Conrad Thesis: A Study of Discrepancies Between Advanced Placement (AP) Calculus AB and BC Exam Scores

A Study of Discrepancies between Advanced Placement (AP) Calculus AB and BC Exam Scores

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Abstract

AP Calculus AB and AP Calculus BC are nearly identical courses. However, AP Calculus AB exam scores are among the lowest exam scores annually while AP Calculus BC exam scores are typically among the highest scores each year. Further, the AP Calculus BC exam AB subscores are also higher, on average, than the AP Calculus AB scores overall.

This thesis explores the discrepancies between AP Calculus AB and AP Calculus BC exam scores. The researcher hypothesized that the difference in scores likely had to do with the intrinsic motivation an individual student had when enrolling in the course and how that student fared throughout the school year. This thesis examined four school years' worth of enrollment data at one online provider and compared this data to AP exam scores. Further, a survey was given to students both in local districts as well as this same online provider in the 2017-2018 school year, asking individual students to report their reason(s) for enrolling in their calculus course, their semester scores, and their AP exam score.

The data from the 2017-2018 school year did not show statistically significant data to correlate enrollment reason(s) to AP exam scores. The survey questions, however, could be broken down even further than the researcher did for this project. In future studies, this same survey could be analyzed more granularly or given with restrictions to students who partake in the survey to glean more accurate or detailed data.

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Chapter 1

Introduction

Advanced Placement (AP) Calculus AB and AP Calculus BC are nearly identical courses. Per the College Board (2017), the difference between the two courses is not depth, but breadth. All of the content in AB is covered in BC, but BC adds four additional topics to be covered. Neither course is any more difficult than the other. However, AP Calculus AB scores are consistently low, if not one of the lowest-scoring courses nationally, while AP Calculus BC is one of the top three courses each year. In 2015, BC was the third-highest scoring course behind Chinese and Spanish, and second only to Chinese in 2016 (The College Board, 2015, 2016).

This thesis explores why these courses, when reported to be of the same difficulty, have such discrepant scores on the AP exam each spring. The Calculus BC scores also provide an AB subscore, showing students how they performed on the topics that are also in AB, which is still consistently higher than the AB scores alone. Why are scores for these courses so disparate when they cover the same topics, and often use the same questions?

The only other research found regarding these same topics is research done by the College Board itself. While the College Board routinely publishes reports, results, and research on Advanced Placement courses and college placement, the details about each exam, the granularity of the questions, and data about the individual questions are not released publicly nor to instructors for personal use. Further, only demographic data is

collected and published for these exams and no other in-house data is released. It is unknown why individual students enroll in Advanced Placement courses and there is no known research correlating matriculation purposes to AP exam scores.

This thesis explores the data that can be gleaned from an individual online provider of these courses and compares this data to the national data released by the College Board. The researcher hypothesized that the reason(s) for enrollment have an impact or can predict student success on the AP exam in the spring. The researcher anticipated that students enrolled for purposes *they* chose, such as their own learning preference, as opposed to an outside influence or conflict, would lead to higher exam scores. These results did not come back to show statistical significance for the participants in this study, though there are other correlations that could be researched further in future studies or with larger populations.

Chapter 2 explores the history of the College Board and AP Calculus as an offering. Further, an experienced teacher and administrator gives his personal experience as both a College Board committee member and AP Calculus teacher. Then, the chapter looks at one Midwestern non-profit service provider of K-12 online courses, where the courses and curriculum are already written for students. This provider is state-sponsored, AdvancEd accredited, and works in partnership with local school districts and families to supplement the educational opportunities available to their students. This provider uses Blackboard as a Learning Management System, and there are "master" courses copied for individual teachers' sections each semester. While the instructors can add personal flair, announcements, and supplemental materials, the course content is delivered in identical fashion, graded with identical rubrics, and uses identical assessments. In a classroom,

multiple variables including teacher experience, teaching style, attendance, and difference in assessments (either different questions or levels of difficulty) can certainly be confounding variables to explain different instructors' students' exam scores. However, the majority of these variables are non-existent with this non-profit provider, and yet the AP exam scores remain as discrepant as the national averages, if not more so.

Chapter 3 discusses the methodologies behind the research at the online provider, looking at historical data in two contexts: students who took AP Calculus sometime between 2014 and 2017, and students who took AP Calculus in the 2017-2018 school year. Then, it discusses a survey given to students both at the online provider and in local districts in the 2017-2018 school year. The results from the historical research and survey are reported in Chapter 4. All analyses are provided in Chapter 5.

This thesis also analyzes student final scores compared with AP exam scores. A survey was given to students at the aforementioned online provider, as well as participating local face-to-face school districts, that tracked student scores throughout the school year. As mentioned above, the online courses are delivered almost identically. This thesis sought to find an explanation as to why Student X gets a 95% in the class overall and gets a 1 on the AP exam while Student Y gets a 92% in the course but earns a 4 on the AP exam. No strong correlation or explanation was found; the underlying causes of these discrepancies were not statistically significant. However, we can continue to improve the courses so students are better prepared for the AP exam. Doing so could ensure student performance in the class is consistent with their AP exam scores. Chapter 4 provides a table of a handful of assignments that show a statistically significant change in student scores. While some minor changes may not show an overall change in AP

exam scores, over time, more changes could lead to a significant improvement in AP exam scores.

This thesis not only includes a study of AP scores for both Calculus AB and BC over time, but compares how the scores have shifted as the course content has been changed, either with adding or removing certain concepts. An analysis of research enrollment reasons and motivation factors to compare AP scores, as well as the online provider's and participating districts' students' final scores (percentages) for each semester.

Chapter 2

History of AP Calculus

This chapter will focus on the history of calculus being included as a course offered by the College Board. It will explore how the course has changed, how the exam has changed, and how student scores have reflected these changes.

Further, it will explore the history of AP Calculus through one individual teacher's experience and how this individual caters his teaching to ensure student success on the exam in the spring.

Lastly, this chapter will compare and contrast AP Calculus AB and BC at one Midwestern online provider of these courses. This particular online provider made some changes to these courses in the summer of 2017. This chapter will dive into the changes that were made, if and how this impacted student scores, and will discuss changes being made in the course going forward.

History of the College Board

Advanced Placement courses are a brand of the College Board, a non-profit organization whose goal, according to its website, is to "expand access to higher education" (College Board, 2018). The College Board was founded originally as the College Entrance Examination Board on December 22, 1899 at Columbia University with delegates from twelve colleges and universities (Harrison, Low, Raymond, and Schurman, 1900).

In the late 1800s, for several decades, schools had "been formed for the purpose of perfecting the relation between the high school and the college" (Monroe, 1900, p. 87). In 1890, only 3.5% of seventeen year olds had graduated high school (National Center for Education Statistics, 2000). It was found that several colleges had different admission requirements and thus a lack of consistency for students hoping to attend one college or university compared to another. In 1887, the first association was formed, with members from fifteen schools throughout the state of Pennsylvania (Monroe, p. 88). More associations formed throughout other states and over time, paved the way for a "national adaptation of certain practices" (Monroe, p. 89). The first committee was appointed in 1895, and this committee's final report was presented four years later.

On December 22, 1899, the twelve delegates for the College Entrance Examination Board agreed upon eleven subjects for examination. Of these eleven subjects, mathematics was one, and the topics to be examined included: elementary algebra, both to quadratics and beyond quadratics; advanced algebra; plane geometry; solid geometry; and plane trigonometry (Harrison, Low, Raymond, and Schurman, p. 10). Calculus was nowhere in the picture.

History of Adding AP Calculus to the College Board Curriculum

As more and more students were graduating high school and moving to higher education, the College Board looked to expand into high school classrooms. The Advanced Placement program was born in 1955 to address this need, enabling "students to pursue college-level studies while still in high school" (The College Board, 2015). Calculus was added to this curriculum in the same year to "expand access to and preparation for higher education" (Ogden, personal communication, 2018). Since then,

the Advanced Placement program has grown exponentially, with 104 original high schools participating in 1955 to almost 19,000 schools participating in the 2012-2013 school year (The College Board, 2013). The calculus course added in 1955 was more similar to the current BC course, with hopes of the course replicating a full year of college-level calculus (Ogden, personal communication, 2018).

Ten years later, in 1965, the Mathematical Association of America (MAA) published a report from the Committee on the Undergraduate Program in Mathematics (CUPM) that outlined a proposed general curriculum in mathematics. This proposed curriculum divided introductory calculus into two separate courses: Introductory Calculus; and Multivariate Calculus, Limits and Differential Equations (1965).

Taking the advice of the MAA, the College Board then decided to split its Advanced Placement Calculus course into two separate courses in 1969 (Ogden, personal communication, 2018). This split "was intended to meet the needs of students who were ready to study college-level calculus in high school, but perhaps not at the pace necessary to complete a year's worth of calculus in an academic year. AB students typically study calculus for one year in preparation for the exam, which earns a semester's credit for successful candidates" (Ogden, personal communication, 2018).

As of 2015, the College Board distinguishes between the two Advanced Placement courses, claiming "AP Calculus AB is equivalent to that of a first-semester college calculus course, while AP Calculus BC is equivalent to a first-semester college calculus course and the subsequent single-variable calculus course. Calculus BC is an extension of Calculus AB rather than an enhancement…" (The College Board, 2015).

Changes to AP Calculus Calculator Usage

The format of the AP exam for both calculus classes has changed over time as well. When the courses were added to the College Board's curriculum in 1969, calculators were not permitted. In 1975, the National Advisory Committee on Mathematical Education (NACOME) published an article arguing that students in eighth grade and above should have access to calculators for all class work and exams (NACOME, 1975). Five years later, in 1980, the National Council for Teachers of Mathematics (NCTM) released its *Agenda for Action*, recommending that "mathematics programs take full advantage of the power of calculators and computers at all grade levels" (NCTM, 1980).

In following suit of national recommendations, the College Board decided to add calculators to its curriculum. Though the College Board still only allows, but does not require, calculators for the SAT, it is necessary for the SAT subject test for mathematics (College Board, 2018). Similarly, The College Board followed suit by allowing calculators for the calculus courses in 1984. However, the permission of using calculators only lasted one year at this time. In 1993, once again the College Board allowed the use of calculators again on both the AB and BC exams. By 1995, the exams required calculators, and, to date, continue to have both calculator and non-calculator portions of the exam.

With the addition of calculators to the curriculum, both with permission and later as a requirement, the exam shifted to account for the change. The College Board and a veteran AP Calculus teacher agree that there was no noticeable shift in scores (Ogden, personal communication, 2018; Brandell, personal communication, January 20, 2018).

The College Board defended its process for significant changes to exams or format, stating when an "exam changes in any substantive way, [they] undergo a statistically rigorous standard-setting procedure" (Ogden, personal communication, 2018). Further, the exam still includes non-calculator questions that "provide opportunities for students to demonstrate that they can evaluate limits, derivatives, integrals, and series without their calculators." The veteran teacher agreed, adding, "Calculator-required questions just shift from approach" (Brandell, personal communication, January 20, 2018). This "allows for manipulation of more dense and complicated functions and expressions" (Brandell, personal communication, January 20, 2018).

Data Gleaned Annually from AP Calculus Exam

The College Board is notorious for giving extremely limited access to its exams, exam questions, and documents. The majority of research analyzing the College Board's reuse of specific questions on exams focuses on the SAT, rather than other brands of the College Board, including Advanced Placement. The College Board does not deny reusing questions. To protect the integrity of the exam and to guarantee its reputation and reliability with colleges, the College Board "has increased test form development to reduce reuse, strengthened prevention and detection techniques, and bolstered efforts to identify and pursue those sharing copyright-protected test content" (The College Board, 2017). While this statement is a direct result of shared data about the SAT, it is reasonable to assume that the College Board has the same security measures for all of its exams.

The College Board releases a wealth of data about its exams each year. This data, however, does not include results based on individual questions from the multiple choice

parts of the exam. There is a committee that comprises of fifteen people (ten from universities, five from high schools) that go through the exam annually and draw correlations and analysis based on the questions. These questions "are recycled for reliability" and are not "released domestically" (Brandell, personal communication, January 20, 2018). However, the full exams of the international version are released annually. Even though these are released internationally, the domestic copies are not allowed to be kept and must be returned to the College Board where they are kept secure. This security is to protect the reliability of the exam itself more so than the worry that questions could be recycled with identical or similar values. The questions, even if recycled, maintain "depth of knowledge" required to do well on the exam. On an international level, the exams are released in full "to make in-roads in the Far East" (Brandell, personal communication, January 20, 2018).

Further, there are currently only three full AP Calculus exams available publicly through the College Board: 1988, 1998, and 2012. The Free Response Questions are released to the public on an annual basis, but the multiple choice questions are what remain secure. Other copies of full exams (currently, the exams from 2013-2017) are available to members of the College Board who are designated as teachers of the AP curriculum, but these are only available in a secure audit webpage. These exams are not to be distributed or printed for any use outside of a physical classroom, and students are not allowed to keep these for any reason.

The College Board provides a course description for each Advanced Placement course they offer. The course description not only includes a brief list of topics in each course, but breaks these down further with standards and objectives to be met. Calculus

AB has a reduced number of topics compared to BC, so it is expected that each topic is covered on the exam. However, BC has more topics, so it is impossible for every topic to be covered on the exam. Without seeing individual exams year-to-year, it is not possible to break down what proportion of topics are covered on the BC exam or even which ones are *always* covered on each year's exam. It also is not possible to break down what proportion of the test covers which topic(s) year-to-year without having access to exam questions. However, Brandell argues that the proportion of topics studied in each year's practice exam "are close enough" to the actual exam, and thus agrees the practice exams are fair study material in order for students to succeed on the exam. (It is discussed later in this chapter how Brandell uses practice exams as an instructor to ensure students have the proper preparation outside of simply taking the practice exam provided by the College Board.) While it cannot be proven what proportion of questions cover new topics, it can be almost guaranteed that when the College Board adds content to the curriculum, there will be at least one question to cover each new topic on that year's exam. This is something Brandell (2018) confirmed, but can also be observed when comparing new course descriptions to the secure exams for the same year.

Though the College Board keeps these questions and exams secure, they do a comprehensive analysis of each question annually. The publication provided to the public is the annual AP report, and the Chief Reader report analyzes each free response question in detail. For the free response questions, it might be expected to see more area or volume problems on the AB exam, but fewer questions of that topic on the BC exam. It is expected to see a table of sorts, though the context of this changes each year or across AB to BC (Brandell, personal communication, January 20, 2018). In looking at annual trends,

it can be guaranteed that there will be some sort of series question on the BC exam, as this is the main topic that separates the BC curriculum from AB.

In terms of the multiple choice questions, certain topics can be expected to be covered to a certain extent each year. While some questions may be reused, recycled, or removed each year, it is predictable what to expect in the following year's exam. Instead of looking year-to-year, though, it is better to look at five- or six-year trends. In AB, it is almost guaranteed there is a question on inverse functions. On the opposite end of the spectrum, in BC, of the topics that are not guaranteed to be covered each year, there might only be one question to cover that topic on a given year's exam. This, according to Brandell (2018), could be why AB scores are lower. A student is guaranteed to have every topic covered in AB, while a BC student might get by easy with other topics covered with only one question or never at all.

The College Board analyzes each question and also looks at these patterns over time. With certain questions or question types being recycled, it often warrants that the exam needs to remove a question in subsequent years or dispose of those questions when scoring student exams. With this, there comes some statistical manipulation or expected skewness in scores. In 2017, there was at least one question where 50% of the AB students earned a 0 on that question. It is hard to guarantee that if a student scores a specific percentage on the exam, that student will get a specific score for the exam. For example, if a student scores a 60% on the exam one year, it could be an exam score of a 4. The following year, a 60% could be an exam score of a 3. This is because the exam *does* change year-to-year, and when certain questions are eliminated from scoring, each year is essentially curved. It is better to think about "norming" and to "look holistically"

rather than at specific numbers (Brandell, personal communication, January 20, 2018). The College Board argues some skewness is to be expected, but analyzes performance "to assure the data and scores are *not* skewed" (Ogden, personal communication, 2018). The College Board "construct[s] and analyze[s] exams to assure that they are equitable across forms and over time" with statistical rigor; they "begin by constructing exams to rigorous standards for content, skills, and difficulty" before going on to analyze performance (Ogden, personal communication, 2018).

Students who take the BC exam also get an AB subscore reported. Each year, there are two shared free response questions on the AB and BC exams. While a guaranteed number of multiple choices questions cannot be reported, it is assumed many of these are repeated across course exams as well. The topics covered, though, are expected to require "the same depth of knowledge required to answer the questions correctly" (Brandell, personal communication, January 20, 2018). The College Board defends its validity in the AB subscore claiming, "Psychometricians have models for testing questions across forms and over time. They also have models that assure the AB subscores for the BC exam performance correlate with the scores students would have earned had they taken the AB exam" (Ogden, personal communication, 2018).

When looking at data, historical trends and statistical manipulation can be used to make changes in the exam each year. It might be worth looking into specific demographic data to see if there are any trends that go against the grain or expected scores on questions or the exam as a whole. Defending its procedure, Ogden emphasizes that the "item review process is extraordinarily robust, with many opportunities to remove questions that appear to be assessing something other than the intended targets of

assessment" (2018). The College Board publishes demographic data broken down by gender, race, and state. It should be noted that they cannot provide answers to individual questions on the exam, nor how individual students scored on each equation. In fact, certain other information is hard to obtain on a national level. While the College Board and Brandell come from the platform of equity and access for all students, some sensitive information could be quite important, including socioeconomic status of the student and their family or the experience of the teacher in the course.

Which Calculus Course Is the Best Fit for a Student: Non-AP, AB, or BC?

Students preparing to take calculus often have to face a decision: which calculus course is right for them? Here, it will be discussed which course a student *should* take and the factors that come into play for students to consider when enrolling in a specific course. The reason(s) *why* a student chose to enroll in a certain course, which could be different than the course they should actually have enrolled in, are reported in Chapter 4 and discussed in Chapter 5.

The first major consideration would be what course(s) the student's school offers. If a student only has one option available, or is unaware of options elsewhere, the decision seems to be made for them. However, when a school offers two options, students and parents need to take careful consideration when enrolling. Brandell chalked Advanced Placement to be the "gold standard" and because AP is "specific to college courses, it has a leg up on IB [International Baccalaureate]" (Brandell, personal communication, January 20, 2018). So, this can be attractive to many students and parents. Further, many schools give different weight to Advanced Placement courses in students' grade point averages. Most schools and colleges operate on a 4.0-system, with

an A being a 4.0. However, "many high schools and colleges give AP classes an additional point. So it's possible to have a 5.0 GPA credit from an AP class. Or, a student could get a B in an AP class but still have a 4.0 GPA" (Kohli, 2015).

Looking at students who are at schools that offer both AB and BC, and who will likely only take one year of AP Calculus, it is not surprising that the "'top-end' kids" to go into BC instead of AB (Brandell, personal communication, January 20, 2018). Some kids may choose to enroll in BC more for the experience over AB, but do not take the exam. Overall, "the AB scores tend to be lower than BC for districts that offer both, compared to those that only offer AB" (Brandell, personal communication, January 20, 2018). This is discussed in later chapters, but Brandell is "not surprised in institutions that offer both that BC scores are 'really good' and AB are lower because they [BC] attract the more high-end student" (2018).

As Brandell mentioned, some students enroll simply for the experience. It is not always expected that students who take an AP course will choose to test out of that same course in college. However, it seems the AP experience shows a high correlation to success in college. From 2006-2016, four-year colleges in Ohio were studied to compare students who entered their first year with AP credits to those who did not. On average, the students who were AP credit recipients (earning a 3, 4 or 5 on the AP exam) had higher average first-year grade point averages, attempted more credit hours throughout the school year, higher course completion rates, and higher first-to-second-year persistence rates, both at the same or another four-year Ohio institution (Mustafa and Compton, 2017). Rather than hoping for a specific AP exam score, students might enroll to gain the AP experience: learning necessary work and study habits, self-discipline, and

get the practice of being enrolled in a rigorous curriculum thereby hoping to prepare for higher education. Multiple studies also confirm that students who simply partake in taking AP courses are more likely to graduate college in four years (Mattern, Marini, and Shaw, 2013), more likely to perform the same as or better than non-AP counterparts in the subsequent college courses related to their AP exam (Patterson and Ewing, 2013), and more likely to major in a discipline related to that AP exam than students who did not take an exam in that content area (Mattern, Shaw, and Ewing, 2011).

One Teacher's Experience

While the College Board keeps a lot of its data and rigorous processes to update curriculum and exams secure, it is not one individual who makes these decisions each year. As mentioned above, there are committees that look at the data each year. These committees include high school teachers, past and present. Current high school teachers can also be involved with the AP curriculum in other ways through the College Board. Teachers can be readers, the individuals who score and grade the exams; can teach other teachers how to teach AP, so these teachers can be AP-certified and then teach the class with the College Board's approval; and can partake on committees, among other roles.

One such teacher is Dr. Joseph (Joe) Brandell, Ph.D. As of January 2018, Dr. Brandell teaches both high school and college-level courses. He does consulting, which "falls into several piles: College Board AP Calc[ulus]; pre-AP with vertical teaming, a new initiative; pre-AP national faculty member; algebra scaffolding process; private consulting with individual school districts; working with hospital systems … for instruction and assessment to work and acquire continuing education credits for hospitals" (Brandell, personal communication, January 20, 2018). Additionally, he

remains to be a lecturer and faculty member at a university, because "schools of education are saturated with on-campus, full-time faculty which swallow up adjunct positions" (2018).

While Brandell does not consider himself an expert in Advanced Placement Calculus or the College Board, he claims his credentials will say otherwise. At one point, the College Board was involved in training consultants. The College Board "put together a framework for a multi-day workshop and a one-day workshop" (Brandell, personal communication, January 20, 2018). Once the workshop was created, "the powers that be put together a team that was titled the AP Calculus Curriculum, Instruction, and Assessment team" (Brandell, personal communication, January 20, 2018). These team members' names are listed on the inside cover of the book provided to teachers each summer at the AP Summer Institute workshops, and Dr. Brandell is on that team. The team originally consisted of about ten people, of whom only a handful are still active. Further, he has been on the Standards Committee, "which only emerges every five to six years," as one of five high school teachers (Brandell, personal communication, January 20, 2018). Though his credentials clearly show his involvement with the College Board and curriculum, he "hesitates to say 'expert' because others outperform [him]" (2018). Dr. Brandell also teaches the AP Summer Institute Workshops to teachers looking to get AP-certified. Currently, Brandell only teaches AP Calculus BC and his colleague teaches AP Calculus AB.

One thing Dr. Brandell does, as many teachers do, is make data-driven decisions when writing his lessons to ensure his students get the best experience and education possible. It is "important for [him] to give students a high-quality AP experience" and to

have an “internal test to know how [he is] doing” (Brandell, personal communication, January 20, 2018). Brandell not only looks at his students’ semester grades (scores), but runs a five-number summary for each test and at the end of each semester. However, Brandell admits that fourth quarter grades are “quite soft,” as the quarter itself is designed to be soft for students, so he prefers to use the end of third quarter data for his most accurate correlations and to predict scores on the AP exam (Brandell, personal communication, January 20, 2018).

When asked if there is a correlation between semester one and semester two grades, or semester two with the AP exam, Brandell reiterates to focus on third quarter grades. Toward the end of the fourth quarter, many “students are in five AP classes” and are preparing for multiple exams (2018). He wants his students to practice, and often grades scores as credit or no credit. (This is not uncommon in review units. This is discussed more about changes in grading at one Midwestern online provider in the section below.) So, if Brandell were to look at a true second semester overall grade, there is “probably no direct correlation” between semester one and semester two as “second semester grades are artificially high” (Brandell, personal communication, January 20, 2018). Similarly, when asked if there would be a similar correlation for semester grades to his BC students’ AB subscores, Brandell says he uses AB subscores “only for propaganda,” but would not expect it to vary by semester; rather, he again recommends looking at the third quarter scores for the most accurate data (Brandell, personal communication, January 20, 2018).

To protect sensitive student data, the semester scores (percentages) Brandell reported will not be discussed here. All AP exams are graded on a scale from 1 to 5, with

5 being the highest. A 3 can often earn college credit, while a 4 or 5 might allow a student to test out of taking that course in college. Historically speaking, Brandell's students' "median grade is a 4" (Brandell, personal communication, January 20, 2018). Brandell confirmed via email that he typically has 65-70 students per year, teaching two sections of about 33-35 students each. As many students take BC for the "experience and challenge," Brandell finds the median more reliable than the average. In one particular year, students had a median of a 5, but since then, his students "historically hit fours" and this has been "consistent for years" (Brandell, personal communication, January 20, 2018). Brandell is able to draw correlations between student grades and narrow this down to an interval of three percentage points. He says the median of his students fall in this range, and typically students whose final grades are in this range will get a 4 on the AP exam, and he uses this "as a predictor for AP credit" (Brandell, personal communication, January 20, 2018). Dr. Brandell has not run scores for data when it comes to significance, but claims his other trends "are great predictors for who will and how many students will do well" on the AP exam (Brandell, personal communication, January 20, 2018). With that, he can connect "very strong correlations between median grades and first semester" (Brandell, personal communication, January 20, 2018).

Further, Brandell believes in equity and access for all students. When preparing his students for the AP exam, he wants to ensure students not only know what to expect, but do "not get blindsided" by the exam (Brandell, personal communication, January 20, 2018). With that, he proclaims his grading system is a bit different than most teachers'. As mentioned, Brandell uses the whole semester instead of one exam to predict student scores, but he "need[s] the opportunity to ask kids troubling questions" (Brandell,

personal communication, January 20, 2018). He gives students AP practice throughout the year, and firmly believes "the final exam is not the time to give practice AP" (Brandell, personal communication, January 20, 2018). He purposely writes his tests to not cater to students who are (or are not) getting certain grades, but expects their scores to be reflected on the exams themselves. Throughout the semester, Brandell's goal is to "give students ample practice. Free response questions and multiple choice are good ways to give practice without grading" (Brandell, personal communication, January 20, 2018). With this, he gives timed practice in the classroom. He anticipates multiple choice questions will take two minutes each, then projects student success on the AP exam from that. Brandell gives thirty-minute practice multiple choice quizzes, consisting of fifteen questions each. Using this, he "looks around students answering two-thirds of that, so they should expect to get sixteen or seventeen problems right" on the AP exam (Brandell, personal communication, January 20, 2018). To reiterate, he added that he uses the median from these quizzes "to set curves," as he "wants to give the AP experience without a threat to grade" (Brandell, personal communication, January 20, 2018).

When asked whether he feels the practice exams provided by the College Board are weighted with the same questions or types of questions as the actual exams, Dr. Brandell expressed he feels the practice exams are "close enough" but believes it is more a matter of "how you use these, and when" (Brandell, personal communication, January 20, 2018). He cautions that teachers sometimes "overteach the practice tests and that skews … expectation[s] of how kids will do on the [AP] exam" (Brandell, personal communication, January 20, 2018). With that, he encourages using them for students to get the feel and practice of AP questions and anticipates students will do well on those

questions. Moreover, he feels it is important to "teach a concept, then let kids try it, see if they can figure it out, what prompts lead to doing problems certain ways," then discuss it as a class (Brandell, personal communication, January 20, 2018).

At the time of the interview, Brandell wanted to experiment with a few new ideas and teaching methodologies. His goal with the experiment was to provide students with AP questions from previous exams that cover content the students had not yet learned, or only seen part of. Brandell was interested to see how students would "respond to something they've never seen or only seen slivers of, like teaching two-thirds of a topic and then testing" (Brandell, personal communication, January 20, 2018). He added that he "can't use conventional grading for that," so he would "look for the median and scaffold up or down from that" (Brandell, personal communication, January 20, 2018). As there was no follow-up interview and Brandell's students' AP results are not included in this study, it is not yet known whether or not his experiment proved successful.

AP Calculus at One Midwestern Online Provider

The College Board is explicit and transparent in the overlap in the curricula of AP Calculus AB and AP Calculus BC. It is clear that everything in AP Calculus AB is covered in AP Calculus BC, with only one additional unit typically covered in BC and a handful of minor topics in the other units for AP Calculus AB.

Such is the case at one particular Midwestern non-profit service provider of K-12 online courses. The researcher has been a full-time instructor at this online provider since 2014. Sometime between 2010 and 2013 (it is unknown exactly when, even by the course developers), this online provider created its own AP Calculus courses, adapting the content from other online vendors and with the help of a content specialist to write

lessons. As the course development process is quite lengthy and involved, and the AP Calculus courses are so similar, these courses were created to be almost identical, with the exception being the additional units in AP Calculus BC.

Further, the units are separated differently across semesters, as there is more content to cover in AP Calculus BC. The AP Calculus content at this online provider covers seven main topics (units): Functions, Limits and Derivatives, Differentiation Rules, Applications of Derivatives, Integrals, Applications of Integrals, and Differential Equations. AP Calculus AB has four units in each semester. Semester One covers the first four of these units, while Semester Two covers the last three, followed by a review unit.

In AP Calculus BC, though, the first six units listed above are covered in Semester One. Semester Two covers Differential Equations, and includes an additional unit before this to cover Techniques of Integration. There are also two units not included in AP Calculus AB: Parametric and Polar Equations, and Sequences and Series. Lastly, Semester Two includes a review unit. This gives six total units in Semester One and five total units in Semester Two for AP Calculus BC.

Within the seven shared units of AP Calculus AB and AP Calculus BC, there are a handful of additional lessons within units in AP Calculus BC only:

1. L'Hospital's Rule: This topic was already included in the AP Calculus BC curriculum when the courses at the online provider were created. This topic was introduced in AP Calculus AB in 2016 (retrieved July 11, 2018). Thus, the online provider copied the lesson for this topic from AP Calculus BC to AP Calculus AB that school year. It is now a permanent lesson in both courses. This is included in Unit 4: Applications of Derivatives.

2. Newton's Method: Newton's Method is included in AP Calculus BC, Unit 4: Applications of Derivatives. This lesson is not included in AP Calculus AB.
3. Techniques of Integration: This entire unit is included in AP Calculus BC, but this unit as a whole is not included in AP Calculus AB. In AP Calculus BC, this unit includes six lessons. Two of these lessons (Approximate Integration and Arc Length) are included in AP Calculus AB as additional lessons on Unit 6. The remaining four lessons (Integration by Parts, Partial Fractions, Improper Integrals, and Applications to Physics and Engineering) are in AP Calculus BC only.
4. Models for Population Growth: This lesson is included as a fourth lesson in the Differential Equations unit in AP Calculus BC, but is not included in AP Calculus AB. The other three lessons in this unit are identical across courses.

The lesson content for both courses include the same text, script, resources, and homework assignments for the shared lessons. A minor exception for the homework assignments is that there are additional questions in AP Calculus BC to cover the additional topics noted above. The homework assignments were completed through another online vendor, which provided assessment questions aligned to the textbook used in the course. Each unit typically has at least one discussion post for students and/or a project to be completed in that unit. These additional assignments are also identical across AP Calculus AB and AP Calculus BC. As of the 2017-2018 school year, the only unit without a discussion or project in either course is Unit 6: Applications of Integrals in AP Calculus BC. The discussion assignment that is in Unit 6: Applications of Integrals for AP Calculus AB is included in Unit 7: Techniques of Integration of AP Calculus BC.

This is to give students more time, practice, and experience with integrals before completing the additional assignment.

Lastly, through the 2017-2018 school year, the assessments in these two courses were also nearly identical. Similar to the homework assignments, the questions that cover the additional lessons in AP Calculus BC are reflected in the unit multiple choice assessments. Some units simply have an additional question to cover these topics, meaning that unit test is worth more points in AP Calculus BC than in AP Calculus AB, while other unit tests in AP Calculus BC would replace a question on the unit test for AP Calculus AB with a question specific to AP Calculus BC. In fact, this makes the tests more reflective of the AP exam, as discussed earlier. Not all topics can be assessed, or with as many questions, on the AP Calculus BC exam because there simply is more content in the curriculum to assess. Similarly, the free response portions of the assessments from the shared units were identical across AP Calculus AB to AP Calculus BC, with the exception of an occasional extra question for AP Calculus BC students to cover BC-specific content. It should be mentioned here that all multiple choice questions and free response questions on these assessments came from previous AP exams, practice exams, or course descriptions provided by the College Board.

The AP Calculus courses at this particular Midwestern online provider had not been updated for several years before 2017. In fact, the only three major changes to either course included the addition of the lesson on L'Hospital's Rule to the AB curriculum in 2016, the addition of a final exam to cover semester two material in each class, and the removal of the lesson covering the epsilon-delta definition of a limit the same year. (The College Board removed this from the curriculum sometime prior to 2014.) The

instructors of the courses were finding gaps in the lesson content and were able to identify which assignments students often skipped, performed lowly on, and which assignments students asked the most questions on before submitting.

As of the end of the 2016-2017 school year, there were five instructors who taught the AP Calculus courses through this online provider. Four of the five instructors met frequently and compiled a list of assignments that needed to be updated, tweaked, or even removed from the course based on the data compiled. These instructors also ranked which assignments would need immediate attention (assignments that needed to be updated or fixed) compared to assignments that could be simply tweaked and looked at more in-depth at a later date.

These instructors also determined that students could benefit from additional practice of the free response questions. The instructors added practice free response questions to each unit with questions taken from previous AP exams, provided by the College Board.

With that, in the summer of 2017, the following changes were made to the course content in AP Calculus AB and AP Calculus BC:

1. Unit 1 Discussion: The original discussion post in Unit 1 of both courses asked students to find an online resource to help with computing derivatives, integrals, or other math- or science-related interactives. This discussion was neither assessed nor related directly to the content of the course. Further, it was asking students to find and use resources that would not be available to them on the AP exam. This discussion was replaced with an "AP Tips and Tricks" discussion

prompt designed specifically to help students prepare for taking the AP exam; then, this discussion was moved from Unit 1 to the review unit in each course.

2. Unit 2 Discussion: The original discussion prompt asked students to discuss Zeno's Paradox and the decay of carbon atoms. This discussion post was tweaked to be more specific to exponential decay and moved from Unit 2: Limits and Derivatives to Unit 1: Functions, and is placed after the lesson on exponential decay and the Unit 1 Activity (which was an assignment that the instructors deemed was not a high priority to update as of 2017).
3. Epsilon-Delta Proofs: As mentioned above, the College Board removed this content from its curriculum. This assignment was replaced with a new project that asks students to identify derivatives, average and instantaneous rates of change, and discontinuities of a graph. This relates directly to the content still covered in Unit 2.
4. Unit 3 Project: The original project in Unit 3 asks students to apply derivatives and the chain rule to an airplane descending. This project was updated to provide students with more scaffolding and step-by-step guidance to complete the project without changing the final product or expected result.
5. Unit 4 Discussion: The original discussion prompt asked students to discuss competition in mathematics and other classrooms. This prompt was not related to the course content and distracted students from the content of Unit 4. The new discussion prompt asks students to provide the graph of a function and its first and second derivatives, but not to provide the equations or any other indicators of which graph is the original or which derivative. Then, a classmate is supposed to

reply by identifying which graph is the original function and each of its derivatives, with explanation provided.

6. Unit 5 Essay: While the original assignment was titled an "essay," it truly was a project or presentation. This assignment asked students to discuss the history of calculus, either from Isaac Newton's or Gottfried Leibniz's perspective; or to discuss the controversy between who invented Calculus: Newton or Leibniz. This assignment was identified as one that students often plagiarized or felt distracted from the content, but the instructors were unable to create an entirely different assignment in its place. Instead, the prompt was tweaked to allow students to choose from one of three prompts about the history of calculus: the controversy of Newton and Leibniz; discuss the contribution women have made to the invention of calculus; or discuss the impact of Egyptian, Greek, and Indian cultures and their impact on the invention of calculus.
7. Unit 6 Discussion: The original discussion prompt asked students to debate the future of energy and their personal beliefs on global warming and/or conservation of energy as a whole. This was determined to be unrelated to calculus entirely and distracted students from the content. The discussion prompt was updated with a similar prompt to the new Unit 4 discussion, though this time it asks students to post graphs of an original equation, its first derivative, and its antiderivative. This discussion was moved to Unit 7: Techniques of Integration in AP Calculus BC, after students completed more lessons about integrals.
8. Drain Tank Project: This project is in the Differential Equations unit in each course. Similar to the Unit 3 Project, the Drain Tank Project was updated to

include more direct instructions and scaffolding for students, as well as an updated grading rubric.

The projects in Units 9 and 10 of AP Calculus BC were not touched with the summer 2017 updates to these courses.

For these reasons, the data for students who took AP Calculus at this particular online provider in the 2017-2018 school year is kept separate from the data for students who took these courses in prior school years. It is noted explicitly when the data is combined.

Going forward, this online provider continues to update its courses on an annual basis. Changes to the AP Calculus AB and BC courses were scrutinized in the summer of 2018 and the researcher presented a change document to the Administrator of Educational Programs and the Instructional Product Development team. These changes included:

1. Unit 2 Project: The researcher suggested changing this project for students to be more scaffolded and with a more transparent rubric for students.
2. Unit 5 Project: This project is not relevant to mathematical content in Calculus. The researcher recommended changing this project to be more reflective of mathematical content and to be directly tied to standards outlined in the College Board's Course Description.
3. Differential Equations Project: The researcher suggested changing this project completely, providing students with a more relevant real-world example using differential equations and scaffolding the instructions more clearly for students. This project is in Unit 7 in AP Calculus AB and in Unit 8 in AP Calculus BC.

4. Instructional Videos: The researcher found multiple replacement videos to be placed in various lessons throughout both AP Calculus courses, both new and as replacements for existing videos.
5. Pacing Guide: The researcher determined that many students were skipping assignments or earning low scores on particular assignments based on their various due dates throughout the term. The researcher suggested a more detailed pacing guide with hard due dates for students that has all unit work due before the unit test itself, and the two parts of the unit test due on separate days.

Lastly, the Instructional Product Development (iPD) team had already determined that the use of a third-party separate online provider for the homework assignments will be removed from the course. This team worked to integrate all new assignments based on the textbook used for the course to replace the homework assignments, unit tests, and, eventually, the final exams in each semester of both AP Calculus courses. As of August 2018, the scope of iPD's work was simply to "remove [the third-party] from the courses." As the final exams were not already taken through the third-party site, the final exams were not updated with iPD in the same project. Aligning the final exams for each semester will be a separate project later. This will mean the homework assignments will be more correlated in style and rigor to the unit tests and final exams, unlike in previous years where the homework was based on the textbook while the unit tests and final exams utilized questions from past AP exams and were written in a different style than the homework. For students, this could mean higher correlations to unit test and final exam scores. Further, the assessments that were replaced were not removed from the course

completely, so these questions will be free resource documents for the students to use and study from in preparation for the AP exam each spring.

Discrepancy in AP Scores at the Online Provider

The indicated similarities between AP Calculus AB and AP Calculus BC at the particular online service provider outlined above would logically lead to similar AP exam scores. However, history has proven the opposite. In fact, the scores at the online provider are just as discrepant, if not more so, than the national averages for the respective exams.

Upon initially looking into these courses at the online provider, the biggest concern were the scores for 2016. The online provider's AP Calculus AB exam score average was 1.762, which is more than a full point less than the national average of 2.96 (College Board, 2016). However, that same year, the BC average exam score was 3.80 (College Board, 2016) while the online provider's average BC exam score was 3.86. Further, the BC exam's AB subscore at the online provider was 4.302, again higher than the national average AB subscore of 3.98.

In 2016-2017, it seemed this trend reversed. The online provider's AB exam average score (3.133) was *higher* than the national average AB exam score of 2.93 (College Board, 2017) while the online provider's BC exam average score of 3.581 was *lower* than the national average score of 3.78. The AB subscore for the BC students at the online provider was 4.129 and the national average was 4.00. It is unknown why these scores flip-flopped for one school year.

The 2017-2018 school year returned to the trend. The online provider's average AB exam score of 2.476 was lower than the national average score of 2.927 (College

Board, 2018) and the online provider's BC exam score of 3.821 was higher than the national BC average score of 3.748. The AB subscore for the BC exam is not yet reported for the 2018 exam.

With the exception of the 2016-2017 school year, it seems the trend at the online provider is that the AB exam scores are typically lower than the national average, but the BC exam scores are typically higher. The discrepancy between the scores is widened for the online provider. In 2015-2016, the online provider's BC exam average was more than two full points higher than the AB exam average, yet the national average difference was only 0.84. In 2017-2018, the online provider's BC exam average was 1.345 points higher than the AB exam average, while the national difference (0.821) was more than half a point *less* discrepant.

The underlying reasons for these discrepancies are researched further in Chapter 4 and discussed in Chapter 5.

Chapter 3

Study Methodology

This chapter will describe the methodology for gathering data and the methodology for doing research behind three subpopulations in Advanced Placement Calculus AB and BC courses. The researcher wanted to be able to compare historical data for students who have taken these courses in the past, with students who took either Advanced Placement Calculus AB or Advanced Placement Calculus BC in the 2017-2018 school year. The data to compare and draw correlations across the three subpopulations is outlined in Chapter 4 with analysis in Chapter 5.

Recruitment of Participants

As mentioned above, there are three subpopulations for this study. Subpopulation One does not include participants currently enrolled in a calculus course, but rather students who took AP Calculus sometime before the 2017-2018 school year at a particular Midwestern online provider. The participants in this subpopulation agreed to being a part of research and having data stored and shared for research purposes upon enrollment in their online courses. This is included in the provisions with using a particular online provider.

Subpopulation Two includes participants who took AP Calculus in the 2017-2018 school year at the same online provider as Subpopulation One. The only difference between Subpopulation One and Subpopulation Two is the year in which students

enrolled. It is explained in Chapter 2 why the 2017-2018 data is kept separate for this particular research. However, in Chapter 4, some of the data is grouped together. It is noted explicitly when this happens.

Subpopulation Three includes students taking calculus, both AP and non-AP, through this particular online provider or in face-to-face schools. The researcher contacted six local face-to-face high schools to get participants. The researcher reached out to the superintendents, principals, counselors, and registrars of each of these six schools multiple times via email and phone, while also offering to recruit participants in person. We will refer to these schools as School A-F.

School A is a small, private school that only offers AP Calculus AB. This school was willing to participate in the research. The guidance counselor and AP Calculus instructor reached out to students and parents via email, after the researcher recruited students face-to-face in their classroom.

Schools B, C, and D are three large high schools in a single district. The researcher had limited communication with each of these schools. The superintendent gave each individual school the discretion to participate. School B chose to leave the decision to participate in the hands of the individual AP Calculus instructors. The researcher had multiple phone and email conversations with the assistant principal at School C, who said she would try to recruit students before the end of the school year. There was never any confirmation if this happened. The researcher and the assistant principal at School D left multiple messages for each other, but never had a one-on-one conversation to discuss the research.

School E did not respond to any communication for multiple months before opting out of participating in the research.

School F is a large district. School F also did not respond for multiple months, but showed interest. The researcher had a phone conversation with the principal and an email conversation with the AP Calculus instructor at School F. The instructor explained she could have students complete the survey as part of her class after the AP exam was finished, or pass along the survey information to students and parents if a conversation with the researcher was necessary. The researcher confirmed the email included all necessary information. There was no confirmation if this email was passed along to students and/or parents or if School F participated in the survey.

Subpopulation One

There are three subpopulations for this study. The first subpopulation, to be referred to as Subpopulation One, of participants for this study is high school students in AP Calculus, both AB and BC, courses who took AP Calculus sometime before the 2017-2018 school year. The goal of the study is to see if matriculation purposes correlate with final scores and AP exam scores. As it is not possible to have students who took these classes in the past be current participants in a survey, Subpopulation One includes students who took AP Calculus courses through a particular Midwestern non-profit service provider of K-12 online courses before the 2017-2018 school year. Upon enrolling in a course with this provider, the "*reason for enrollment*" is collected into one of five categories: Course Unavailable at Local School, Credit Recovery, Learning Preference of the Student, Scheduling Conflict, Other, or the enroller can choose not to reply. This data is stored by the online provider for research purposes and publications.

This data was then provided by the research institute at the online provider to the researcher. The researcher was also given data for each of these student's final scores for each semester and the AP exam score at the end of the year, for students whose score was reported to the online provider.

Further, the research institute provided data to the researcher breaking down individual student gradebooks. The researcher was then able to take these results and compare not only final semester scores with AP exam scores, but also look for correlations with individual assignment scores, unit tests, and projects.

Subpopulation Two

Subpopulation Two includes students at the same Midwestern non-profit service provider as Subpopulation One, except it is *all* students who enrolled in an AP Calculus course in the 2017-2018 school year. The online provider stored the same data for this school year, but it is kept separate as the AP Calculus courses underwent curriculum changes between the 2016-2017 and 2017-2018 school years. These changes are described in detail in Chapter 2.

This Subpopulation includes *all* students who enrolled in AP Calculus AB or AP Calculus BC in the 2017-2018 school year. These students were also asked to voluntarily be a part of Subpopulation Three. It is not possible for the researcher to know which students did or did not participate in the survey and thus are also part of Subpopulation Three. This does not affect correlations or conclusions as Subpopulations One and Two are treated as historical data and kept separate from the survey data from Subpopulation Three.

Subpopulation Three

The last subpopulation of participants, to be referred to as Subpopulation Three, is students who took calculus in the 2017-2018 school year. The researcher created a survey asking current students to self-report previous math class final scores and the reason(s) they enrolled in their calculus course in 2017-2018. The survey included twenty-one potential reasons a student would have enrolled in his or her course. Students were encouraged to select as many as applicable. The researcher categorized these twenty-one options into the five non-null categories from the online provider to find correlations between past students and current students.

Upon filling out the survey, students were asked to provide an email address and personal identification number or keyword so they would be contacted a second time after the AP exam scores were released in July 2018. A member of the research committee who was not the researcher collected and saved the data from the first round of the survey. This person then contacted the participants and asked them to complete a second survey. This survey asked participants to provide their email address, personal identification number or keyword, their final score for their calculus course, and their AP exam score from the 2018 exam. It also asked for BC students to provide the AB subscore from their exam. This committee member provided all data to the researcher after removing email addresses to protect identity. The researcher then paired participants and their results from the first round of the survey to the second to assign a final course score and an AP exam score with the reason(s) each student enrolled in their calculus course.

Collecting and Separating the Data: Subpopulation One

The data for Subpopulation One was provided from the research institute at the online provider. The research institute pulled the data for three school years (2014-2015, 2015-2016, and 2016-2017) and provided the data for each user enrolled in each section of the AP Calculus courses, for each item or assignment in the gradebook. Overall, this included over 35,000 items of data for the researcher to parse through.

The researcher identified six subgroups of this data pull that elucidate the most accurate reflection of student work. Of the six subgroups, the researcher was able to identify that five will be irrelevant to the scope of this study. The five subgroups the researcher did not find relevant include:

1. Data for the instructors in the course: The instructors are enrolled as users in the online platform, and as the instructors are not actual students enrolled in the AP class. This data would skew the overall population to include non-submissions or zeroes in the scores.
2. Data for students who were dropped from the course: The researcher was able to identify students in the course who had the majority of assignments not submitted. While some students had submissions for assignments, these submissions were few enough (possibly only in the introductory unit or none at all) to where the researcher felt confident that the student had indeed dropped the course.
3. Data for Unit 0: The first unit in the course is an orientation and navigation unit, called Unit 0. (The mathematical content begins with Unit 1.) This Unit 0 data is not indicative of a student's performance in calculus and includes assignments

where students simply have to contact their instructor, indicate intent to take (or not take) the AP exam in the spring, and enroll in the homework vendor platform.

4. Data for discussion assignments: The AP Calculus courses underwent major content changes during the summer of 2017. Thus, the data provided in this data pull was from before these changes occurred. Included in the assignments that were changed were discussion board assignments for students to interact with each other. However, the prompts for these discussions were not aligned to calculus content and would not be indicative of student performance on the AP exam. Discussion prompts included, but were not limited to, asking students for their opinion on competition in classrooms, discussing the future of energy, and finding a resource for an online graphing calculator or other interactives on a specific website.
5. Data for homework scores: While this seems counterintuitive, the AP Calculus courses used a separate online vendor to provide homework assignments, test banks, and practice questions. (The unit assessments were completed in the course itself.) Students had anywhere from ten to infinite submission attempts on each part of each homework question. Thus, a student could try any particular question multiple times until getting the desired score. With this, the majority of students would eventually get full credit on an assignment, or close to it.

    Further, the course had a late policy that changed a few times in this timeframe. Homework scores could include deductions or partial credit scores that would not be consistent across sections of the course, instructors, or even per student, if individual exceptions were made to extend due dates.

The sixth subgroup of this data is the subgroup the researcher decided to focus on and draw correlations from. This subgroup included students' individual scores from the unit tests, both multiple choices and free-response question parts; the review final, which was graded for an actual score in 2014-2015 and 2015-2016, but not included in gradebook totals in 2016-2017; final exam scores for each semester; and the final semester score for each student's semester totals. These semester totals do include the scores of the other gradebook items and assignments that the researcher put into the other five subgroups, as it is comprehensive of each semester as a whole. Overall, this leaves 6,983 individual pieces of data to analyze.

Collecting and Separating the Data: Subpopulation Two

The data for Subpopulation Two was provided separately but in the same manner as Subpopulation One. The researcher was able to parse apart over 13,000 data pieces into seven subgroups. Six of the subgroups include data not used in this study. Three of these six (instructor data, drops, and Unit 0 scores) are removed for the same reasons mentioned for Subpopulation One. The other three subgroups not used are:

1. Homework Scores: Similar to Subpopulation One, this data is not used because homework scores could be inflated and are typically not indicative of student achievement on the AP exam. Unlike Subpopulation One, this tab includes the data from discussion assignments. With the changes made to the course prior to the 2017-2018 school year, the discussion assignments are more aligned to content and relevant for students to complete. However, these discussions are still analogous to the other homework assignments in that students could have multiple submission attempts and the content is not assessed directly on unit tests.

2. Post-AP Module Scores: In the fall of 2017, the Midwestern online service provider created a module to be completed after the AP exam in the second semester of all AP courses. This module was not required for all students, and is not related to the course content. Thus, this data is both not indicative of student achievement, and is unrelated to this study.
3. Review Unit: This unit is completed after new mathematical content is introduced and before students complete the final exam for the second semester. This data was originally separated so the researcher could draw correlations, however this unit was not graded consistently and the review test is not graded for credit. Thus, the researcher felt the data would be skewed or misleading and decided not to use it in the end.

The remaining subgroup include the remaining student data from the gradebook: all unit tests and final exams, as also done for Subpopulation One.

Collecting and Separating the Data: Subpopulation Three

As already discussed, the collection of data for Subpopulation Three was conducted via a two-part online survey where students self-reported final scores for previous math classes and their calculus course from 2017-2018.

The data for Subpopulation Three need not be separated or have questions to be ignored, like some of the irrelevant or misleading data collected in Subpopulations One and Two. The researcher was able to identify which students participated only in the first survey and did not report scores in the second survey. These scores were separated in that they were inconclusive and unable to draw any correlations without having an AP exam

score to correlate. This data is used to report results from round one in Chapter 4 and discussed in Chapter 5.

There were thirty-three responses to the first round of survey data. The researcher was able to determine that two submissions were repeat submissions. One repeat submission included an identical identifier from the student and all data submitted was identical. The second repeat submission had a similar but not identical identifier. However, this particular student wrote in their own reason(s) for taking the course and this reason was not only identical in both submissions, but unique enough that the researcher felt it was okay to remove. The person collecting the data confirmed, maintaining confidentiality, that this was the same student. Thus, thirty-one responses to the first round of the survey are used. Of the thirty-one responses, only one student reported being enrolled in a non-AP Calculus course. This student's particular responses are noted in Chapter 4, and this student did not participate in the second survey.

The second round of data included fifteen responses from the first round of respondents, with no repeats. All fifteen responses were able to be paired with the first round of data for each of these students.

Categorizing the Survey Categories

As mentioned above, the researcher categorized the twenty-one options from the online survey into the five non-null categories from the online provider to find correlations between past students and current students. Each of the five categories is listed below with the online survey options the researcher distinguished for each category. The numbered bullets are the five categories while the lower alpha bullets are the survey options that the researcher felt fell in that respective category.

1. Course Unavailable at Local School
    a. My school did not offer non-AP Calculus.
    b. My school does not offer this course, so I am taking it online.
2. Credit Recovery
    a. This course is credit recovery.
3. Learning Preference of the Student
    a. I took Pre-Calc and did well, so I jumped to BC.
    b. I wanted an AP course.
    c. I wanted an AP math course, but did not want to take Statistics.
    d. I am genuinely interested in calculus.
    e. I wanted to take the class, but do not want to take the AP exam.
    f. I am in non-AP Calculus but plan to take the AB test.
    g. I am in non-AP Calculus but plan to take the BC test.
    h. (Online students only): I like taking courses online.
    i. (Online students only): I learn math better online.
4. Scheduling Conflict
    a. (Online students only): I had a scheduling conflict with another course face-to-face.
    b. (Online students only): I am taking this course in addition to a full load at school.
5. Other
    a. I took Pre-Calc, so non-AP or AB was the next option.
    b. I took AB, so BC was the next option.

c. A trusted adult (parent, counselor, etc.) advised that I take this course.
d. I want to earn college credit.
e. It will look good on my transcript.
f. I needed a senior year math course and this was the "best option."
g. (Online students only): I did not want to take this course with the teacher at my school.

The researcher also allowed students to write in their own responses to why they enrolled in their course. Two students included responses that the researcher failed to include on the original survey:

1. It is a school requirement, but not the student's choice to enroll.
2. Student wanted BC, but school only offered AB.

Neither student included any other reason(s) why they enrolled in their course.

Additionally, one student indicated they are enrolled in AP Calculus AB, but chose the option, "I am in non-AP Calculus but plan to take the BC test." This student only responded to the first round of survey data, though, so this inconsistency does not affect data when comparing AP exam results.

Uniformizing the Survey Data

Prior to students reporting the reason(s) they enrolled in their calculus class in 2017-2018, the students also answered survey questions about prior math courses. The researcher asked students to provide a numerical score for a student's final score (not final exam) in previous math classes, including Algebra I, Geometry, Algebra II, Pre-Calculus/Trigonometry/FST (Functions, Statistics, and Trigonometry), non-AP Calculus,

or previous AP Calculus courses. For all non-AP courses, the researcher only asked for overall annual score, but requested final scores for each term and an AP score for any previous AP Calculus course taken.

However, several students provided letter grades rather than numerical scores. To uniformize this data, the researcher assigned numerical scores to the letter grades, as outlined in Table 3.1. No student reported a letter grade lower than a C in the survey.

Table 3.1. Numerical Scores Assigned to Reported Letter Grades.

Letter Grade	Numerical Score Assigned by Researcher
A	95
A-	92
B+	88
B	85
B-	82
C+	78
C	75

The final question requested the reporting of any previous AP scores, and it led to students providing answers in multiple formats. The researcher asked students to provide a final numerical score for each term, a final overall score, and an AP exam score. Two students provided scores in the format XX/XX/XX or XX/XX/XX/XX, with all values provided being two-digit values. As AP scores only are scored 1 through 5, the researcher felt confident assuming the student who submitted three two-digit values provided three trimester scores, while the other student provided three trimester scores and an overall score for the course. Two students provided a single two-digit score, which the researcher

assumed is a final score for the entire course. One student provided two two-digit scores and one single-digit score, which the researcher assumed were two semester scores and an AP exam score.

Chapter 4

Results

This chapter will report the results of all three Subpopulations, including the data gleaned from both surveys given to Subpopulation Three. The researcher's analysis and interpretation of this data can be found in Chapter 5.

Results: Subpopulation One

Subpopulation One consists of students who took AP Calculus AB or AP Calculus BC at a specific online provider in the 2014-2015, 2015-2016, and 2016-2017 school years.

There are five groups of data the researcher ran for Subpopulation One. The first group of data are the overall averages for students who reported AP exam scores to the online provider. The total enrollment for these courses was much higher, as not every student who enrolled took the AP exam. Further, not every student who took the exam reported their score to the online provider.

Table 4.1. AP Calculus Exam Scores for 2014-2017.

Demographic	n	Average Score	Median Score
AB Exam Score for AB Students	139	3.525	4
BC Exam Score for BC Students	102	3.543	4
AB Exam Score for BC Students Who Also Took AB	98	4.102	5
BC Exam Score for BC Students Who Also Took AB	98	3.531	4

The researcher also ran a correlation to compare the AB and BC exam scores for the 98 students who enrolled in both courses. This linear correlation r-value is 0.8724. (Going forward, any r-value referenced will imply a linear correlation r-value.)

The second group of data the researcher compared for Subpopulation One was individual unit test scores to reported AP exam scores. Each unit test has two parts: a multiple-choice (MC) part and a free-response question (FR) part. The researcher ran each part individually, as well as an overall score for each unit test. The data labeled for AB students correlates their AB unit test scores to their AB exam score. Similarly, BC students' scores were run against their BC exam score. The researcher did not compare unit test scores for students who took both and cross reference AB unit test scores vs BC exam and vice versa. This is because students who took both courses likely had repeat test questions from AB to BC and the scores could be artificially inflated.

Table 4.2. AP Calculus AB Unit Test Scores vs AP AB Exam Scores for 2014-2017.

Correlation	n	r-value
Unit 1 MC to AP AB Exam Score	6	0.632
Unit 1 FR to AP AB Exam Score	6	0.274
Unit 1 Overall to AP AB Exam Score	6	0.540
Unit 2 MC to AP AB Exam Score	6	0.425
Unit 2 FR to AP AB Exam Score	6	0.316
Unit 2 Overall to AP AB Exam Score	6	0.464
Unit 3A MC to AP AB Exam Score	6	0.276
Unit 3A FR to AP AB Exam Score	5	0.384
Unit 3A Overall to AP AB Exam Score	5	0.320
Unit 3B MC to AP AB Exam Score	6	0.701
Unit 3B FR to AP AB Exam Score	5	0.429
Unit 3B Overall to AP AB Exam Score	5	0.739
Unit 4 MC to AP AB Exam Score	6	0.561
Unit 4 FR to AP AB Exam Score	5	0.571
Unit 4 Overall to AP AB Exam Score	5	0.595
Unit 5 MC to AP AB Exam Score	7	0.389
Unit 5 FR to AP AB Exam Score	7	0.414
Unit 5 Overall to AP AB Exam Score	7	0.517
Unit 6 MC to AP AB Exam Score	7	0.369
Unit 6 FR to AP AB Exam Score	7	0.249
Unit 6 Overall to AP AB Exam Score	7	0.553
Unit 7 MC to AP AB Exam Score	7	0.131
Unit 7 FR to AP AB Exam Score	7	0.594
Unit 7 Overall to AP AB Exam Score	7	0.457

Note. The n-values are inconsistent from test-to-test because not all students submitted every assignment.

Table 4.3. AP Calculus BC Unit Test Scores vs AP BC Exam Scores for 2014-2017.

Correlation	n	r-value
Unit 1 MC to AP BC Exam Score	15	-0.208
Unit 1 FR to AP BC Exam Score	15	0.439
Unit 1 Overall to AP BC Exam Score	15	0.060
Unit 2 MC to AP BC Exam Score	15	0.544
Unit 2 FR to AP BC Exam Score	14	-0.103
Unit 2 Overall to AP BC Exam Score	14	0.337
Unit 3A MC to AP BC Exam Score	15	-0.038
Unit 3A FR to AP BC Exam Score	14	-0.089
Unit 3A Overall to AP BC Exam Score	14	-0.065
Unit 3B MC to AP BC Exam Score	15	-0.034
Unit 3B FR to AP BC Exam Score	14	0.376
Unit 3B Overall to AP BC Exam Score	14	0.227
Unit 4 MC to AP BC Exam Score	15	-0.048
Unit 4 FR to AP BC Exam Score	14	-0.233
Unit 4 Overall to AP BC Exam Score	14	-0.169
Unit 5 MC to AP BC Exam Score	15	0.192
Unit 5 FR to AP BC Exam Score	14	-0.221
Unit 5 Overall to AP BC Exam Score	14	6.44E-17
Unit 6 MC to AP BC Exam Score	15	-4.79902E-17
Unit 6 FR to AP BC Exam Score	14	0.094
Unit 6 Overall to AP BC Exam Score	14	0.059
Unit 7 MC to AP BC Exam Score	16	0.325
Unit 7 FR to AP BC Exam Score	16	-0.063
Unit 7 Overall to AP BC Exam Score	16	0.226
Unit 8 MC to AP BC Exam Score	16	-0.058
Unit 8 FR to AP BC Exam Score	16	0.522

Unit 8 Overall to AP BC Exam Score	16	0.172
Unit 9 MC to AP BC Exam Score	16	0.348
Unit 9 FR to AP BC Exam Score	16	0.134
Unit 9 Overall to AP BC Exam Score	16	0.321
Unit 10 MC to AP BC Exam Score	16	0.242
Unit 10 FR to AP BC Exam Score	16	0.418
Unit 10 Overall to AP BC Exam Score	16	0.470

Note. The n-values are inconsistent from test-to-test because not all students submitted every assignment.

The third group of data the researcher compared for Subpopulation One was final exam scores for both semester one and semester two, as well as an overall year score.

Table 4.4. Semester Final Exam Scores vs AP Exam Scores for 2014-2017.

Correlation	n	r-value
AB Semester One Final Exam Score to AP AB Exam Score	5	0.438
AB Semester Two Final Exam Score to AP AB Exam Score	3	0.225
BC Semester One Final Exam Score to AP BC Exam Score	15	0.514
BC Semester Two Final Exam Score to AP BC Exam Score	1	1

Note. Only one student from BC Semester One received a BC Exam Score of a 1. This is not the same student who reported a Semester Two final exam score. If we remove this student from the data set, our n-value drops to 14 and the correlation r-value drops to 0.04. All 14 remaining students received a 3 or higher on the AP exam.

Table 4.5. Semester Final Overall Scores and Year-Long Overall Scores vs AP Exam Scores for 2014-2017.

Correlation	n	r-value
AB Semester One Final Overall Score to AP AB Exam Score	6	0.482
AB Semester Two Final Overall Score to AP AB Exam Score	7	0.572
AB Year-Long Overall Score to AP AB Exam Score	6	0.500
BC Semester One Final Overall Score to AP BC Exam Score	15	-0.052
BC Semester Two Final Overall Score to AP BC Exam Score	16	0.027
BC Year-Long Overall Score to AB BC Exam Score	15	-0.038

The fourth group of data the researcher compared for Subpopulation One included student unit exam scores compared with their final exam and final scores for those semesters. The researcher did not compare unit tests taken in semester one to final scores for semester two or vice versa. As this data includes all students, not just those who reported AP exam scores, the n-values are much higher. Further, the researcher did not compare the two parts of the test individually or as an overall score. These values find a correlation between each individual part of the test to the final scores reported. The n-values also are low for semester two exams because, as mentioned in Chapter 2, the final exam did not exist for some of the years from which data was pulled.

Table 4.6. AP Calculus AB Unit Test Scores vs Semester Exams and Final Scores for 2014-2017.

Correlation	n	r-value
Unit 1 to Semester One Final Exam	265	0.450
Unit 1 to Semester One Final Score	281	0.712
Unit 2 to Semester One Final Exam	266	0.384
Unit 2 to Semester One Final Score	282	0.687
Unit 3 to Semester One Final Exam	527	0.516
Unit 3 to Semester One Final Score	548	0.743
Unit 4 to Semester One Final Exam	264	0.535
Unit 4 to Semester One Final Score	266	0.768
Semester One Final Exam to Semester One Final Score	141	0.690
Unit 5 to Semester Two Final Exam	90	0.151
Unit 5 to Semester Two Final Score	223	0.607
Unit 6 to Semester Two Final Exam	90	0.145
Unit 6 to Semester Two Final Score	224	0.691
Unit 7 to Semester Two Final Exam	90	-0.0004
Unit 7 to Semester Two Final Score	221	0.629
Semester Two Final Exam to Semester Two Final Score	45	0.389

Note. Unit 3 has two separate unit tests, or four parts, throughout the term. This was run as one correlation in this table.

Table 4.7. AP Calculus BC Unit Test Scores vs Semester Exams and Final Scores for 2014-2017.

Correlation	n	r-value
Unit 1 to Semester One Final Exam	310	0.084
Unit 1 to Semester One Final Score	312	0.358
Unit 2 to Semester One Final Exam	308	0.238
Unit 2 to Semester One Final Score	310	0.406
Unit 3 to Semester One Final Exam	615	0.114
Unit 3 to Semester One Final Score	619	0.481
Unit 4 to Semester One Final Exam	308	0.242
Unit 4 to Semester One Final Score	310	0.468
Unit 5 to Semester One Final Exam	307	0.247
Unit 5 to Semester One Final Score	307	0.549
Unit 6 to Semester One Final Exam	305	0.315
Unit 6 to Semester One Final Score	305	0.503
Semester One Final Exam to Semester One Final Score	155	0.416
Unit 7 to Semester Two Final Exam	96	-0.060
Unit 7 to Semester Two Final Score	281	0.491
Unit 8 to Semester Two Final Exam	96	0.232
Unit 8 to Semester Two Final Score	281	0.613
Unit 9 to Semester Two Final Exam	94	0.013
Unit 9 to Semester Two Final Score	279	0.654
Unit 10 to Semester Two Final Exam	95	0.148
Unit 10 to Semester Two Final Score	277	0.583
Semester Two Final Exam to Semester Two Final Score	368	0.260

Note. Unit 3 has two separate unit tests, or four parts, throughout the term. This was run as one correlation in this table.

Lastly, the researcher compared the reason for enrollment provided when the student was added into the course to the student's semester final scores and, if reported, AP exam scores. The overall averages include averages only of students who reported an enrollment reason, not of all students enrolled in the course.

Table 4.8. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2014-2017.

Enrollment Reason: Course Unavailable at Local School			
Semester	n	Average Score	Median Score
AB Semester One Final Score	49	83.29%	90.58%
AB Semester Two Final Score	37	83.70%	90.33%
BC Semester One Final Score	73	90.55%	93.15%
BC Semester Two Final Score	57	86.84%	90.53%
AB Semester One Final Exam	49	79.39%	90.00%
AB Semester Two Final Exam	13	66.15%	66.67%
BC Semester One Final Exam	72	82.34%	82.76%
BC Semester Two Final Exam	30	62.63%	66.19%
AB AP Exam Score	7	3	3
BC AP Exam Score	4	4	4

Table 4.9. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2014-2017.

Enrollment Reason: Learning Preference of the Student			
Semester	n	Average Score	Median Score
AB Semester One Final Score	11	82.03%	88.01%
AB Semester Two Final Score	12	81.02%	90.59%
BC Semester One Final Score	12	92.14%	94.38%
BC Semester Two Final Score	8	83.53%	90.18%
AB Semester One Final Exam	10	75.00%	77.50%
AB Semester Two Final Exam	5	62.67%	73.33%
BC Semester One Final Exam	12	82.00%	84.48%
BC Semester Two Final Exam	5	60.00%	66.67%
AB AP Exam Score	1	1	1
BC AP Exam Score	N/A	N/A	N/A

Table 4.10. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2014-2017.

Enrollment Reason: Scheduling Conflict			
Semester	n	Average Score	Median Score
AB Semester One Final Score	14	75.52%	84.53%
AB Semester Two Final Score	11	80.63%	85.75%
BC Semester One Final Score	3	83.14%	81.78%
BC Semester Two Final Score	4	90.55%	90.80%
AB Semester One Final Exam	12	67.08%	65.00%
AB Semester Two Final Exam	5	42.67%	33.33%
BC Semester One Final Exam	3	63.64%	68.97%
BC Semester Two Final Exam	3	64.44%	66.67%
AB AP Exam Score	3	2.333	1
BC AP Exam Score	2	3	3

Table 4.11. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2014-2017.

Enrollment Reason: Other			
Semester	n	Average Score	Median Score
AB Semester One Final Score	29	86.92%	87.89%
AB Semester Two Final Score	26	80.60%	80.42%
BC Semester One Final Score	25	86.50%	88.44%
BC Semester Two Final Score	22	86.48%	88.80%
AB Semester One Final Exam	29	86.38%	90.00%
AB Semester Two Final Exam	22	66.36%	66.67%
BC Semester One Final Exam	25	74.21%	75.86%
BC Semester Two Final Exam	10	74.00%	76.67%
AB AP Exam Score	3	4	5
BC AP Exam Score	3	4.667	5

Table 4.12. Semester Final Scores, Semester Final Exams, and AP Exam Scores for 2014-2017.

Overall Scores			
Semester	n	Average Score	Median Score
AB Semester One Final Score	103	83.11%	87.89%
AB Semester Two Final Score	86	82.01%	89.00%
BC Semester One Final Score	113	89.63%	92.17%
BC Semester Two Final Score	91	86.62%	90.31%
AB Semester One Final Exam	100	79.50%	85%
AB Semester Two Final Exam	45	63.26%	66.67%
BC Semester One Final Exam	112	79.99%	82.76%
BC Semester Two Final Exam	48	64.84%	66.67%
AB AP Exam Score	See Table 4.1.	See Table 4.1.	See Table 4.1.
BC AP Exam Score	See Table 4.1.	See Table 4.1.	See Table 4.1.

Results: Subpopulation Two

Subpopulation Two included students at the same online service provider as Subpopulation One, except it is all students who enrolled in an AP Calculus course in the 2017-2018 school year. The researcher ran the data in the same five groups as Subpopulation One. Table 4.13 discusses the AP exam scores for students enrolled at the same online provider as Subpopulation One.

Table 4.13. AP Calculus Exam Scores for 2017-2018.

Course	n	Average Score	Median Score
AB Exam Score for AB Students	21	2.476	2
BC Exam Score for BC Students	27	3.778	4

Note. There were no students who took AP Calculus BC in 2017-2018 who had taken AP Calculus AB with the same online provider.

The second data run for the 2017-2018 students also compared individual unit test scores to AP exam scores. However, different from Subpopulation One, the 2017-2018 students' unit test overall scores are not an overall unit test score. The researcher did not compile a single unit test score for each unit. Instead, the correlations run were simply putting all unit test scores for each part into a single correlation, similar to how the data was run for Tables 4.6 and 4.7 in Subpopulation One.

Table 4.14. AP Calculus AB Unit Test Scores vs AP Exam Scores for 2017-2018.

Correlation	n	r-value
Unit 1 MC to AP AB Exam Score	18	0.056
Unit 1 FR to AP AB Exam Score	18	-0.237
Unit 1 Overall to AP AB Exam Score	36	-0.098
Unit 2 MC to AP AB Exam Score	18	0.229
Unit 2 FR to AP AB Exam Score	18	0.164
Unit 2 Overall to AP AB Exam Score	36	0.189
Unit 3A MC to AP AB Exam Score	18	0.199
Unit 3A FR to AP AB Exam Score	18	0.006
Unit 3A Overall to AP AB Exam Score	36	0.113
Unit 3B MC to AP AB Exam Score	18	-0.143
Unit 3B FR to AP AB Exam Score	18	-0.002
Unit 3B Overall to AP AB Exam Score	36	-0.079
Unit 4 MC to AP AB Exam Score	18	0.160
Unit 4 FR to AP AB Exam Score	18	0.216
Unit 4 Overall to AP AB Exam Score	36	0.173
Unit 5 MC to AP AB Exam Score	21	-0.072
Unit 5 FR to AP AB Exam Score	21	0.057
Unit 5 Overall to AP AB Exam Score	42	-0.019
Unit 6 MC to AP AB Exam Score	21	0.056
Unit 6 FR to AP AB Exam Score	21	0.404
Unit 6 Overall to AP AB Exam Score	42	0.199
Unit 7 MC to AP AB Exam Score	21	0.022
Unit 7 FR to AP AB Exam Score	21	0.373
Unit 7 Overall to AP AB Exam Score	42	0.106

Table 4.15. AP Calculus BC Unit Test Scores vs AP Exam Scores for 2017-2018.

Correlation	n	r-value
Unit 1 MC to AP BC Exam Score	27	0.554
Unit 1 FR to AP BC Exam Score	25	0.154
Unit 1 Overall to AP BC Exam Score	52	0.348
Unit 2 MC to AP BC Exam Score	27	0.223
Unit 2 FR to AP BC Exam Score	27	0.029
Unit 2 Overall to AP BC Exam Score	54	0.106
Unit 3A MC to AP BC Exam Score	27	0.174
Unit 3A FR to AP BC Exam Score	27	0.174
Unit 3A Overall to AP BC Exam Score	54	0.170
Unit 3B MC to AP BC Exam Score	27	0.569
Unit 3B FR to AP BC Exam Score	27	0.422
Unit 3B Overall to AP BC Exam Score	54	0.482
Unit 4 MC to AP BC Exam Score	27	0.477
Unit 4 FR to AP BC Exam Score	26	0.432
Unit 4 Overall to AP BC Exam Score	53	0.447
Unit 5 MC to AP BC Exam Score	27	0.406
Unit 5 FR to AP BC Exam Score	27	0.586
Unit 5 Overall to AP BC Exam Score	54	0.463
Unit 6 MC to AP BC Exam Score	27	0.259
Unit 6 FR to AP BC Exam Score	25	0.216
Unit 6 Overall to AP BC Exam Score	52	0.239
Unit 7 MC to AP BC Exam Score	27	0.391
Unit 7 FR to AP BC Exam Score	26	0.022
Unit 7 Overall to AP BC Exam Score	53	0.193
Unit 8 MC to AP BC Exam Score	27	0.248
Unit 8 FR to AP BC Exam Score	27	0.030

Unit 8 Overall to AP BC Exam Score	54	0.162
Unit 9 MC to AP BC Exam Score	27	0.140
Unit 9 FR to AP BC Exam Score	27	0.278
Unit 9 Overall to AP BC Exam Score	54	0.177
Unit 10 MC to AP BC Exam Score	27	0.589
Unit 10 FR to AP BC Exam Score	26	0.316
Unit 10 Overall to AP BC Exam Score	53	0.448

The third group of data the researcher compared for Subpopulation Two was final exam scores for both semester one and semester two, as well as an overall year score.

Table 4.16. Semester Final Exam Scores vs AP Exam Scores for 2017-2018.

Correlation	n	r-value
AB Semester One Final Exam Score to AP AB Exam Score	18	-0.272
AB Semester Two Final Exam Score to AP AB Exam Score	21	0.113
BC Semester One Final Exam Score to AP BC Exam Score	27	0.359
BC Semester Two Final Exam Score to AP BC Exam Score	27	0.281

Table 4.17. Semester Final Overall Scores vs AP Exam Scores for 2017-2018.

Correlation	n	r-value
AB Semester One Final Overall Score to AP AB Exam Score	18	0.024
AB Semester Two Final Overall Score to AP AB Exam Score	21	0.266
BC Semester One Final Overall Score to AP BC Exam Score	27	0.494
BC Semester Two Final Overall Score to AP BC Exam Score	27	0.425

Table 4.18. Semester One vs Semester Two Final Scores for 2014-2018.

School Year(s)	n	r-value
AB 2014-2017	15	0.696
AB 2017-2018	30	0.677
AB 2014-2018	45	0.645
BC 2014-2017	18	0.400
BC 2017-2018	40	0.671
BC 2014-2018	58	0.521
All Overall	103	0.644

The researcher felt compiling all data from 2014-2018, thus including both Subpopulation One and Subpopulation Two, was important to put in a single table for easy navigation.

The fourth group of data the researcher compared for Subpopulation Two included student unit exam scores compared with their final exam and final scores for those semesters. Similar to data for Table 4.6, the researcher did not compare unit tests taken in semester one to final scores for semester two or vice versa. As this data includes all students, not just those who reported AP exam scores, the n-values are much higher. Further, the researcher did not compare the two parts of the test individually or as an overall score. These values find a correlation between each individual part of the test to the final scores reported.

Table 4.19. AP Calculus AB Unit Test Scores vs Semester Exams and Final Scores for 2017-2018.

Correlation	n	r-value
Unit 1 to Semester One Final Exam	84	0.317
Unit 1 to Semester One Final Score	84	0.472
Unit 2 to Semester One Final Exam	84	0.444
Unit 2 to Semester One Final Score	84	0.554
Unit 3 to Semester One Final Exam	168	0.438
Unit 3 to Semester One Final Score	168	0.623
Unit 4 to Semester One Final Exam	84	0.351
Unit 4 to Semester One Final Score	84	0.658
Semester One Final Exam to Semester One Final Score	42	0.768
Unit 5 to Semester Two Final Exam	66	0.254
Unit 5 to Semester Two Final Score	66	0.291
Unit 6 to Semester Two Final Exam	66	0.435
Unit 6 to Semester Two Final Score	66	0.542
Unit 7 to Semester Two Final Exam	66	0.447
Unit 7 to Semester Two Final Score	66	0.475
Semester Two Final Exam to Semester Two Final Score	33	0.643

Table 4.20. AP Calculus BC Unit Test Scores vs Semester Exams and Final Scores for 2017-2018.

Correlation	n	r-value
Unit 1 to Semester One Final Exam	99	0.478
Unit 1 to Semester One Final Score	99	0.655
Unit 2 to Semester One Final Exam	100	0.358
Unit 2 to Semester One Final Score	100	0.597
Unit 3 to Semester One Final Exam	198	0.342
Unit 3 to Semester One Final Score	198	0.572
Unit 4 to Semester One Final Exam	99	0.580
Unit 4 to Semester One Final Score	99	0.755
Unit 5 to Semester One Final Exam	99	0.386
Unit 5 to Semester One Final Score	99	0.593
Unit 6 to Semester One Final Exam	97	0.394
Unit 6 to Semester One Final Score	97	0.611
Semester One Final Exam to Semester One Final Score	50	0.700
Unit 7 to Semester Two Final Exam	79	0.270
Unit 7 to Semester Two Final Score	79	0.275
Unit 8 to Semester Two Final Exam	80	0.125
Unit 8 to Semester Two Final Score	80	0.441
Unit 9 to Semester Two Final Exam	80	0.201
Unit 9 to Semester Two Final Score	80	0.456
Unit 10 to Semester Two Final Exam	79	0.217
Unit 10 to Semester Two Final Score	79	0.411
Semester Two Final Exam to Semester Two Final Score	40	0.424

Lastly, the researcher compared the reason for enrollment provided when the student was added into the course to the student's semester final scores and, if reported,

AP exam scores. The overall averages include averages only of students who reported an enrollment reason, not of all students enrolled in the course.

Table 4.21. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2017-2018.

Enrollment Reason: Course Unavailable at Local School			
Semester	n	Average Score	Median Score
AB Semester One Final Score	19	80.32%	78.12%
AB Semester Two Final Score	17	67.65%	68.91%
BC Semester One Final Score	36	89.13%	92.98%
BC Semester Two Final Score	30	89.34%	91.71%
AB Semester One Final Exam	19	65.16%	66.67%
AB Semester Two Final Exam	17	71.01%	78.57%
BC Semester One Final Exam	36	80.84%	84.48%
BC Semester Two Final Exam	30	75.78%	80.00%
AB AP Exam Score	10	2.1	1
BC AP Exam Score	24	3.958	4

Table 4.22 addresses the enrollment reason of "Credit Recovery." This was not addressed in Subpopulation One, as no students in Subpopulation One indicated "Credit Recovery" as their reason to enroll.

Table 4.22. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2017-2018.

Enrollment Reason: Credit Recovery			
Semester	n	Average Score	Median Score
AB Semester One Final Score	1	80.78%	80.78%
AB Semester Two Final Score	N/A	N/A	N/A
BC Semester One Final Score	2	91.30%	91.30%
BC Semester Two Final Score	N/A	N/A	N/A
AB Semester One Final Exam	1	23.81%	23.81%
AB Semester Two Final Exam	N/A	N/A	N/A
BC Semester One Final Exam	2	87.93%	87.93%
BC Semester Two Final Exam	N/A	N/A	N/A
AB AP Exam Score	N/A	N/A	N/A
BC AP Exam Score	N/A	N/A	N/A

Note. "N/A" indicates there are no students who enrolled for "Credit Recovery" reasons in that particular semester who reported scores for that term.

Table 4.23. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2017-2018.

Enrollment Reason: Learning Preference of the Student			
Semester	n	Average Score	Median Score
AB Semester One Final Score	2	89.53%	89.53%
AB Semester Two Final Score	1	75.03%	75.03%
BC Semester One Final Score	1	91.79%	91.79%
BC Semester Two Final Score	2	49.63%	49.63%
AB Semester One Final Exam	2	78.57%	78.57%
AB Semester Two Final Exam	1	92.86%	92.86%
BC Semester One Final Exam	1	82.76%	82.76%
BC Semester Two Final Exam	2	63.33%	63.33%
AB AP Exam Score	1	5	5
BC AP Exam Score	N/A	N/A	N/A

Table 4.24. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2017-2018.

Enrollment Reason: Scheduling Conflict			
Semester	n	Average Score	Median Score
AB Semester One Final Score	15	82.42%	86.09%
AB Semester Two Final Score	11	66.60%	67.34%
BC Semester One Final Score	4	83.51%	83.00%
BC Semester Two Final Score	7	66.79%	58.99%
AB Semester One Final Exam	15	74.92%	83.33%
AB Semester Two Final Exam	10	63.57%	67.86%
BC Semester One Final Exam	4	72.41%	77.59%
BC Semester Two Final Exam	3	64.44%	66.37%
AB AP Exam Score	5	2.4	3
BC AP Exam Score	2	2.5	2.5

Table 4.25. Semester Final Scores, Semester Final Exams, and AP Exam Scores by Enrollment Reason for 2017-2018

Enrollment Reason: Other			
Semester	n	Average Score	Median Score
AB Semester One Final Score	5	81.47%	80.62%
AB Semester Two Final Score	5	67.80%	66.12%
BC Semester One Final Score	7	84.34%	90.43%
BC Semester Two Final Score	6	76.50%	79.23%
AB Semester One Final Exam	5	57.14%	71.43%
AB Semester Two Final Exam	5	61.43%	57.14%
BC Semester One Final Exam	7	79.80%	82.76%
BC Semester Two Final Exam	6	73.33%	73.33%
AB AP Exam Score	5	2.8	3
BC AP Exam Score	1	2	2

Table 4.26. Semester Final Scores, Semester Final Exams, and AP Exam Scores for 2017-2018.

Overall Scores			
Semester	n	Average Score	Median Score
AB Semester One Final Score	42	81.66%	85.59%
AB Semester Two Final Score	34	67.56%	67.74%
BC Semester One Final Score	50	88.15%	92.26%
BC Semester Two Final Score	45	82.13%	88.59%
AB Semester One Final Exam	42	67.35%	80.95%
AB Semester Two Final Exam	33	67.97%	71.43%
BC Semester One Final Exam	50	80.34%	82.76%
BC Semester Two Final Exam	41	73.98%	80.00%
AB AP Exam Score	See Table 4.13.	See Table 4.13.	See Table 4.13.
BC AP Exam Score	See Table 4.13.	See Table 4.13.	See Table 4.13.

Subpopulations One and Two: T-Test Results

The researcher compiled all enrollments for the 2014-2018 students (a combination of Subpopulations One and Two) and ran two-tailed, unpaired t-tests to compare enrollment reason with AP exam score.

Table 4.27. Enrollment Reasons vs AP Exam Scores for 2014-2018.

Compared Enrollment Reasons	2-tailed, unpaired t-test p-value
AB "Course Unavailable" Compared to "Other"	0.341
AB "Course Unavailable" Compared to "Scheduling Conflict"	0.738
AB "Other" Compared to "Scheduling Conflict"	0.574
BC "Course Unavailable" Compared to "Other"	0.649
BC "Course Unavailable" Compared to "Scheduling Conflict"	0.0496
BC "Other" Compared to "Scheduling Conflict"	0.500
AB and BC Combined "Course Unavailable" Compared to "Other"	0.517
AB and BC Combined "Course Unavailable" Compared to "Scheduling Conflict"	0.072
AB and BC Combined "Other" Compared to "Scheduling Conflict"	0.397

Note. Only one student reported "Learning Preference of the Student" and provided an AP exam score to the online provider. Thus, a two-tailed, unpaired t-test could not be run to compare that individual student to an entire group of other students with different enrollment reasons.

The researcher also compared the scores of certain assignments that changed significantly in the summer of 2017. As outlined in Chapter 2, there were eight assignments that were tweaked, replaced, or removed from the courses. Three of these assignments (Unit 1 Discussion, Unit 4 Discussion, and Unit 6 Discussion) were changed to assignments that did not resemble the previous version and are not comparable. The Epsilon-Delta Proofs assignment was removed from the course. The four remaining assignments that underwent significant changes are outlined in Table 4.28.

Table 4.28. 2014-2017 vs 2017-2018 Assignment Score Averages.

Assignment	2-tailed, unpaired t-test p-value
Unit 2 Discussion	0.056
Unit 3 Project	0.012
Unit 5 Essay	0.004
Drain Tank Project	0.041

Results: Subpopulation Three, Round One

Subpopulation Three consists of students who took AP Calculus in the 2017-2018 school year who also participated in the survey given to all students. As discussed in Chapter 3, thirty-one individual students participated in the first round of the survey. Table 4.29 outlines the basic demographics of these thirty-one students' enrollments. The "online" students only indicate students who took their calculus course through the particular online provider. "Non-online" students took the course in person at their high school.

Table 4.29. Demographics of Subpopulation Three, Round One.

Demographic	n
Online AB Enrollment	13
Non-Online AB Enrollment	9
Online BC Enrollment	8
Online Non-AP Enrollment	1

Note. There were zero non-online students who enrolled in either AP Calculus BC or non-AP Calculus who participated in the survey.

The online non-AP Calculus student is an outlier for the survey. As discussed in Chapter 3, this student reported only one response on the survey as to why they enrolled in their course: "I took Pre-Calc, so non-AP or AB was the next option." This student also reported previous math class scores for Algebra I (95%), Geometry (85%), Algebra II (95%), Pre-Calculus (95%), and non-AP Calculus (75%). The survey was taken during the second semester of the school year, so it can be assumed the 75% for non-AP Calculus was a first semester score, as this is the course the student was currently enrolled in at the time of the survey.

As this student is an outlier, their data is reported here and kept separate from totals reported below.

Further, the one student who reported they had to take AP Calculus as a school requirement did not include any previous math course scores nor any other reasons for enrolling in the course. This student's data is not used in this study.

Lastly, one student reported their only reason for enrollment was that they wanted to take AP Calculus BC, but their school did not offer it, so they had to take AP Calculus AB. This student provided previous math course scores, which are included in the data reported below. All other respondents reported at least one previous math score and at least one of the twenty-one reasons for enrollment on the first survey.

Table 4.30. First Survey Results: Previous Algebra I Scores.

Demographic	n	Average Score	Median Score
Online AB	11	95	95
Non-Online AB	9	95	95
AB Overall	20	95	95
BC Respondents	7	97.57	97
All Respondents	27	95.50	95

Note. All BC respondents took their AP Calculus BC course through the online provider, so there are no Non-Online BC scores to report. Henceforth, all BC responses will be reported as such.

Table 4.31. First Survey Results: Previous Geometry Scores.

Demographic	n	Average Score	Median Score
Online AB	11	92.34	92.75
Non-Online AB	9	94.67	95
AB Overall	20	93.39	95
BC Respondents	7	96.79	96
All Respondents	27	94.27	95

Table 4.32. First Survey Results: Previous Algebra II Scores.

Demographic	n	Average Score	Median Score
Online AB	12	93.42	95
Non-Online AB	9	94.56	95
AB Overall	21	93.90	95
BC Respondents	8	97.75	98
All Respondents	29	94.97	95

Table 4.33. First Survey Results: Previous Pre-Calculus Scores.

Demographic	n	Average Score	Median Score
Online AB	11	93.27	95
Non-Online AB	9	94.89	95
AB Overall	20	94	95
BC Respondents	6	96.5	97
All Respondents	26	94.58	95

Table 4.34. First Survey Results: Previous Non-AP Calculus Scores.

Demographic	n	Average Score	Median Score
Online AB	4	93.75	95
Non-Online AB	1	95	95
AB Overall	5	94	95

Note. Zero BC respondents provided a previous non-AP Calculus score. Thus, all values provided are both for AB respondents and all respondents to this question.

The last course requested for previous scores were for students who had taken AP before the current school year. Three students enrolled in AP Calculus AB provided first term scores only, so it can be assumed these scores were these students' first term scores for the current school year. These values were 95%, 80%, and 80%.

A fourth AB student provided scores for all three previous terms (81%, 95%, and 85%), as well as a final score (82%), but no AP exam score. This student participated in the second round of the survey, but provided values that did not match the values provided in the first round. This student did not indicate their reason for enrollment was for "Credit Recovery." Thus, this student's data is excluded from the previous AP course data, but their reported scores for this school year are included in the data from round two of the survey.

The remaining students who had taken an AP Calculus course previous were all BC students in 2017-2018. This data is reported in Table 4.35 below.

Table 4.35. First Survey Results: Previous AP Course Scores.

Term	n	Average Score	Median Score
First Term	5	94	95
Second Term	5	97.2	97
Third Term	1	98	98
Final Score	2	96.5	96.5
AP Exam Score	4	4.25	5

The twenty-eight AP Calculus students who provided at least one reason for enrollment from the survey collectively provided 150 responses. Four students reported only one reason of the twenty-one provided on the survey. The highest number of reasons chosen was one student who selected eleven of the twenty-one options. No student reported exactly three reasons for enrolling, but students reported any other number of reasons from 1 to 11. The total responses for each option on the survey are reported in Table 4.36 on the next page.

Table 4.36. Total Number of Responses for First Survey Options.

Survey Option	Number of Responses
My school did not offer non-AP Calculus.	8
My school does not offer this course, so I am taking it online.	11
This course is credit recovery.	0
I took Pre-Calc and did well, so I jumped to BC.	2
I wanted an AP course.	17
I wanted an AP math course, but did not want to take Statistics.	5
I am genuinely interested in calculus.	11
I wanted to take the class, but do not want to take the AP exam.	2
I am in non-AP Calculus but plan to take the AB test.	0
I am in non-AP Calculus but plan to take the BC test.	0
(Online only): I like taking courses online.	3
(Online only): I learn math better online.	1
(Online only): I had a scheduling conflict with another course face-to-face.	7
(Online only): I am taking this course in addition to a full load at school.	1
I took Pre-Calc, so non-AP or AB was the next option.	13
I took AB, so BC was the next option.	4
A trusted adult (parent, counselor, etc.) advised that I take this course.	12
I want to earn college credit.	18
It will look good on my transcript.	19
I needed a senior year math course and this was the "best option."	12
(Online only): I did not want to take this course with the teacher at my school.	4
Total	150

Note. As mentioned in Chapter 3, one student selected they are enrolled in non-AP Calculus but plan to take the BC test. However, this student indicated they are actually enrolled in AP Calculus AB. Further, this student confirmed in the second survey that they were enrolled in AB and took the AB exam.

As outlined in Chapter 3, the researcher grouped these survey options into the five categories at the online provider. Using the distinction from Chapter 3, the survey results can be grouped as outlined in Table 4.37.

Table 4.37. Total Number of Responses for First Survey Options by Enrollment Category.

Category	Number of Responses
Course Unavailable at Local School	19
Credit Recovery	0
Learning Preference of the Student	41
Scheduling Conflict	8
Other	82
Total	150

The researcher also broke down the most chosen reasons for enrollment by demographic. This is to compare AP Calculus AB with AP Calculus BC enrollment purposes in Chapter 5. The researcher felt it would be more conducive to look at the three most chosen responses than just a single one, as there is a lot of repetition.

Table 4.38. Most Chosen Responses to First Survey Options by Demographic.

Demographic	n	Top Three Chosen Response
Online AB	9	It will look good on my transcript.
	8	I wanted an AP course.
	8	I took Pre-Calc, so non-AP or AB was the next option.
Non-Online AB	6	I needed a senior year math course and this was the "best option."
	5	I took Pre-Calc, so non-AP or AB was the next option.
	5	It will look good on my transcript.
AB Overall	14	It will look good on my transcript.
	13	I took Pre-Calc, so non-AP or AB was the next option.
	12	I wanted an AP course.
BC Respondents	7	I want to earn college credit.
	6	My school does not offer this course, so I am taking it online.
	5	It will look good on my transcript.
	5	I wanted an AP course.
	5	I am genuinely interested in calculus.
All Respondents	19	It will look good on my transcript.
	18	I want to earn college credit.
	17	I wanted an AP course.

Results: Subpopulation Three, Round Two

Fifteen students responded to the second round of the survey. All fifteen students were participants in the first survey, as the second survey was only sent to participants from round one.

Table 4.39. Demographics of Subpopulation Three, Round Two.

Demographic	n
Online AB Enrollment	6
Non-Online AB Enrollment	6
Online BC Enrollment	3

The second survey asked students to report final semester scores.

Table 4.40. Second Survey Results: Semester One Scores for 2017-2018.

Demographic	n	Average Score	Median Score
Online AB	6	84.92	88.75
Non-Online AB	6	94	93.5
AB Overall	12	89.46	89.25
BC Respondents	3	90.33	93
All Respondents	15	89.63	90.5

Table 4.41. Second Survey Results: Semester Two Scores for 2017-2018.

Demographic	n	Average Score	Median Score
Online AB	6	85.33	89
Non-Online AB	6	92.08	94
AB Overall	12	88.71	90
BC Respondents	3	88	87
All Respondents	15	88.56	90

Table 4.42. Second Survey Results: Semester One vs Semester Two Scores for 2017-2018.

Demographic	n	r-value
Online AB	6	0.985
Non-Online AB	6	0.935
AB Overall	12	0.952
BC Respondents	3	0.781
All Respondents	15	0.942

The second survey also asked students to report their AP exam scores. BC students were also asked to provide their AB subscores from the exam.

Table 4.43. Second Survey Results: AP Exam Scores.

Demographic	n	Average Score	Median Score
Online AB	6	3.167	3
Non-Online AB	6	3.333	3
AB Overall	12	3.25	3
BC Respondents	3	3.667	4
All Respondents	15	3.333	3
BC Respondents: AB Subscore	3	3.667	4

Note. The BC respondents' AB subscores each matched their individual BC exam scores.

The researcher also compared previous non-calculus math course scores to AP exam scores.

Table 4.44. Second Survey Results: Previous Non-Calculus Math Courses to AP Exam Scores.

Previous Math Course	n	r-value
Algebra I	13	0.443
Geometry	14	0.631
Algebra II	14	0.444
Pre-Calculus	13	0.638

One of the respondents to the second survey was the student from round one who provided neither previous course scores nor any of the twenty-one reasons for enrollment. This student's data has been removed from the data set going forward. Removing this student from the data set actually increases the averages for both AB and overall for the round two data (semester scores and AP exam score).

A second response in the second round of data includes the student who provided previous scores, but whose given reason for enrollment was that they wanted to take BC, but their school did not offer it. As this student adds no data to the reasons for enrollment, their data is removed from the data set to compare reasons for enrollment to semester and AP exam scores. Once again, removing this student from the data set increases the overall averages for semester one scores and AP exam score, but the semester two score average dropped. The medians for semester one and AP exam scores increased, and the median remained the same when removing this student.

Of the thirteen remaining students whose data is used in round two, these students contributed 76 of the original 150 responses. Each student provided at least two

responses, with the highest number of options selected being the student who chose eleven of the twenty-one reasons for enrollment.

Table 4.45. Responses to First Survey Options by Students Who Responded to Second Survey.

Survey Option	Number of Responses
My school did not offer non-AP Calculus.	6
My school does not offer this course, so I am taking it online.	5
This course is credit recovery.	0
I took Pre-Calc and did well, so I jumped to BC.	1
I wanted an AP course.	8
I wanted an AP math course, but did not want to take Statistics.	1
I am genuinely interested in calculus.	6
I wanted to take the class, but do not want to take the AP exam.	0
I am in non-AP Calculus but plan to take the AB test.	0
I am in non-AP Calculus but plan to take the BC test.	0
(Online only): I like taking courses online.	2
(Online only): I learn math better online.	1
(Online only): I had a scheduling conflict with another course face-to-face.	4
(Online only): I am taking this course in addition to a full load at school.	0
I took Pre-Calc, so non-AP or AB was the next option.	8
I took AB, so BC was the next option.	2
A trusted adult (parent, counselor, etc.) advised that I take this course.	6
I want to earn college credit.	9
It will look good on my transcript.	10
I needed a senior year math course and this was the "best option."	5
(Online only): I did not want to take this course with the teacher at my school.	2
Total	76

Table 4.46. Responses to First Survey Options by Enrollment Category by Students Who Responded to Second Survey.

Category	Number of Responses
Course Unavailable at Local School	11
Credit Recovery	0
Learning Preference of the Student	19
Scheduling Conflict	4
Other	42
Total	76

Table 4.47. Most Chosen Responses to First Survey Options by Students Who Responded to Second Survey.

Demographic	n	Top Three Chosen Response
Online AB	4	It will look good on my transcript.
	4	I took Pre-Calc, so non-AP or AB was the next option.
	4	I wanted an AP course.
	4	My school did not offer non-AP Calculus.
Non-Online AB	4	I needed a senior year math course and this was the "best option."
	4	I took Pre-Calc, so non-AP or AB was the next option.
	4	It will look good on my transcript.
AB Overall	8	It will look good on my transcript.
	8	I took Pre-Calc, so non-AP or AB was the next option.
	6	I wanted an AP course.
	6	I want to earn college credit.
BC Respondents	3	I want to earn college credit.
	3	My school does not offer this course, so I am taking it online.
	2	It will look good on my transcript.
	2	I wanted an AP course.
	2	I am genuinely interested in calculus.
	2	I took AB, so BC was the next option.
All Respondents	10	It will look good on my transcript.
	9	I want to earn college credit.
	8	I wanted an AP course.
	8	I took Pre-Calc, so non-AP or AB was the next option.

The researcher compiled all data from the second survey and ran two-tailed, unpaired t-tests to compare enrollment reason with AP exam score. If a student provided at least one of the twenty-one reasons for enrollment in any given category, their AP exam score was included in that category. (For example, if a student indicated they wanted an AP course, but did not necessarily indicate they were genuinely interested in calculus, they are still counted in the "Learning Preference of the Student" category.)

As expressed, students were allowed to choose multiple reasons for enrollment. Thus, some student scores were compared against themselves in the t-tests. As the researcher did not ask students to rank enrollment reasons, it is not possible to discern a single category to include the scores.

Table 4.48. Enrollment Reasons vs AP Exam Scores.

Compared Enrollment Reasons	2-tailed, unpaired t-test p-value
AB "Course Unavailable" Compared to "Learning Preference of the Student"	0.690
AB "Course Unavailable" Compared to "Other"	0.813
AB "Course Unavailable" Compared to "Scheduling Conflict"	0.462
AB "Learning Preference of the Student" Compared to "Other"	0.444
AB "Learning Preference of the Student" Compared to "Scheduling Conflict"	0.261
AB "Other" Compared to "Scheduling Conflict"	0.458
AB and BC Combined "Course Unavailable" Compared to "Learning Preference of the Student"	0.718
AB and BC Combined "Course Unavailable" Compared to "Other"	0.803
AB and BC Combined "Course Unavailable" Compared to "Scheduling Conflict"	0.232
AB and BC Combined "Learning Preference of the Student" Compared to "Other"	0.495
AB and BC Combined "Learning Preference of the Student" Compared to "Scheduling Conflict"	0.130
AB and BC Combined "Other" Compared to "Scheduling Conflict"	0.239

Note. Every single student chose at least one reason in the "Other" category. Thus, all t-test comparisons run with "other" include all scores provided. Also, each of the three BC respondents chose at least one reason from the "Course Unavailable at Local School," "Learning Preference of the Student," and "Other" categories. These t-tests could not be conducted.

The researcher then ran two-tailed, unpaired t-tests comparing only the most chosen enrollment reasons by demographic. To compare each enrollment reason individually would require 210 total comparisons per demographic.

Table 4.49. Most Chosen Enrollment Reasons vs AP Exam Scores.

Groups Compared	2-tailed, unpaired t-test p-value
AB "It will look good on my transcript" Compared to BC "I want to earn college credit."	0.968
AB "I took Pre-Calc, so non-AP or AB was the next option" Compared to BC "I want to earn college credit."	0.600
AB "I wanted an AP course" Compared to BC "I want to earn college credit."	0.769
AB "I want to earn college credit" Compared to BC "I want to earn college credit."	1.000

Lastly, the researcher compared the AP exam scores for students who took their AP Calculus course online versus those who did not.

Table 4.50. AP Exam Scores for Online vs Non-Online Students from Second Survey.

Groups Compared	2-tailed, unpaired t-test p-value
AB Online vs Non-Online	0.684
Overall Online vs Non-Online	0.790

Chapter 5

Discussion and Conclusion

This chapter will discuss and analyze the data presented in Chapter 4. Additionally, this chapter will connect the results from Chapter 4 to the information presented in Chapter 2. Then, conclusions and future exploration opportunities will be presented for further consideration.

Discussion: Results from Subpopulations One and Two

While Subpopulations One and Two were run separately, it is important to note that these Subpopulations truly are identical with only one difference: the year(s) from which the data was pulled. There are other key factors to consider when analyzing this data.

As mentioned in Chapter 2, there were some changes made to policies, assignments, and assessments over the years in the AP Calculus courses at the online provider. These discrepancies could easily lead to skewed scores and conclusions. Possible grading discrepancies could include, but are not limited to:

1. Late Grades: AP courses at the online provider are the only courses that have hard due dates. For several years, applying a reduction in score was left to instructor discretion. Once a late grade policy was put in place, the verbiage of this policy left it open to some interpretation. Even though instructors were asked to follow this policy, it was not followed consistently across sections, courses, or

departments. And, there is no guarantee all instructors followed this policy and applied the reduction in score to late submissions.

2. Resubmission Policies: Similar to the late policy, resubmissions of assignments for credit have been left to teacher discretion. Thus, some students' scores might be artificially inflated because one instructor allowed for resubmission or test corrections whereas another instructor of the same course might not have.
3. Missing Assignment Scores: If a student fails to submit an assignment, typically the score remains blank in the gradebook. In a final score, this is calculated identically to a zero being entered in the gradebook for that student, so it does not affect the student's overall semester scores. (The semester final scores are calculated simply as number of points earned out of total points available in the course. A student who fails to submit an assignment has thus earned zero points, which is equivalent in the final score to having a zero entered.) However, if an instructor filled in a zero for a missing assignment, it affects the number of submissions and thus averages and medians for individual assignments or assessments reported.
4. Extra Credit: The online provider has a company-wide policy to not award extra credit or allow students to earn more than 100% on an individual assignment. However, the online grading system does not prevent this. There are assignment scores included in the data where students earned more than 100% of the available points. It is unknown if this was a breach of policy regarding extra credit or a simple mistake on the instructor's part, accidentally hitting a wrong button when entering scores or another mistake.

One other important factor to consider is that the AP exam is not graded based on a percent. To reiterate, earning a 60% on the AP exam one year could be an AP exam score of a 2, while a tougher exam in another year could mean a 60% earns a 4. Comparing school years can be difficult if AP percentages are not considered, however this data is not provided to be compared.

Looking at the AP exam scores for 2014-2018 (Tables 4.1 and 4.13), it is important to note that the averages for every demographic are less than the median for the same demographic, except in one instance: the 2017-2018 AP Calculus AB students. One contributing factor could be that this school year is a small sample size (n=21) compared to looking at several years at a time. It also could just be an outlier and not representative of years as a whole, as Table 4.1 suggests.

However, looking at each of these two tables, it can be reasonably assumed that each cohort of students has students who perform lowly or poorly on the exams who bring the average down, while the majority of students outscore the average, thus driving the median up. This implies the majority of students are scoring above the mean.

It is important to note that students who took both AP Calculus AB and BC sometime 2014-2017 at the online provider had a linear correlation r-value of 0.8724. Using the industry standard of 0.7 implying a strong correlation, it can be reasonably assumed that students who take both courses can predict their BC score based on what they earned on the AB exam.

Typically, AP Calculus AB students perform lowly on AP exams while the AP Calculus BC students are among the top averages for all AP exams (with an AB subscore even higher). In May 2018, the average AP Calculus AB exam score was 2.927 and the

AP Calculus BC exam score was 4.04 (College Board, 2018). Looking at individual school years' scores in the past, the online provider's AP Calculus AB students have lower averages than the national AB exam average while the BC students outperform the national BC exam average. It looks as though 2016-2017 is an exception to this rule for both the AB and BC students, but this still does not explain why there is a discrepancy between AB and BC consistently each year. The researcher's anticipation was that the enrollment purpose would be an indicator, hypothesizing that students who have more internal motivation instead of outside pressure or factors would score higher or were more likely to enroll in BC than AB.

With hopes of finding underlying reasons based on performance that could possibly lead to the score discrepancy, the researcher broke down each unit test in both AP Calculus AB and AP Calculus BC and compared these scores to AP exam scores (Tables 4.2, 4.3, 4.14, and 4.15). Looking at each unit individually, no single unit seems to have a strong correlation to the overall AP exam score. One particular unit (Unit 3B: the second half of the Differentiation Rules unit) shows the highest correlation for AB students only, and only for 2014-2017. This same unit showed almost no correlation in 2017-2018, and in fact had a negative correlation in 2017-2018 for the AB students in this same unit.

Further, synthesizing the units into their individual semesters, there also is no strong correlation between semester exams, semester scores, and AP exam scores (Tables 4.4, 4.5, 4.16, and 4.17).

As none of the individual units or semesters correlate to AP exam scores, it can be questioned whether or not students are adequately prepared for the AP exam with the

coursework itself. The researcher then looked at comparing the unit tests to the semester exams (Tables 4.6, 4.7, 4.19, and 4.20). Historically speaking, the AB students showed a strong correlation for three of the first four units (Unit 1: Functions, Unit 3: Differentiation Rules, and Unit 4: Applications of Derivatives) to semester one scores. The AB students from 2017-2018 did not follow this pattern for any unit in either semester. However, the semester one final exam showed a strong correlation to the semester one final score in both Subpopulations. This could be attributed to the final exam being worth more points than an individual unit test or simply that AB students' final exams really do correlate with final scores.

The BC students showed no correlation for individual units or semester exams in 2014-2017. The 2017-2018 BC students had one unit (Unit 4: Applications of Derivatives) that showed a strong correlation to the semester final score, and also showed a strong correlation between the semester one final exam and final score. This, again, could be because the exam is worth more points or truly that students show a correlation.

It is interesting to note that none of the four demographics show any strong correlations between semester two material, neither units nor exams, and final scores. Considering Dr. Brandell's argument that fourth quarter scores are artificially inflated and students typically have a lot of AP practice and review at the end of the year, it is not surprising that the online provider's students also do not show a correlation of unit work to final scores. Referring back to the possible grading discrepancies mentioned at the beginning of this chapter, students' final scores for semester two possibly being artificially inflated due to credit-or-no-credit grading, waiving of the late policy, or extra

credit, would all distract from a true correlation value for the second semester's units scores to final scores.

Table 4.18 discusses these four demographics one step further and looks for correlations between semester one and semester two final scores. While some years show moderate correlations (or strong correlations when rounded to one decimal place), the overall correlation is not strong enough to make a conjecture. The sample size here is low for four total school years, as not all students took both semesters of the courses each year, but it again is not surprising that there is no strong correlation because the second semester scores are artificially inflated. Moreover, the students who perform poorly in the first semester likely dropped the course at the semester. Thus, the scores for the students who provide both scores for both terms likely had higher first semester scores to begin with, giving a sample bias in this statistic. On the other hand, students who joined at the semester also would not have two semesters' worth of scores to report. It can be assumed students who join at the semester are likely stronger students who hope to gain extra knowledge or practice before taking the AP exam, and thus would also artificially inflate average scores in the second term.

With the unit scores and semester scores lacking a strong correlation to AP exam scores, the researcher compared the semester exam scores and AP exam scores based on reasons for enrollment (Tables 4.8-11, 4.21-4.25). For Subpopulation One, almost all of the average scores are less than the median score for each group. This shows that a few outlier students bring the averages down but the majority of students outperform the average, regardless of their enrollment reason. However, as a whole, it is important to note that students whose course was unavailable at their local school outperformed

students who had a learning preference to enroll in the course except for one group (BC Semester One Final Score). This is counterintuitive to the researcher's hypothesis. As already stated, the researcher anticipated students with a learning preference would show intrinsic motivation and thus would outperform students enrolled for other purposes, though the data for 2014-2017 shows otherwise.

Subpopulation Two, however, does not show this as an overarching pattern. In fact, there are no two categories that show any patterns to mimic this.

It is important to note that when looking at both final exam scores and semester final scores in both Subpopulations, all overall scores show the averages are below the medians (Tables 4.12 and 4.26), regardless of enrollment reason.

Breaking each reason for enrollment down further, when the patterns can be noticed that certain reasons outperform others, the question remains if this performance is statistically significant. To determine significance, the researcher uses an industry standard of a p-value less than 0.05. Using this p-value, only one subgroup (Table 4.27) shows statistical significance between AP exam scores: BC "Course Unavailable" compared with "Scheduling Conflict." This shows that students who take AP Calculus BC because the course is unavailable at their local school significantly outperform their peers who enroll due to a scheduling conflict on the AP exam. Going with the researcher's hypothesis, students who enroll because the course is unavailable could prefer to be in the course compared to their counterparts who had scheduling conflicts, and thus the hypothesis that students with higher motivation or preference to be in the course do significantly outperform their counterparts.

Further, one other subgroup in Table 4.27 could show significance. The t-test run was two-tailed. The combined AB and BC scores for these same two enrollment reasons ("Course Unavailable at Local School" and "Scheduling Conflict") would show significance if this test were one-tailed. A p-value of 0.072 would be cut in half to 0.036.

Discussion: Results from Subpopulation Three

Chapter 2 discusses that the researcher contacted several school districts with hopes of reaching hundreds of calculus students in the 2017-2018 school year. Unfortunately, this did not happen, and only thirty-one students chose to participate. Nevertheless, the results from Subpopulation Three are important results to look at, though might not be representative of all students who opted to not participate, nor of all calculus students as a whole. The low turnout for the survey (broken down in Table 4.29) could include omission bias, response bias, non-response bias, among other possible biases that skew the data or lead to small sample size. This is further compounded with the fact that the second survey was only offered to students who completed the first survey, decreasing the possible sample size even further (Table 4.39).

There are some interesting patterns when looking at the previous math course scores reported by Subpopulation Three. It is important to mention again that some students did not provide numerical scores, so the researcher had to assign values (Table 3.1) to find averages and medians. As the value assigned by the researcher is likely a floor for possible student scores, these values are likely lower than the true scores for students from Subpopulation Three. Thus, this could explain why many averages are greater than the median scores for some demographics. For example, this is the case for all averages reported in Table 4.30 for previous Algebra I scores. This pattern is also true

for BC students' geometry scores (Table 4.31). However, all other reported scores in Tables 4.31-4.34 have medians greater than the averages. This is not surprising, as students who continue to succeed in math throughout high school would be more likely go on to take an AP math course, compared to their peers who discontinue taking math beyond the required credits for graduation or do not perform well and would enroll in an elective instead. Further, as several students report, one reason many students enrolled in their math course in 2017-2018 was because it was simply the next course. Whether or not students know other options were available is unknown. Similarly, it is unknown if they had to enroll due to school policy (which one student did indicate, but no other students added this when they chose the options on the survey). So, students who do well in Algebra II might have no other option than to continue to Pre-Calculus or a similar course, and onto some calculus course beyond that.

Though these previous math course scores could be indicators of enrolling in AP, Table 4.44 shows that previous math course scores do not predict AP exam scores. The course with the highest correlation is Pre-Calculus, which is not surprising, but is not a strong correlation or an indicator enough to rely on this information to predict an AP exam score. This could be broken down further with larger sample sizes or in future years to see whether previous math course scores show a difference between predicting AB versus BC exam scores, but this was not done for this study.

In aforementioned paragraphs and Chapter 2, it is discussed that the second semester scores for AP students are typically artificially high. This pattern continues into Table 4.35, where all term score medians are greater than the averages, except in the second term. However, Table 4.35 addresses previous courses as reported by students.

For the 2017-2018 students, the pattern is actually the opposite. Tables 4.40 and 4.41 show averages decrease from semester one to semester two, though the medians increase.

Regardless of the course, all demographics show extremely strong correlations between semester one and semester two scores, however, as reported in Table 4.42. This differs from Table 4.18, where previous students' scores did not show this. A few reasons to explain this discrepancy could again be non-response bias to the survey, small sample numbers, or demographics. In Table 4.18, the scores reported have a higher proportion of AP Calculus BC students reporting scores whereas Subpopulation Three was heavily weighted with AB student responses. Further, Subpopulation Three also only includes students who took the AP exam and not all AP students as a general population.

Looking further into the researcher's hypothesis, it cannot be determined what students' "other" reasons for enrolling are (Table 4.37). Breaking down what these "other" options could be, Table 4.36 offers possible reasons. The researcher was reminded of at least two reasons not listed that students provided independently, and this list could be expanded with a larger sample of students. However, without knowing the "other" reasons for certain, the next-highest category with reasons for enrollment is "Learning Preference of the Student," indicating some student-centered motivation or intrinsic reason to take the course. Table 4.38 breaks these down even further by demographic, hoping to find enrollment reasons for AP Calculus AB students separate from AP Calculus BC students.

In order to compare the reasons provided in these tables with AP exam scores, the researcher broke down which reasons the participants from the second survey provided (Tables 4.45 and 4.46) with their reported exam scores (Table 4.43). The most popular

reasons reported are recorded in Table 4.47. Again using the industry standard p-value of 0.05, Subpopulation Three returned no statistically significant comparisons between enrollment reason categories (Table 4.48) nor by most chosen responses (Table 4.49). The closest comparison shows a difference between students in both AB and BC who enrolled for their own learning preference when compared to a scheduling conflict. While this p-value (0.130) is not statistically significant, running this as a one-tailed t-test or with more respondents could pose the argument that students who enroll for intrinsic reasons are more likely to outperform their peers who have scheduling conflicts on the AP exam.

Lastly, while only one online provider was used in this study, Table 4.50 shows no significance between taking an AP Calculus course online or in a local district.

Conclusions

While very few correlations and t-tests run for this study show statistically significant results, there is plenty of information that can be gleaned from these results. When considering individual assignments and improving the course(s) themselves, Table 4.28 is an indicator that students do show a change in performance on assignments when these assignments are altered. (Table 4.28 shows three of four assignments showed statistically significant changes in scores, and the fourth assignment would also show statistical significance if compared with a one-tailed t-test.) It cannot be proven through the particular online provider that only four assignments made an impact on student AP exam scores, but over time, there might be a shift. Chapter 2 discusses the past changes to assignments, but the changes made in Summer 2018 could show other changes to AP exam scores (for better or worse). It is possible that in future years, these scores may

show a correlation to AP exam scores. It is important for instructors of any school or institution to collect data and reflect annually on what works for students and how to improve instruction and practice to see student success increase.

It also seems that, at least for AP Calculus AB students, the perception is that AB is the course that follows Pre-Calculus. It is unknown whether the perceptions is also that AB must be taken before BC. However, as online learning is still a realm of uncertainty to a lot of students, parents, and schools, students may not realize they can enroll in AP Calculus BC through a provider (online or not) outside of their local district, if the district does not provide all options of calculus courses.

Without knowing each of the student's true motivation(s) to take their particular calculus course, we cannot prove with this study that motivation is necessarily a factor nor conclude that AP Calculus BC students will always outperform AP Calculus AB students. This study provides a small window into this realm, and while some conjectures can be made that intrinsic motivation, enrollment reasons, and previous perceptions of which class students take next all contribute and could moderately predict a student's AP exam score, this study should be performed annually and on a much larger scale.

Moreover, the motivations for student enrollment may differ among schools or states that have different graduation requirements. Non-public schools are not required to adhere to state guidelines for graduation, so students in non-public schools may have other motivation to take or not take certain courses. It would be best to open this study in ripples, comparing the local districts in an entire county or intermediate school district first, then across an individual state, before comparing nationally.

As scores do tend to seem consistent, to protect the integrity of the exam, the researcher feels the College Board has no need to change its curriculum nor release more data publicly. It could be conducive to individual schools or instructors to see individual breakdowns of student performance on the AP exam, though. If an instructor can see their students all performed lowly on a specific question, question type, or standard, that particular instructor could alter their teaching in subsequent years to improve student learning and scores.

Future Exploration Opportunities

This study was designed to look at a specific scope of options. The data gleaned from previous school years as well as the surveys in 2017-2018 offer a lot of other avenues to explore that this study does not consider. Among these include correlating previous math course scores with AP exam scores: This study had only fifteen respondents to the second survey. These correlations could be run to see if previous math courses predict AP exam scores or not. The survey also included twenty-one options for students to choose their reason(s) for enrollment. When comparing each reason to one other, there are a possible 210 t-tests to be run for each enrollment reason. The researcher did this by category instead, but running each individual reason against the others could provide deeper insight into which particular reason(s) show statistical significance. These reasons could also be broken down one step further to compare AB and BC enrollments.

Going forward, this study could be expanded in future years in multiple ways. The first suggestion the researcher has is to offer the survey to more students over multiple years. It is difficult to make educated comparisons and conclusions when comparing multiple years of categorized data with only one year of specific data. Further,

as grading policies and other policies implemented for a longer duration at the particular online provider, the scores will be more accurate to reflect student success. Uniformizing this data will make it easier to compare on a provider-level. This gives clout as to why Dr. Brandell's data is typically standard as well, as his data reflects only his teaching and classroom and not all teachers in his building or district.

Using one provider's data is also important for individuals at that particular provider. With the changes made in Summer 2018, it will be important to compare data going forward to see which changes are or are not statistically significant to student success and learning. This can be expanded to encouraging all instructors to compare results annually to improve, as Dr. Brandell has done in his own practice. At the particular online provider used in this study, data could have been provided further to find correlations not just at the unit level, but to dig deeper into specific assessment questions or lessons show indicators of student success. This could lead to minor tweaks in changing lessons, assessments, or exams instead of entire assignment replacements.

It also would be useful to compare data from other online providers and not just the one used in this study. This could open more research into online learning, the delivery of Advanced Placement courses online, and how that is different from being in a physical classroom. The College Board does not allow practice tests to be delivered online, so as of 2018, the online providers have fewer resources and opportunities to give their students the true "AP experience" and practice that students who take the courses in their local districts do.

Should this study be replicated in future years, it also could provide more parameters around student responses to the survey. The first recommendation the

researcher has is to add other options, giving more than the twenty-one the researcher conjured. However, this would lead to even more potential tests and comparisons to run. One option to limit this is to put a maximum number of options students can choose. This study asked students to select all that apply, but it would also work to force students to elect only a certain number of options and/or to rank the options they select. This can give more insight to researchers as to why students enroll or what a student's true motivation is upon enrollment.

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