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CALCULUS REMEDIATION AS AN INDICATOR FOR SUCCESS ON THE CALCULUS AP EXAM

Ty Stockham

CALCULUS REMEDIATION AS AN INDICATOR FOR SUCCESS ON THE CALCULUS AP EXAM

A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

In

Teaching: Mathematics

by

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ABSTRACT

This study investigates the effects of implementing a remediation program in a high school Advanced Placement Calculus AB course on student class grades and success in passing the AP Calculus AB exam.

A voluntary remediation program was designed to help students understand the key concepts and big ideas in beginning Calculus. Over a period of eight years the program was put into practice and data on student participation and achievement was collected. Students who participated in this program were given individualized recitation activities targeting their specific misunderstandings, and then given an opportunity to retest on chapter exams that they had taken prior to remediation. Students were able to improve their scores on the original chapter exams and their grade in the class by demonstrating a greater understanding of the material after participating in the remediation sessions. This process was repeated for all chapter exams given during the academic year.

In this study, a data analysis comparing the percent gain, after remediation, in each student's overall class grade to their AP Calculus AB exam scores was conducted. Additionally, AP Calculus AB exam scores of students enrolled in these classes were compared to AP Calculus AB exam scores globally both pre and post implementation of the remediation program.

The results of this study demonstrate that there is a substantial positive correlation between student participation in the remediation program and greater

success on the AP Calculus AB exam. The average AP Calculus AB score for the students enrolled in AP Calculus AB during the eight-year period of implementing the remediation program increased by over 9%.

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CHAPTER ONE

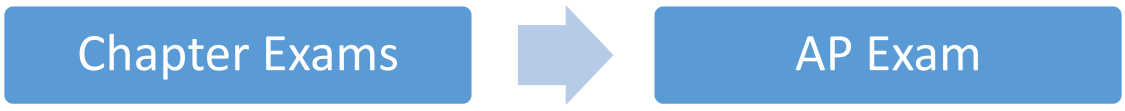
INTRODUCTION

Background

"Calculus was not made to be easy. It already is." This famous quote by Jaime Escalante from the movie *Stand and Deliver* is a statement that goes against the feelings of the majority of Calculus students. Numerous conversations with past students has demonstrated that a majority of students have a pre-conceived idea that the class is difficult and contains the kind of mathematics that only a genius can comprehend. When such notions exist, the Calculus teacher is facing a "brick wall" of pre-conceived notions that must be taken down, brick by brick, in order for learning to take place. In my twenty-six years of teaching mathematics, eleven of which were spent teaching AP Calculus, I have often thought about ways to open students' minds and get them to see that the mathematical concepts that I will teach them are accessible. Once this barrier has been breached, I have found most students enjoy learning the concepts that a beginning Calculus course offers, since it uses the majority of skills learned in previous math classes. A student finds a derivative and then may need to algebraically manipulate its form to proceed in the problem. A student may need to find the area of a cross-section using geometry to find the volume of a solid using integration. A student may need to use a trigonometric identity to substitute an integrand to evaluate a definite integral. Students are

able to see why they have been asked to learn algebra, geometry, and trigonometry.

Some of the objectives I have in teaching a high school Advanced Placement Calculus course are that I can demonstrate that Calculus can be fun, that my students will enjoy learning mathematics, and they can be successful in the course. If these objectives are met, students might consider pursuing a STEM major as an interesting and realistic option. An instructional goal I have for my students is that they develop a deep conceptual understanding of the concepts of Calculus and other areas of mathematics. To achieve this goal, I have found that another Jaime Escalante quote applies: "The key to my success with youngsters is a very simple and time-honored tradition: hard work for teacher and student alike." The most accurate measures that I have to evaluate students' understanding are their Chapter exam scores and their scores on the Advanced Placement exam for Calculus AB. Starting in 2007, the pathway to success on the AP Calculus AB exam during the beginning years of teaching this class assumed that success in chapter exams correlated directly with success in AP exams; this can be envisioned as follows:



During the first four years of teaching AP Calculus AB my students were not passing the exam at the rate that I was aiming for. About half of my students were passing the exam annually. I wanted to increase the rate at which my

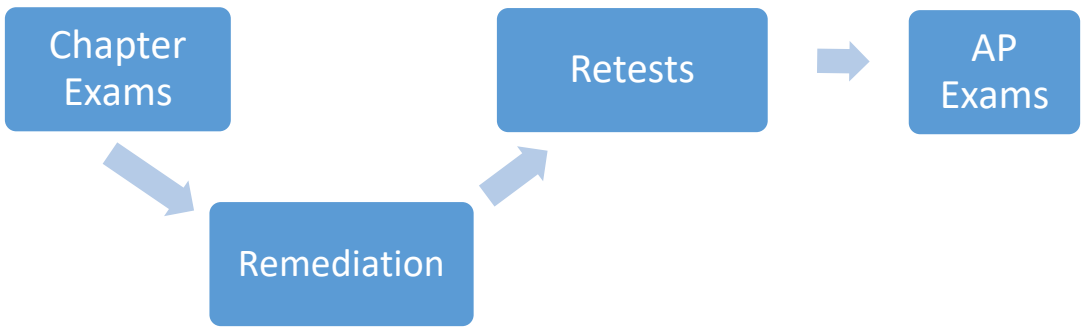
students were passing the exam. What could I do to get the students getting scores of “1’s” and “2’s” to slide over enough to get a passing score of “3” or higher? Through self-inspection I went back to my experience coaching boys’ basketball. The key to my teams’ success were that we worked both harder and more efficiently. We spent hours shooting, working on fundamentals, and practicing good habits. The coaching staff would review game video to see where mistakes were made so that we could design and implement changes in our practice plans. The players would also watch game videos and critique themselves to see where their mistakes were, take ownership of them, and then learn from their mistakes to perform better at the skills necessary to succeed on the court. Why not apply this same philosophy to the Calculus classroom? If students could see where they were making mistakes on the skills needed to have a deep understanding of the concepts taught in Calculus AB, and then reflect and remediate on them, then maybe they would perform better on the Calculus AB exam. So starting in 2010 I set forth to put together a remediation program that would give my students the opportunity to review their mistakes and learn from them.

The remediation program I developed utilizes resources that demonstrate how to perform the skills and concepts that the students were evaluated on in the class and on their Chapter exams. For example, if a student showed they did not understand how to take the derivative of a composite function using the Chain Rule, they could read and see how this process is done, see step-by-step

examples that show via multiple representations how the skill may be executed, and then practice taking derivatives of various functions using the Chain Rule. The remediation program provides multiple detailed solutions for each problem so that students can see different ways of completing a problem. Students can then see if they were successful and learn from any mistakes they made. The remediation program is comprehensive, providing students an opportunity to remediate on all the concepts taught in the class and address any gaps with the basic concepts needed to fully understand the concepts taught in a Calculus class. I essentially decided to change the pathway to success on the AP Exam by inserting an intermediate remediation program:

An issue that arose once I had developed the remediation program was how I could get my students to buy in to coming in after school to work on the Calculus concepts. A solution to this issue came from frustration that my students and I experienced after the grading of a chapter exam. If a student received a low score, the weight of the exam score caused their overall class grade to suffer. So, I offered students a chance to review their mistakes made on the chapter exam and to improve their grade in the class by voluntarily coming in on their own time to participate in this remediation program. This program would allow all students to either individually or collaboratively work on improving their understanding of the processes and to learn from their mistakes through active

learning and practice of the skills and concepts in the class. To ensure that students did not become overwhelmed, remediation was focused solely on concepts with which students struggled. Once the remediation process was finished, students had the opportunity to retest on the concepts they originally missed. For each chapter I put together a retest that was made up of a combination of multiple choice and free response questions for each original concept that appeared on the original chapter exam. The number of questions on the retest for each original concept ranged from three to five. On the retest, whatever percentage of questions a student correctly answered determined what percentage of points would be added to that student's score on the original chapter exam. Each student was allowed to voluntarily engage in the remediation process for all questions that they missed on each original chapter exam taken throughout the school year. The pathway to success on the AP Calculus AB exam in my class had changed once more; to motivate participation, students who participated in remediation were given the option of retesting, to improve their overall grade in the class. This can be envisioned as:



For the majority of my students this was a game-changer. Every student had the opportunity to remediate missed concepts and then demonstrate his/her new level of understanding, if any, for every chapter exam. Each student could improve his/her class grade, which was his/her main goal, and I could get the students to remediate on the skills they needed to master to be successful on the Calculus AP AB exam.

Over the next eight years the average AP Calculus AB pass rates for my classes increased by an average of 4%. This was exciting for me as a teacher. I wanted to know how (if at all) my remediation program contributed to the increase in scores. Using the data collected from my remediation program for the last eight years, the question I would like to answer in this study is:
To what extent is there a correlation between student participation in the remediation program and the rate of success on the AP Calculus AB exam?

Research Goal

Research has been conducted to see if universities can improve the success rate of their students passing the entry level Calculus course as a way to steer students into continuing or pursuing a STEM major (Watt, 2014; Broussard, 2013). Success in this first year Calculus course is considered an indicator of students continuing in a STEM course of study, or changing their major into a non-STEM path. Colleges and universities are implementing support programs and looking at changing teaching strategies to support student understanding of

the material in an entry level Calculus course and foster greater success that would lead to a pursuit of a STEM degree. If a student is able to successfully pass the entry level Calculus class, the student is more likely to continue in their current course of study and complete a STEM degree.

With over 250,000 high school students annually taking the AP Calculus AB exam, it is imperative that high school Calculus teachers find ways to improve the experience of their students through effective teaching strategies and implementing programs that support their students in understanding the big ideas in the course, thereby giving the students the best opportunity to succeed in this class. The implementation of supportive programs that reform previously traditionally taught calculus classes at the college level have been shown to have an impact on STEM retention (Bullock, 2017). Why not start at the high school level with good teaching practices, such as offering tutoring and remediation, as a way to provide a better pathway to STEM related fields in college?

The overarching goal of this research study is to investigate to what extent (if at all) the remediation program described above correlates positively with students passing the AP Calculus AB exam.

CHAPTER TWO
LITERATURE REVIEW

Significance

"The US President's Council of Advisors on Science and Technology report predicts over the next decade approximately one million more STEM graduates above and beyond the current graduation level will be needed in order the meet the demands of the U.S. workforce" (Watt, 2014). "Calculus is the primary gateway for most students heading into the technical and scientific fields that will drive the economy of the 21st century… We are losing too many of them." (Bressoud, 2013).

The preceding two quotes suggest that there is a need for students entering college looking to pursue a STEM major. Since Calculus I is a required introductory course for STEM majors, success in it is seen as a predictor as to whether students will continue in that major or change direction to a new major. If a student can develop a sense of inner confidence and belief that they can succeed in understanding the key concepts in a beginning level Calculus course, they are more likely to continue on to Calculus II and continue on with their STEM major. Calculus teachers at the high school and collegiate levels should promote positive interactions in their classes, "… because students' first year experience plays such a critical role, it follows that social and academic

integration within students' first year STEM courses, such as Calculus I, is of particular importance for STEM-intending students" (Johnson, 2012).

Administrators at universities and colleges have called for research into what type of interventions could benefit students that are enrolled in beginning Calculus. At Boise State University, Calculus "is a gateway requirement for their degree… Too often, and for too many, Calculus functioned as an artificial barrier to progress, resulting in dissatisfaction among constituent departments and their students" (Bullock, 2015). Pass rates in the class averaged 51%. Members of the Mathematics Department at Boise State University came together in faculty learning communities to develop a coherent Calculus course that was accepted and taught by all involved faculty. The calculus instructors "chose to adopt a similar pedagogical approach which included devoting class time to solving problems, working in small groups, facilitated by the lead instructor and a learning assistant." By instituting this change in teaching the Calculus course, "pass and withdrawal rates pre and post implementation reveal an increase in pass rate of 13.4% and a drop in withdrawal rate of 3.9% as a result of the project" (Bullock, 2015).

Subsequent research was conducted to measure the effects of the reform of the Calculus I program at Boise State University on student retention. One of the goals of the reform was to keep STEM students in their chosen major by achieving greater success in this gateway class. STEM students taking the traditional Calculus course were compared to STEM students taking the new

version of the course. According to the study, the new Calculus course improved retention by “a modest overall gain of 3.3 percentage points (p= .078). We found strong effects on women and underrepresented minorities. The new Calculus course improved retention for both of these groups by more than 9 percentage points, a large effect” (Bullock, 2017).

Help outside of class in the form of tutoring and appropriate remediation programs can have a positive impact. Studies have shown that tutoring and recitation programs at the undergraduate level for beginning Calculus students improved student success in these courses. One study found that “the implementation of highly structured recitation activities that focus on placing the student in an active role of developing their conceptual understandings of mathematics via verbal, geometric, numeric and algebraic representations can increase the student success rate in calculus and increase first-year retention rate” (Watt, 2014). Another study found that recitation for Calculus students was beneficial. “…formal implementation of recitations and study groups … were able to affect students’ confidence in working homework problems by using supplemental workshops. These types of interventions show promise as ways to remove barriers associated with calculus” (Pyzdrowski, 2011).

The remediation program I developed to help students in a college-level Calculus course was designed to help students have a better experience with this course by giving them an opportunity to understand the concepts in the course at a deeper and more meaningful level. The program is offered

voluntarily after school. Research has shown that “Instructors who employed generally accepted good teaching practices (e.g. clarity in presentation and answering questions, useful homework, fair exams, **help outside of class**), were found to have the most positive impact.” “The existence and support of a tutoring center where students could get help outside of class were found to have a positive impact” (Sonnert, 2013).

The goal of my remediation program is to help the students develop a greater understanding of the material. A measure of the students’ level of understanding in calculus is the annual Advanced Placement Calculus AB exam. A score of 3 or higher on this exam, depending on the university, demonstrates a level of understanding that allows a student to receive credit for Calculus I in their first year of college. Research has shown that, “on average students who earned a 3 or higher on the AP Calculus Exam had higher first-year college GPA’s than students of similar ability that did not take an AP Calculus Exam” (Hedrick, 2016). Research also shows when comparing grades of students in their next college calculus course that “students who had received advanced placement because of AP scores outperformed the students who had not skipped the relevant calculus course” (Hsu, 2013).

One of the desired outcomes that have come out of implementing the remediation program is that students seem to develop a greater sense of confidence in themselves and their ability to perform the tasks in Calculus. This may lead to a greater chance of success on the AP Calculus AB exam. Students

develop a greater sense of academic connections in the class and have social interactions with each other when working together on the remediation program. A Calculus community forms when the students are banded together to work to understand the material at a high level and to put themselves in a better position to be successful on the AP Calculus AB exam. This outcome of academic and social connections has shown to contribute to the success of Calculus I students in college. “It appears that… institutions have successful Calculus I programs at least in part because of the social and academic integration they are able to facilitate through student support services” (Johnson, 2013).

One of the benefits for students enrolled in my Calculus class that voluntarily participate in the remediation program is the experience of how to study productively. At the collegiate level, the expectation is for students to spend at least as much time studying outside of class as they spend in lecture. A student who is able to study effectively in high school has a better chance to succeed in college. “Time spent studying, however, was found to be a productive effort for students who took calculus in high school, regardless of their performance,” (Barnett, 2013).

I would like to find out if the remediation program that I ask my Calculus students to participate in could have the same positive effect at the high school level as remediation programs implemented at the collegiate level. The significance of these findings could offer high school Calculus teachers, and maybe mathematics teachers in general, a process for improving the

mathematical experience for more of their students, and possibly guide more of our young students to consider pursuing a STEM career in their future.

CHAPTER THREE
METHODOLOGY

Methodology

I intend to achieve my goal of finding out if a remediation program given in a high school Advanced Placement Calculus course would correlate with the success of students passing the AP Calculus AB exam by taking the remediation data that I have accumulated over the last eight years and running a statistical analysis comparing multiple concepts against each other. These comparisons are:

- Comparing each student's percentage gain in the class (after participating in remediation) with their score on the AP Calculus AB exam. Is there a correlation between the student's percentage gain of their overall grade in the class and their AP score? This would suggest a correlation between a student's participation in the remediation program and their success on the AP Calculus AB exam.
- Comparing the performance of the students in my Calculus AB classes on the AP Calculus AB exam with the performance of the students globally that annually take the AP Calculus AB exam prior to and after the implementation of the remediation program. This may show that participation in the remediation program allows the students I teach to

have a better success rate on the AP Calculus AB exam than students that take the exam globally.

The data that I have compiled over the last eight years includes: 1) the percentage gained in the class grade after remediation on each chapter exam for each student 2) the number of questions answered incorrectly by each student on three of the original chapter exams taken in the class (chapters three, five, and six) out of the total number of questions on each original exam, and 3) the student score on the AP Calculus AB exam. An example of this data is shown in Figure 1.

Student	Year	% gain	CH 3 # missed/14	% gain	CH 5 # missed/9	% gain	CH 6 # missed/8	% gain	CH 7 # missed/12	AP Score
1	2016	7.5	6	4.7	5	10.2	4	11.7	9	3
2	2016	3.2	3	1.5	6	1.9	2	4.9	5	5
3	2016		11	4.2	6	6.2	6	3.6	10	1
4	2016	3.7	3	1.2	3	3.5	2		1	5
5	2016		2		3		3		0	5
6	2016	2.7	4	5.2	5	2	2		6	4
7	2016	2.3	8		7	1.6	5		9	1
8	2016	4.2	7	3.3	8	10.8	7	2	8	2
9	2016	6.2	6		8		7		8	2
10	2016	5.2	8	2.3	6	3	5	2.3	7	4
11	2016		2	3.7	4	4.9	3	3.8	4	5
12	2016	6.1	4	2.9	4	4.2	3		0	5
13	2016	2.2	9	6.8	8					
14	2016		12		9		4		6	1
15	2016	4.5	7	5.2	8	2.4	4		3	3
16	2016	3.6	4	5.9	6	3.2	5	6.4	6	4
17	2016		10		8		7	1.6	9	
18	2016		11		6					
19	2016	3.6	9	5.1	7	5.3	5		8	2
20	2016		6	3.3	8		5	1.3	8	1
21	2016	5.9	5	3.4	6	5.5	4	5.8	9	3
22	2016	3.5	5		7	2.3	3		6	3
23	2016	2.9	7	1.2	7	6.4	8		7	
24	2016	4.1	6		3	13.1	8		7	3
25	2016	6.7	6		3		0		2	5
26	2016		13	2.7	7	5.6	6		8	1
27	2016		5	1.3	6	2.3	6	2	6	1

Figure 1. Sample Excel File of Data Collected from Student Remediation/AP Scores from 2016.

Procedures

Students who take my AP Calculus AB course are given an exam at the end of each chapter. The exam is made up of multiple-choice and free-response questions. Each chapter exam has a non-calculator and calculator section. After the grading of each student's exam, a spreadsheet is made by the instructor that records how many of the chapter exam questions were answered incorrectly by each student. Free-response questions that earned partial credit are shown with the amount of credit the student earned.

Students are then given the opportunity to remediate on any of the original concepts they misunderstood on the original chapter exam. Based on which question a student missed on the original chapter exam, practice problems are assigned to help the student gain a greater and deeper understanding of the material. Students are encouraged to collaborate with peers to discuss any misconceptions when working on the prepared problems. The instructor is present for all remediation activities to provide any assistance needed. Detailed solutions with multiple representations (graphical, analytical, and numerical) are provided to help each student comprehend the concepts that are being remediated. Once a student is finished with the remediation provided, they may review the original chapter exam to further understand their misconceptions.

Once the student has finished their remediation, they are now in a position to take a retest. They are required to only retest on the concepts they

missed on the original chapter exam. For each concept that was evaluated on the original chapter exam, there are three to five questions, multiple choice and/or free-response, on the retest. The percentage of the questions the student answers correctly on the retest will determine the amount of points they receive back on their chapter exam. For example, if a student missed a 200-point question, and on the retest they answered four out of five questions on the targeted concept correctly, eighty percent of the original 200 points, or 160 points, would be added back to their original chapter exam score. This process repeats for each concept the student retests on. A student, if they answer each question on the retest correctly, could earn a perfect score on their original chapter exam.

Once the score of the retest was found, the instructor then entered the new chapter score into the class grading program. Each student's percentage gain in the overall course grade was recorded after the input of the new test scores. This was done for all chapter exams taken throughout the year, which are usually six exams. For the purposes of this study, data from only three chapter exams, chapters three, five, and six, were used, since they were consistently given to the students in the calculus classes over all eight years.

CHAPTER FOUR

DATA ANALYSIS

Participants

The participants in this study were 11th and 12th grade students enrolled in a college-level Advanced Placement Calculus AB course, or what is equivalent to the first quarter of a beginning Calculus college course. Students had the same instructor for the entire eight-year period. The high school that these students attended is located in San Bernardino, CA in an urban setting in Southern California. During the implementation of the remediation program, the average enrollment was approximately 2100 students. The ethnic distribution of students at this comprehensive high school during the same time period was approximately 70% Hispanic, 16% African-American, and 12% White. On average, 95% of the students enrolled annually qualify for free and reduced lunch.

Data Analysis and Findings

For the data analysis of the remediation data and AP Calculus AB exam, an ANOVA test was run using SPSS (Version 21). The first analysis was done comparing the mean AP performance on the AP Calculus AB exam by year.

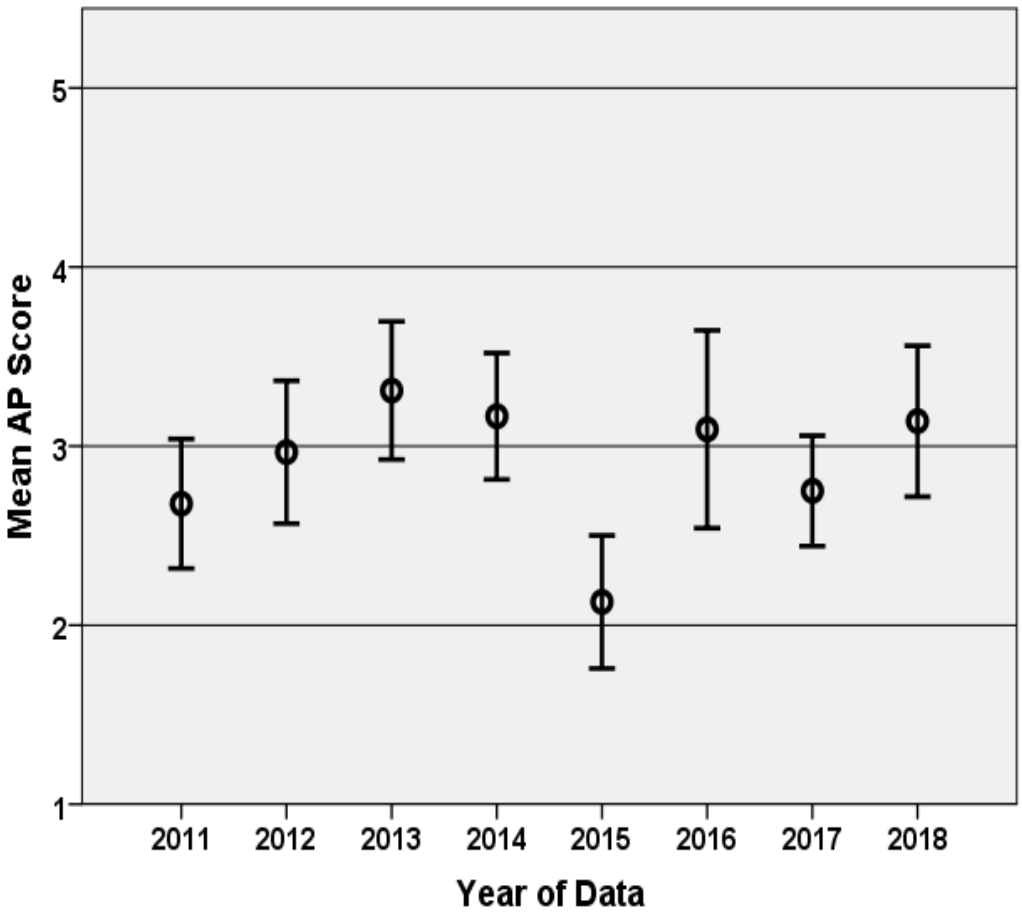


Figure 2. Graph Comparing Year of Data to Mean AP Calculus AB Exam Scores.

The data in Figure 2 shows that the year of 2015 was an outlier. Post-hoc tests from an ANOVA with year class as the predictor of AP scores indicated that 2015 was statistically different from other years, and a contrast t-test comparing 2015 to all other years combined was statistically significant [$t(395) = 4.39$, $p < .001$], and reflected a medium effect size [$r = .22$]. A potential reason for this statistical anomaly was the fact that the instructor was out on jury duty for four

weeks that academic year. The students missed out on a significant amount of material that was not taught in a consistent manner due to that absence. Students did not participate in a remediation for the material that they missed during that absence. For these reasons, the data for this academic year was not included in any statistical analysis moving forward.

A sequential multiple regression analysis comparing the total exam average on the chapter exams across all three chapters and the average gain in the course grade for each student was done. When total chapter exam averages were entered as the first predictor, the corresponding coefficient of multiple determination was $R^2 = .44$, indicating that a good proportion of variance in AP exam scores was explained. When average gain scores are entered after controlling for student performance on the chapter exams, there is an additional 1% variance. The change is statistically significant. Using the omnibus model summary in Table 1, in Model 2, the R/R^2 was .67/.45, with F (2, 346) =142.15, p < 0.001. The change in R^2 from Model 1 to Model 2 was .44 to .45. This change is statistically significant and does produce a large positive Beta for exam scores (Beta = .70, t = 16.60, p < 0.001) and a small positive Beta for average gain attained (Beta =0.11, t = 2.54, p=0.012).

Table 1. Regression Model Summary Comparing Total Exam Average Across All Chapters and Average Gain Attained in the Class.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.664[a]	.441	.439	1.036	.441	273.581	1	347	.000
2	.672[b]	.451	.448	1.028	.010	6.433	1	346	.012

a. Predictors: (Constant), Total Exam Average across Chapters

b. Predictors: (Constant), Total Exam Average across Chapters, Average Gain Attained (All Chapters)

Table 2. ANOVA Summary of Total Chapter Exam Average and Average Gain Attained in the Class When Compared to AP Scores.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	293.584	1	293.584	273.581	.000[b]
	Residual	372.370	347	1.073		
	Total	665.954	348			
2	Regression	300.380	2	150.190	142.149	.000[c]
	Residual	365.574	346	1.057		
	Total	665.954	348			

a. Dependent Variable: AP Score

b. Predictors: (Constant), Total Exam Average across Chapters

c. Predictors: (Constant), Total Exam Average across Chapters, Average Gain Attained (All Chapters)

Table 3. Regression Coefficients of Total Chapter Exam Average and Average Gain Attained in the Class When Compared to AP Scores.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.285	.174		1.636	.103
	Total Exam Average across Chapters	5.446	.329	.664	16.540	.000
2	(Constant)	-.092	.228		-.403	.687
	Total Exam Average across Chapters	5.728	.345	.698	16.599	.000
	Average Gain Attained (All Chapters)	.060	.024	.107	2.536	.012

a. Dependent Variable: AP Score

A statistical analysis comparing AP scores, total chapter exam scores across all three chapters, average gain attained by students in the class (all chapters), and the AP pass/fail data. Table 5 describes correlations of the chapter exam scores (by chapter and total) with the AP scores.

Table 4. Descriptive Statistics Comparing AP scores, Total Chapter Exam Scores Across Chapters, Average Gain Attained by Students in the Class (All Chapters), and the AP Pass/Fail Data.

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
AP Score	349	1	5	3.01	.074	1.383
Total Quiz Average across Chapters	377	.07	.97	.5041	.00898	.17438
Average Gain Attained (All Chapters)	377	.00	11.13	3.7057	.12830	2.49106
APS Pass/Fail	349	.00	1.00	.6017	.02624	.49025
Valid N (listwise)	349					

Table 5. Pearson Correlation Coefficients of Remediation Exam Scores (by Chapter and Total) with AP Calculus AB Exam Scores.

Correlations

		AP Score	Total Quiz Average across Chapters	Average Gain Attained (All Chapters)
AP Score	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	349		
Total Exam Average across Chapters	Pearson Correlation	.664**	1	
	Sig. (2-tailed)	.000		
	N	349	377	
Average Gain Attained (All Chapters)	Pearson Correlation	-.118*	-.335**	1
	Sig. (2-tailed)	.028	.000	
	N	349	377	377

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 3 shows the mean total exam scores (computed as the mean of the three chapter exams) compared with the AP Calculus AB exam scores. This graph clearly indicates that there is a correlation between higher mean total exam scores (all chapters) and higher AP scores ($r=.67$, $p < .001$).

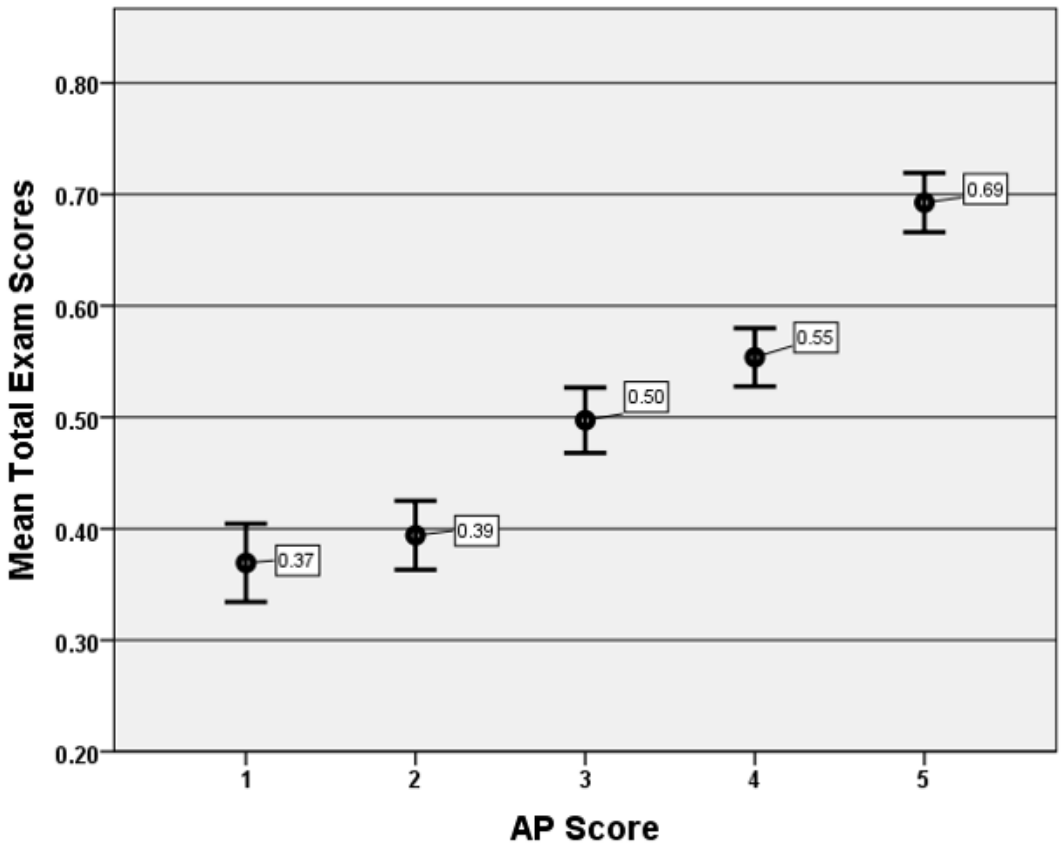


Figure 3. Graph Comparing Mean Total Exam Scores from the Three Chapter Exams to AP Calculus AB Exam Scores.

Figure 4 compares the mean average gain in the class for students after the input of remediation scores with AP scores. Students that scored a “1” or a “5” on the AP exam did not have as high mean average gain as students that scored a “2”, “3”, or “4.” This analysis demonstrates that the center is being moved, that students in the middle are being moved further to the right, or that students that would have been getting a score of “1” or “2” on the AP exam are now scoring higher as a result of the remediation quiz scores.

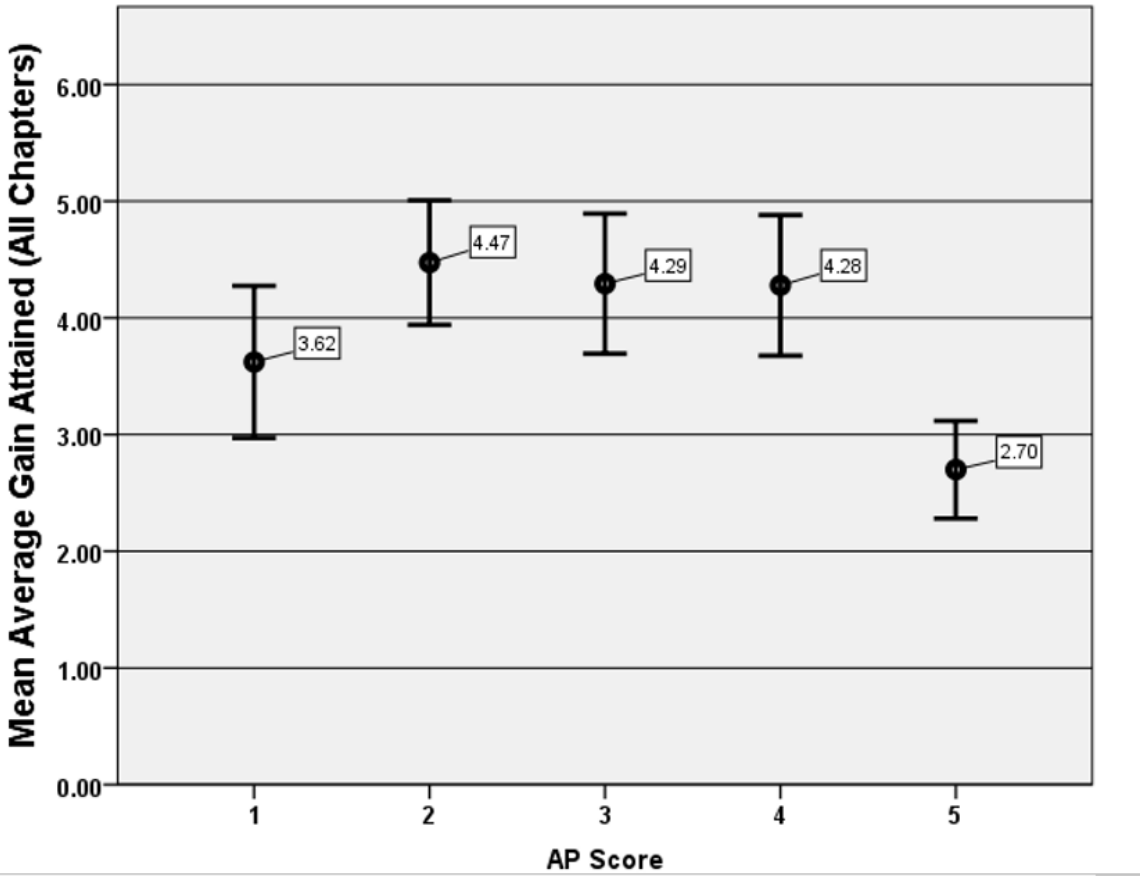


Figure 4. Graph Comparing AP Calculus AB Exam Scores to Mean Average Gain Attained by Students in Class.

The next statistical analysis (see Table 6) compared my students' AP scores prior to the implementation of the remediation program and how they compared to global scores on the AP exam, to my students' AP scores after the remediation program had been implemented and how they compared to global scores on the AP exam. The mean AP score for students in my class was 3.01. The global population mean AP score was 2.48. The results were statistically significant ($t = 5.02$, $p < 0.001$) and had a medium effect size, $r = 0.26$.

Table 6. Single-Sample t-test of AP Scores.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
AP Score	349	3.01	1.383	.074

One-Sample Test

	Test Value = 2.64					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AP Score	5.016	348	.000	.371	.23	.52

Table 7. Chi-Square Test Comparing Pre and Post Intervention Scores on the AP Calculus AB Exam.

AP Score	Std Residual	Pre-Intervention	Post Intervention
1	3.21455025	0.282	0.188
2	1.00790526	0.191	0.215
3	2.30504946	0.252	0.188
4	2.77350098	0.158	0.218
5	3.84307569	0.118	0.191

A Chi-Square analysis and Standard Residual was used to compare pre and post intervention scores on the AP Calculus AB exam. The results from this analysis, shown in Table 7, show that significantly more students were getting a score of "4" or "5" post intervention, and fewer students were getting a score of "1." These results were statistically significant ($p < .001$). This analysis demonstrates the center being moved to the right; student scores improved on the AP Calculus AB exam post intervention.

Table 8. Standardized Residual Comparing Pre and Post Intervention Scores on the AP Calculus AB Exam.

AP Score. Chi-Square (4) = 39.12, p < .001

AP Score	Observed N	Expected N	Residual
1	62	93.0	-31.0
2	71	63.0	8.0
3	62	83.0	-21.0
4	72	52.0	20.0
5	63	39.0	24.0
Total	330		

A statistical analysis was done to compare scores on the AP Calculus AB exam of remediating students to global population scores on the same exam. The results show that during the years that the remediation was in effect, there was a statistically significant effect on remediating student scores, with a mean of 3.01 versus the global population with a mean of 2.82 ($t = 2.59$, $p = 0.01$) (See Table 9).

Table 9. Single Sample t-Test Comparing Scores on the AP Calculus AB Exam of Remediating Students to the Global Population Scores on the AP Calculus AB Exam.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
AP Score	349	3.01	1.383	.074

One-Sample Test

	Test Value = 2.82					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AP Score	2.586	348	.010	.191	.05	.34

A Chi-Square analysis and Standard Residual was used to compare scores on the AP Calculus AB exam of remediating students at the high school I teach at to the global population scores on the same exam (see Tables 10 and 11). The results from this analysis show that during the implementation of the remediation program student scores were improved, and this result was statistically significant ($p < .001$). The negative standardized residuals for students who achieved an AP score of “1” and “5” were underrepresented. A positive standardized residual for the students who achieved an AP score of “2”, “3” and “4” were overrepresented.

Table 10. Chi-Square Analysis of Student Scores Comparing Remediating Students to Global Population of Students That Took the AP Calculus AB Exam.

AP Score. Chi-Square (4) = 31.25, p < .001

	Observed N	Expected N	Residual
1.00	62	94.0	-32.0
2.00	71	45.0	26.0
3.00	62	61.0	1.0
4.00	72	57.0	15.0
5.00	63	73.0	-10.0
Total	330		

Table 11. Standard Residuals of Student Scores Comparing Remediating Students to Global Population of Students That Took the AP Calculus AB Exam.

AP Score	Std Residual	San Gorgonio	Global Population
1	-3.3005479	0.188	0.285
2	3.87585112	0.215	0.136
3	0.1280369	0.188	0.185
4	1.9867985	0.218	0.173
5	-1.1704115	0.191	0.221

CHAPTER FIVE
DISCUSSION AND CONCLUSIONS

Discussion

The goal of this study was to investigate whether (and to what extent) a remediation program designed for and given in a high school Advanced Placement Calculus course would correlate positively with the rate of success of students passing the AP Calculus AB exam. In order to answer this question data was collected and analyzed in a number of comparisons using data from the remediation program, the students' grades in the class, and their scores on the AP Calculus AB exam. AP scores from the global population during this time period were also used in the data analysis. The first comparison was:

Comparing each student's percentage gain in the class (after participating in remediation) with their score on the AP Calculus AB exam.

In order to investigate the potential correlation between a students' percentage gain in the class and their score on the AP Calculus AB exam, I first compared the mean total exam scores on the original chapter exams with AP scores on the AP Calculus AB exam. This comparison showed that students who had a higher mean total exam score on the chapter exams had higher scores on the AP Calculus AB exam (see Figure 3). The data was curvilinear, with students who had a lower mean total exam score performing worse on the

AP Calculus AB exam than students that had a higher mean total exam score. The results of this comparison make sense. Students who scored higher on all chapter exams demonstrated a greater understanding of the material in Calculus AB and were able to show that understanding on the AP Calculus AB exam. The three chapters used in the analysis cover the two major concepts in this class: differentiation and integration, along with some applications of integration. These chapters serve as a foundation for understanding all of the material in the class and on the AP Calculus AB exam. It should be no surprise then, that if students were able to demonstrate a significant level of understanding on the three major exams covering the foundational concepts in Calculus AB that they would also demonstrate the same level of understanding on the AP Calculus AB exam. The chapter exams were given prior to remediating. The remediation program did not have an effect on the mean average of the original chapter exam scores over the eight years the program was in practice. Essentially the pathway to success on the AP Calculus AB exam was investigated as it had been envisioned prior to the implementation of the remediation program:

I then compared the students' percentage gain in the class after remediating to students' scores on the AP Calculus AB exam. The statistical analysis demonstrated that the correlation between these two quantities was statistically significant. The groups that showed the highest average mean gain

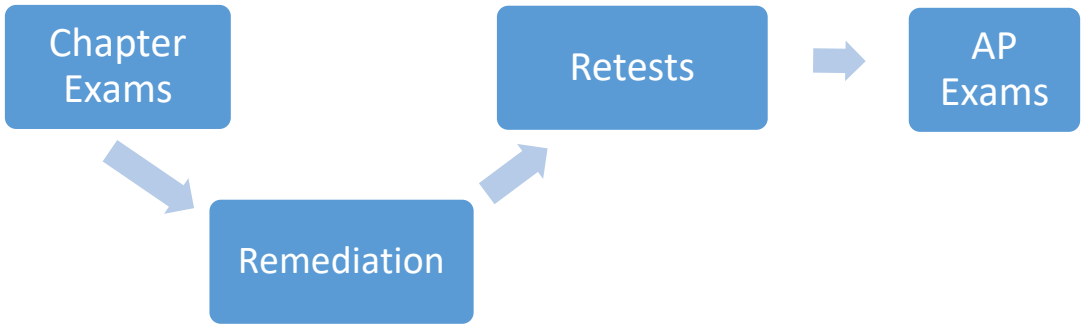
in the class were students that scored a “2”, “3”, and “4” on the AP Calculus AB exam (4.47, 4.29, 4.28 respectively). This information shows that students increased their level of understanding to the point where the needle moved, meaning that students that were at the below average, average, or above average level of understanding at the end of the academic year were moving to the right, or showing a level of understanding on the AP Calculus AB exam that was deemed passing for two-thirds of the students in these groups. This was exciting to see! The comparison of these two quantities demonstrates that this program did have a statistical impact that was clearly measurable to show growth for the middle group of students.

Students who scored a “5” on the AP Calculus AB exam had the lowest mean average gain in the class (2.70). This is likely due to the fact that their grade was already at a high percentage and these students had already performed well on the original chapter exams, and therefore had little to remediate on. These students would then not expect a significant gain in their grade in the class. The next lowest mean average gain was by students that scored a “1” (3.62). These students had a potential for a high mean average gain, as their chapter exam scores were consistently low and they had the most opportunity to gain points in the class. These students may not have followed the remediation program to its potential, or may not have studied the material they did not understand on the original chapter tests adequately enough to show a deeper understanding on the remediation exam, and therefore demonstrated a

lower level of understanding on the retests and the AP Calculus AB exam. Given this data, I want to look at all parts of the remediation program to see if there are changes that need to be made so that the group of students that are in the most need for help in understanding the material have more success with the remediation program, the class and on the AP Calculus AB exam.

To further investigate the possible correlation between students' percentage gain in the class and their score on the AP Calculus AB exam, a comparison was implemented using a Chi-Square analysis and Standard Residual comparing students that took the AP Calculus AB exam at San Gorgonio High School with students who took the AP Calculus AB exam globally. The data showed statistically significant differences. For the eight years that the remediation program was being implemented, two groups had a negative residual, showing that these two groups of students at San G that took the AP Calculus AB exam were underrepresented when compared to the global population that took the AP Calculus AB exam. These two groups were students who scored a "1" (-32) and a "5" (-10). It is interesting to see the "1" group having the highest negative residual; more students are being moved out of this group during the implementation of the remediation program than any other group. The group of students who scored a "2" had a positive residual of 26. This may indicate that students that would have scored a "1" had moved up to a score of "2." The "3" group was relatively unchanged with a positive residual of 1. The students scoring a "4" had a positive residual of 15. An interpretation of

this data suggests that the group of students that would have scored a “2” had moved up to a “3” at close to the same rate as students that would have scored a “3” moving up to a “4,” which may explain why the “3” group remained relatively unchanged. Looking at this data analysis collectively, the “center” was moved to the right when comparing scores from students that had the opportunity to participate in the remediation program to students that took the AP Calculus AB exam around the world. The pathway shown below, that was created to help students find greater success on the AP Calculus AB exam was found, statistically, to do just that.



The last comparison of the study was:

For each of the four years before implementation of the remediation program, and the eight years of implementation, comparing the performance of the students in my Calculus AB classes on the AP Calculus AB exam with the performance of the students globally who took the AP Calculus AB exam.

A statistical analysis was carried out comparing all students that took the AP Calculus AB exam with students that took the AP Calculus AB exam prior to the implementation of the remediation program and after its implementation. The data showed statistically significant differences. A Chi-Square analysis and Standard Residual was used to compare pre and post intervention scores on the AP Calculus AB exam. The results showed that from pre to post intervention the "1" group and "3" group declined (28% to 19%, 25% to 19%), and the "2", "4", and "5" groups increased (19% to 22%, 16% to 22%, 12% to 19%). This analysis could be interpreted as showing more students are scoring in the "2" group because they moved out of the "1" group, and less students are in the "3" group since they have moved up to the "4" and "5" group.

The remediation program that was instituted to aid students in their desire to understand the material in a Calculus AB class to a greater level and to improve their scores on the AP Calculus AB exam was shown to have the desired effect. Prior to the implementation of the remediation program, students in AP Calculus AB had a pass rate of 55.50%. During the eight years that the remediation program was in practice, more students were passing the AP Calculus AB exam than before the remediation program was implemented. The average pass rate for students' post remediation on the AP Calculus AB exam was 59.55%, a gain of 4%. After the remediation program was in place more students were able to demonstrate a level of understanding that the College Board deems a level that would allow students to move on to the next class in a

Calculus series once they have reached the collegiate level. This study adds to the growing research that demonstrates if an intervention program is given to students in a college-level Calculus class that there can be positive gains made to the academic progress made by students, even at the high school level. With greater success in the class and on the AP Calculus AB exam comes greater self-confidence. High school students may be more inclined to pursue a STEM major in college if they see that they can succeed at a college-level mathematics course and have a positive experience. Students that pass the AP Calculus AB exam could enroll in the next course in a Calculus series and be closer to meeting the qualifications to achieving a degree in the STEM major they desire, which would philosophically lead to more students in a position to pursue a STEM career.

Conclusion

The evidence shows that the remediation program instituted in the high school AP Calculus AB classes was successful in increasing the number of students who showed a greater level of understanding of the big ideas and core concepts in a beginning Calculus class as demonstrated in their class grades and AP Calculus AB exam scores. The data analysis showed a positive statistically significant correlation between student participation in the remediation program and the rate of success on the AP Calculus AB exam.

Additionally, there was a substantial positive effect on the pass rate of students on the AP Calculus AB exam over an eight-year period.

Post intervention pass rates on the AP Calculus AB exam were on average 4% higher than pre intervention pass rates for the AP Calculus AB classes at San Gorgonio High school. During the implementation of the remediation program, fewer students tested into the "1" group. More students moved into the "2" and "4" groups. The data suggests a movement to the "right," meaning students that were previously scoring in the "1" to "3" range were now scoring in the "2" to "4" range. The average score on the AP Calculus AB exam from 2007-10 (pre-intervention) was 2.738. **Post-intervention, the average score on the AP Calculus AB exam was 2.996 (2011-2018), an increase of 9.4%.**

Reasons for Bias

While the remediation program had a statistically significant effect on students' ability to demonstrate an understanding of the material at a deeper level, there may have been other factors that could have contributed to greater success on the AP Calculus AB exam. Implementation of more effective teaching practices and a greater knowledge of the subject matter of the exam itself by the instructor may have led students' scores to increase over time. The instructor's ability to present the material in a more understandable manner, implementation of optimal teaching techniques, and the students' earlier

mathematics instructors doing a more effective job of setting a stronger foundation for the key concepts needed to fully engage in a complete understanding of the big ideas in Calculus all could have contributed to improved success rates for students enrolled in Calculus AB during that time period.

There are also certain biases that may have detracted from greater student success on the AP Calculus AB exam. During the eight years of the remediation implementation, the impact of Common Core at the elementary level may have had a negative impact on students' level of understanding on basic concepts, which would lead to gaps in the mathematical foundation that students develop. These gaps follow the student to high school and may detract from the overall understanding of concepts in prerequisite classes for Calculus as well as in the Calculus class itself. During the last five years of this study the seat time that students had in class dropped by ten minutes per school day, or for a cumulative amount of about two weeks of class time. Less time in class means less time to understand the material presented. Along with the remediation program, these positive and negative biases must be looked at as possible factors that may affect the change in success for the group of students over the eight years of this study.

Implications for Future Study

The group of students that showed the greatest gain in the Calculus class and on the AP Calculus AB exam were students in the middle, i.e., those who

demonstrated a below average to average understanding of the material in Calculus AB. Prior to the implementation of the remediation program, more students did not achieve a passing score on the AP Calculus AB exam. Post intervention statistics show more students are moving up to the next level of understanding of the material in a Calculus AB class, as demonstrated by the pass rates during the implementation of the remediation program. There were still students who did not show a greater level of understanding while participating in the intervention. Based on the results of this study, a deeper review of my remediation program to see what changes can be made to reach this group is necessary.

The results of this study should be an impetus to drive my instruction moving forward. Looking at the data for the last eight years from the remediation program to see if there are certain concepts for which students consistently require remediation will guide me to make changes to how I initially teach these skills and how my teaching can be more effective. Prerequisite skills that Calculus students need entering this class that are consistently shown to be lacking can be given more weight when considering departmental instructional changes to prerequisite classes, as well as how these basic skills are spiraled and reviewed throughout the Calculus course.

Continued research using the data from the remediation program over the last eight years could include using demographics such as gender, race, and economic criteria to see if certain sub-groups were affected more than others by

participating in this program. Similar to the study done by Boise State University that looked to measure the effects of the Calculus I program after the institution of intervention programs on different groups of students, data analysis could be done to see if certain groups of students enrolled in my Calculus program pre-intervention had greater success on the AP Calculus AB exam post-intervention.

The idea that a remediation program may be helpful in giving a group of Calculus students the help necessary to develop a greater understanding of key skills and concepts could possibly be implemented in other courses of study in the field of mathematics. This study could provide a basis to design an intervention program that fits the needs of math students at any level. An effective teacher should provide avenues for students to remediate and to achieve a level of understanding that is necessary to move on to the next level of mathematics while achieving a greater sense for how the mathematical concepts all connect. It is true that there is work involved to develop a remediation program, institute it, and continue to refine it. The instructor must also be available outside of the normal hours of class to give students access to any recitation that is offered. The reward for this extra work is the satisfaction that the instructor has done everything possible to put his/her students in the best possible position to succeed. The experiences that students encounter when they have worked diligently to understand material that may be perceived to be difficult, failed, tried again and finally succeeded can lead to a positive self-image and a confidence that they can go on and have similar positive experiences in

mathematics in their future. This gained confidence can have an impact on the decisions to pursue a career in STEM related fields. As math teachers we must try to put our students in the position to succeed, to see the beauty in mathematics, and to allow students to envision a world where mathematics can play a major part of their future endeavors.

APPENDIX

IRB APPROVAL LETTER

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

November 27, 2018

CSUSB INSTITUTIONAL REVIEW BOARD
Administrative/Exempt Review Determination
Status: Determined Exempt
IRB-FY2019-19

Mr. Ty Stockham and Prof. Davida Fischman
Department of Mathematics
California State University, San Bernardino
5500 University Parkway
San Bernardino, California 92407

Dear Mr. Stockham and Prof. Fischman:

Your application to use human subjects, titled "Stockham - AP calc" has been reviewed and approved by the Chair of the Institutional Review Board (IRB) of California State University, San Bernardino has determined that your application meets the requirements for exemption from IRB review Federal requirements under 45 CFR 46. As the researcher under the exempt category you do not have to follow the requirements under 45 CFR 46 which requires annual renewal and documentation of written informed consent which are not required for the exempt category. However, exempt status still requires you to attain consent from participants before conducting your research as needed. Please ensure your CITI Human Subjects Training is kept up-to-date and current throughout the study.

The CSUSB IRB has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval notice does not replace any departmental or additional approvals which may be required.

Your responsibilities as the researcher/investigator reporting to the IRB Committee the following three requirements highlighted below. Please note failure of the investigator to notify the IRB of the below requirements may result in disciplinary action.

- Submit a protocol modification (change) form if any changes (no matter how minor) are proposed in your study for review and approval by the IRB before implemented in your study to ensure the risk level to participants has not increased,
- If any unanticipated/adverse events are experienced by subjects during your research, and
- Submit a study closure through the Cayuse IRB submission system when your study has ended.

The protocol modification, adverse/unanticipated event, and closure forms are located in the Cayuse IRB System. If you have any questions regarding the IRB decision, please contact Michael Gillespie, the Research Compliance Officer. Mr. Michael Gillespie can be reached by phone at (909) 537-7588, by fax at (909) 537-7028, or by email at mgillesp@csusb.edu. Please include your application approval identification number (listed at the top) in all correspondence.

If you have any questions regarding the IRB decision, please contact Michael Gillespie, the Research Compliance Officer. Mr. Michael Gillespie can be reached by phone at (909) 537-7588, by fax at (909) 537-7028, or by email at mgillesp@csusb.edu. Please include your application approval identification number (listed at the top) in all correspondence.

Best of luck with your research.

Sincerely,

Donna Garcia

Donna Garcia, Ph.D., IRB Chair
CSUSB Institutional Review Board

DG/MG

REFERENCES

Barnett, M.D., G Sonnert and P.M. Sadler (2014). Productive and Ineffective Efforts: How Student Effort in High School Mathematics Relates to College Success. *International Journal of Mathematical Education in Science and Technology,* 996-1020.

Bullock, Doug, Janet Callahan, and Susan Shadle. (2015). Coherent Calculus Course Design: Creating Faculty Buy-in for Student Success. Paper presented at the *2015 ASEE Annual Conference and Exposition, Seattle, Washington,* 10.18260/p 23694.

Bullock, Doug, Janet Callahan, and Jocelyn B.S. Cullers. (2017). Calculus Reform- Increasing STEM Retention and Post-Requisite Course Success While Closing the Gap for Women and Underrepresented Minority Students. *American Society for Engineering Education.* https://peer.asee.org/18474

Bressoud, David M., Marilyn P. Carlson, Vilma Mesa, and Chris Rasmussen. (2013). The Calculus Student: Insights from the Mathematical Association of America National Study. *International Journal of Mathematical Education in Science and Technology Vol.* 44, No. 5, 685-698.

Ellis, Jessica, Bailey K. Fosdick, Chris Rasmussen. (2016). Women 1.5 Times More Likely to Leave STEM Pipeline after Calculus Compared to Men: Lack of Mathematical Confidence a Potential Culprit. *PLOS one*, 1-14.

Hedrick, Ben, and Sarah Leonard. (2016). Advanced Placement (AP) Calculus: A summary of research findings concerning college outcomes for AP examinees. The Role of Calculus in the Transition from High School to College Mathematics. *A joint publication of the Mathematical Association of America and the National Council of Teachers of Mathematics,* 47-52.

Hsu, Eric, and David Broussard (2013). Placement and Student Performance in Calculus I. *Insights and Recommendations from the Mathematical Association of America National Study of College Calculus,* Ch. 5, 59-68.

Johnson, Estrella, Kady Hanson. (2013). Academic and Social Supports. *Insights and Recommendations from the MAA National Study of College Calculus,* Ch. 6, 69-82.

Pyzdrowski, Laura J., Ye Sun, Reagan Curtis, David Miller, Gary Winn, and Robin A. M. Hensel. (2013) Readiness and Attitudes As Indicators for Success in College Calculus. *International Journal of Science and Mathematics Education,* 529-554.

Sonnert, Gerhard, and Philip Sadler. (2013). The Impact of Instructor and Institutional Factors on Students' Attitudes. *Insights and Recommendations from the Mathematical Association of America National Study of College Calculus*, Ch. 2, 17-30.

Watt, Jeffrey X., Charles R. Feldhaus, Brandon H. Sorge, Grant A. Fore, Andrew D. Gavrin, and Kathleen A. Marrs. (2014). The Effects of Implementing

Recitation Activities on Success Rates in a College Calculus Course.

Journal of the Scholarship of Teaching and Learning Vol. 14, No. 4, 1-17.