohort activities) could lead not only to an increase in social belonging but also self-efficacy, this could help to explain the narrowing of the achievement gap that we see. Surveys given at the end of the 2-week summer institute indicate that students are already feeling more confident about their mathematical ability in college, and placement test scores from before and after the summer institute have often shown large gains, even though students could not have learned much mathematics during that time. In a study of women in computing, it was shown that teamwork, community, active learning, and collaboration helped young women work to close the gender gap and stay in highly competitive computing programs top universities (Margolis & Fisher 2002). These same elements of teamwork, community, active learning, and collaboration are present for OpSTEM scholars and have likely contributed to their remarkable success at closing the achievement gap and may have worked to mitigate the competitive nature of most STEM classrooms, which typically proves to be a stumbling block for many URM students (Springer & Stanne 1999).

As we continue to collect data, further research will study these groups as they continue through Calculus I and II, and as they continue through their STEM majors. The ultimate goal of OpSTEM is to help students graduate with STEM degrees. Retention in Precalculus I and II is an essential first component of that goal; however, future research studying completion of STEM degrees is forthcoming.

References

ALEKS (2016). Assessment and LEarning in Knowledge Spaces. McGraw Hill Global Education Holdings. https://www.aleks.com.

Award Abstract #1161152: Mathematics Achievement as a STEP for STEM Success. (n.d.). Retrieved December 6, 2015, from http://www.nsf.gov/awardsearch/showAward?AWD_ID=1161152.

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017). Enhancing Diversity in Undergraduate Science: Self-Efficacy Drives Performance Gains with Active Learning. *CBE life sciences education, 16*(4), ar56. doi:10.1187/cbe.16-12-0344

Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why now? An introduction to STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach. In R. M. Capraro, M. M. Capraro, & J. R. Morgan (Eds.) *STEM project-based learning* (pp. 1-5). Boston, MA: Sense Publishers.

Carver, S., Van Sickle, J., Holcomb, J.P., Quinn, C.M., Jackson, D.M., Resnick, A., Duffy, S.F., Sridhar, N., Marquard, A. (2017). Operation STEM: increasing success and improving retention among first-generation and underrepresented minority students in STEM. *Journal of STEM Education, 18*(3), pp. 20-29.

Dawson, P., van der Meer, J., Skalicky, J., & Cowley, K. (2014). On the Effectiveness of Supplemental Instruction: A Systematic Review of Supplemental Instruction and Peer-Assisted Study Sessions Literature Between 2001 and 2010. Review of Educational Research 84(4), pp. 609-639. doi: 10.3102/0034654314540007

English, M. m., & Kitsantas, A. a. (2013). Supporting Student Self-Regulated Learning in Problem- and Project-Based Learning. *Interdisciplinary Journal Of Problem-Based Learning, 7*(2), 127-150. doi: 10.7771/1541-5015.1339

Gafney, L., & Varma-Nelson, P. (2007). Evaluating Peer-Led Team Learning: A Study of Long-Term Effects on Former Workshop Peer Leaders. *J. Chem. Educ. Journal of Chemical Education, 84*(3), 535. doi:10.1021/ed084p535

Gilmer, T. C. (2007). An Understanding of the Improved Grades, Retention and Graduation Rates of STEM Majors at the Academic Investment in Math and Science (AIMS) Program of Bowling Green State University (BGSU). *Journal of STEM Education, 8*(1), pp. 11-21. Retrieved from: http://ojs.jstem.org/index.php/JSTEM/issue/view/96, 16 February 2018.

Haak, D., HilleRisLambers, J., Pitre, E., Freeman, S. Increased Structure and Active Learning Reduce the Achievement Gap in Introductory Biology. *Science, 332*(6034), 1213-1216. doi: 10.1126/science.1204820

Figueroa, T., Cobian, K., Hurtado, S., Eagan, K. (2017). Trends and Pathways for STEM Major Aspirants: A Look at National Data. Paper presented at the 9th conference on Understanding Interventions that Broaden Participation in Science Careers Conference, San Antonio, TX, 4 March 2017.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational psychology review, 16*(3), 235-266. doi: 10.1023/B:EDPR.0000034022.16470.f3

Margolis, J., and Fisher, A. *Unlocking the Clubhouse*. MIT Press 2002.

National Science Foundation, National Center for Science and Engineering Statistics. 2013. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013. Special Report NSF 13-304. Arlington, VA. Retrieved from: http://www.nsf.gov/statistics/wmpd/, 16 February 2018.

Noble, J., & Sawyer, R. (2002). Predicting Different Levels of Academic Success in College Using High School GPA and ACT Composite Score. ACT Research Report Series. Retrieved from: https://files.eric.ed.gov/fulltext/ED469746.pdf, 16 February 2018.

Olson, S., Riordan, D. G., & Executive Office of the, P. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. Executive Office of The President. Retrieved from: https://energy.gov/sites/prod/files/Engage%20to%20Excel%20Producing%20One%20Million%20Additional%20College%20Graduates%20With%20Degrees%20in%20STEM%20Feburary%202012.pdf, 16 February, 2018.

Raines, Joan M. (2012). FirstSTEP: A Preliminary Review of the Effects of a Summer Bridge Program on Pre-College STEM Majors. *Journal of STEM Education: Innovations and Research 13*(1), pp. 22-29. Retrieved from: http://jstem.org/index.php/JSTEM/article/view/1682/1412, 16 February 2018.

Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. doi: 10.1037/0033-2909.130.2.261

Sadler, P. M. and Tai, R. H. (2007). The Two High-School Pillars Supporting College Science. Science, 317 (5837), pp. 457-458. doi: 10.1126/science.1144214

Springer, L., & Stanne, M. E., Donovan, S. S. (1999). Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering. *Review Of Educational Research*, *69*(1), pp. 21-51. doi: 10.3102/00346543069001021

Tai, R. H., Sadler, P. M., and Loehr, J. F. (2005). Factors Influencing Success in Introductory College Chemistry. *Journal of Research in Science Teaching. 42* (9), pp. 987-1012. doi: 10.1002/tea.20082

Tinto, V. (1997). Classrooms as communities: Exploring the educational character of student persistence. *The Journal of Higher Education, 68*, pp. 599-623. doi: 10.2307/2959965

Tinto, V., Goodsell, A., & Russo, P. (1993). Building community among new college students. *Liberal Education, 79* (1), pp. 6-21. Retrieved from EBSCOhost (accession number 9409260314), 16 February 2018.

Wilson, B., Shrock, S. (2001). Contributing to success in an introductory computer science: a study of twelve factors. *ACM SIGCSE Bulletin, 33* (1), pp. 184-188. doi: 10.1.1.88.4671

Wilson, Z., Holmes, L., deGravelles, K., Sylvain, M., Batiste, L., Johnson, M., McGuire, S. Pang, S, & Warner, I. (2012). Hierarchical Mentoring: A Transformative Strategy for Improving Diversity and Retention in Undergraduate STEM Disciplines. *Journal Of Science Education & Technology, 21*(1), 148-156. doi:10.1007/s10956-011-9292-5

Jenna Van Sickle is the Associate Director of the Lilly Fellows Program at Valparaiso University. She has a PhD in mathematics education from Columbia University and studies STEM education, student-centered learning, and the history of mathematics education. In addition to Operation STEM, Jenna has worked on projects such as Crash Course Statistics, and she has a mathematics YouTube channel with over 200,000 views. With the Lilly Fellows Program, she works in faculty development for STEM, social sciences, and professional faculty in the 100-member Lilly Network of Church-Related Colleges and Universities.

Kristen R. Schuler is a high school teacher at Saint Joseph Academy in Cleveland, Ohio. She teaches Physical Science, Chemistry and Physics. Kristen attended Cleveland State University where she earned her Adolescent to Young Adult teaching licenses while pursuing a B.S. in Mathematics and a B.A. in Physics. Kristen served as a STEM Peer Teacher in the Operation STEM program while attending Cleveland State University.

John P. Holcomb is Professor and currently Interim Vice Provost of Academic Programs and Interim Dean of the College of Graduate Studies at Cleveland State University. He holds a Ph.D. in Statistics from the University at Albany. He has collaborated on many research projects that include stroke rehabilitation, bank expansion, and hunger among rural Appalachians. Recently, he has been the leader of Operation STEM—a CSU and NSF-funded project to help students in Science, Technology, Engineering, and Mathematics (STEM) complete the required coursework in precalculus and calculus to achieve their degree.

Susan D. Carver, PhD, Assistant Dean in the Washkewicz College of Engineering at Cleveland State University, is the former Director of the Louis Stokes Alliances for Minority Participation Program and Operation STEM. These two NSF-funded programs serve the under-represented, under-resourced, first generation students pursuing STEM degrees. Dr. Carver earned the Doctorate in Educational Administration and a Masters in Curriculum and Instruction. She is also an adjunct faculty member in the School of Communication at Northwestern University where she teaches cultural intelligence and managing diversity to graduate students. Previously, she created and directed national award-winning community diversity programs.

Andrew Resnick is Associate Professor of Physics at Cleveland State University. He holds a Ph.D. in Physics from the University of Alabama in Huntsville. His current research program studies the physiology of a subcellular structure, the primary cilium, in terms of a fluid flow sensor. Previous research projects include the design and construction of a light microscope installed in the International Space Station in 2010. He is a member of Operation STEM.

Candice M. Quinn is a doctoral student in the Mathematics and Science Education Ph.D. program at Middle Tennessee State University. Her background includes developing the mathematics curriculum for an early preventions summer institute program for science, technology, engineering, and mathematics (STEM) majors with Operation STEM, as well as creation of project-based learning for College Algebra, Trigonometry, and Calculus I. Her research interests include collaborative learning techniques for mathematics courses, integrating mathematics and science education, and retention efforts for undergraduate students majoring in STEM.

Debbie K. Jackson is a Professor and Department Chair for Teacher Education in the College of Education and Human Services at Cleveland State University. Dr. Jackson serves as the principal investigator for several grants related to STEM education, teacher preparation, project-based instruction and computer science education. Dr. Jackson led efforts in curriculum redesign within teacher education programs and in STEM education.

Stephen F. Duffy is a Professor of the Civil & Environmental Engineering at Cleveland State University. He is a Fellow of the American Society of Civil Engineers. Dr. Duffy is the founding Director of the CSU Transportation Center. He has taught more than 20 different courses at Cleveland State University in both the Civil Engineering and Mechanical Engineering programs. He is the author, or co-author of 25 peer reviewed publications, one book and 9 book chapters. Research topics range from STEM based education, to material behavior in high temperature environments, to transportation research and workforce development.

Nigamanth Sridhar is a Professor in Electrical Engineering and Computer Science at Cleveland State University. His research interests are largely focused on computer science education, with specific attention to issues of equity in computer science courses taught in the K-12 school system. This work is supported by grants from the NSF and the Cleveland Foundation. He holds a Ph.D. in Computer Science from Ohio State University.

Appendix 1: International (Non-Resident/Alien) Students

International students have proved to be a difficult group to study and understand at this university during this time period (2009-2017). Over 90% of the international students in the precalculus sequence during this time were from the Middle East, almost all of them from Saudi Arabia. There are three main confounding factors that make it difficult to study this population of students. The first is difficulty regarding the placement test, the second is lower academic performance over time, and the third is academic dishonesty.

First, we will discuss the placement test. Students at this university are supposed to take a mathematics placement test before arriving to campus. They are allowed to take the test online, and if they wish to re-take it, they must do so in person, with a photo ID. International students would often test into higher-level mathematics courses on the first online exam (precalculus or even calculus), but it was clear when they arrived on campus that they were in the wrong course. Convincing these students to move to the correct course often proved difficult. During the academic years of 2009-2017 when this study's data were collected, these factors confounded the Precalculus I grades in particular. Precalculus II grades were not affected as much because it is rare for students to place into Precalculus II directly, so typically students only take Precalculus II after having passed Precalculus I. Among non-international students, it is highly unusual for a student to take a mathematics course at a lower level than the one that the student placed into; however, as Table 28 shows, this is the rule, rather than the exception with international students.

	Fall 2009-Fall 2012 (pre-OpSTEM)		Fall 2013-2017 (post-OpSTEM)	
Remedial Mathematics	0	0%	15	31.3%
Precalculus I	3	10.3%	6	12.5%
Precalculus II	4	13.8%	4	8.3%
Calculus I	16	55.2%	15	31.25%
No placement test score	6	20.7%	8	16.7%
Total	29	100%	48	100%

Table 28. Placement Test Result of International Students in Precalculus 1

Second, over time, the international students coming to the university tended to do worse in their overall academic performance, in spite of the university creating additional supports on an institutional level for these students. At this time, there were many social and political factors that may have contributed to this trend. On the university's side, these international students were coming with funding from their government and providing relief to strained budgets, so there was an incentive to accept and recruit greater numbers of these students. At the same time, political instability in the region may have made international study an attractive option for students, notwithstanding their academic goals.

Table 29 gives the mean overall GPA for international students in the pre-OpSTEM and post-OpSTEM years, both in Precalculus I and Precalculus II as well as the average and standard deviation of the grades in these courses as well as their pass rates.

	Fall 2009-2012 (pre-OpSTEM)			Fall 2013-2017 (post-OpSTEM)		
Precalculus I	Pass Rate=65.5%	μ=2.369	σ=1.693	Pass Rate=41.7%	μ=1.125	σ=1.321
	N=29	Mean overall GPA=2.637		N=48	Mean overall GPA=2.210	
Precalculus II	Pass Rate=75.0%	μ=2.625	σ=1.547	Pass Rate=73.8%	μ=2.336	σ=1.479
	N=16	Mean overall GPA=2.891		N=42	Mean overall GPA=2.648	

Table 29. Pass rates, mean grade and standard deviation, and mean overall GPA for Precalculus I and Precalculus II (note: μ refers to the mean grade and σ refers to the standard deviation of the mean grade in each course).

The final concern is academic dishonesty. Instances of academic dishonesty were a particular cause for concern among some of these international students, and it is a cause of potential confounding. On the one hand, grades earned in dishonest ways could be inflated; on the other hand, penalties for academic dishonesty could deflate grades.

(Endnotes)

i Department of Undergraduate Education

ii Science, Technology, Engineering and Mathematics Talent Expansion Program

iii Division of Human Resource Development

iv Undergraduate Enrollment was obtained from the 2013 Book of Trends and included total undergraduate enrollment for Fall 2012. S&E Bachelor's Degrees data were obtained from Office of Institutional Research for the 2012 – 2013 academic year. S&E degrees included engineering, biology, chemistry, environmental science, geological science, mathematics, physics, and psychology.