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**THE INFLUENCE OF THE AMOUNT OF INSTRUCTIONAL DAYS
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STUDENTS' ADVANCED PLACEMENT (AP) CALCULUS EXAM
SCORES**

Robert M. Fiore

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THE INFLUENCE OF THE AMOUNT OF INSTRUCTIONAL DAYS AND
AMOUNT OF INSTRUCTIONAL TIME ON HIGH SCHOOL STUDENTS'
ADVANCED PLACEMENT (AP) CALCULUS EXAM SCORES

A dissertation submitted in partial fulfillment
of the requirements for the degree of
DOCTOR OF EDUCATION
to the faculty of the Department of
ADMINISTRATIVE AND INSTRUCTIONAL LEADERSHIP
of
THE SCHOOL OF EDUCATION
at
ST. JOHN'S UNIVERSITY
New York
by
Robert M. Fiore

Submitted Date Monday, March 9, 2020

Approved Date Monday, March 9, 2020

Robert M. Fiore

Dr. Seokhee Cho

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ABSTRACT

THE INFLUENCE OF THE AMOUNT OF INSTRUCTIONAL DAYS AND AMOUNT OF INSTRUCTIONAL TIME ON HIGH SCHOOL STUDENTS' ADVANCED PLACEMENT (AP) CALCULUS EXAM SCORES

Robert M. Fiore

The purpose of this non-experimental research was to determine the influence of the amount of instructional days and amount of instructional time in minutes on high school students' Advanced Placement (AP) Calculus exam scores. The study involved 755 students from sixteen high schools across the United States. A Three-Way Between-Subjects Analysis of Variance (ANOVA) revealed that there was a statistically significant difference in AP Calculus scores based on the amount of instructional days, the amount of instructional time in minutes, and the class type (AB or BC). There was not a statistically significant difference in AP Calculus scores based on the school type (public or private). A multiple linear regression revealed that the amount of instructional time in minutes, class type (AB or BC), and the percentage of students who took both an AP Calculus course and exam, were statistically significant contributors towards the linear model predicting a student's AP Calculus score. The amount of instructional days and school type (public or private) were not significant contributors towards the same linear model. The results were important in that they justified the theoretical framework of constructivism. Relevant implications include the support for school districts to increase the amount of instructional time in minutes for the school year.

ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to the faculty and staff of St. John's University, Queens Campus and Astor Place Campus, who guided and supported me along my journey. In particular, I would like to thank the members of my doctoral committee including Dr. Seokhee Cho, Dr. Joan I. Birringer-Haig, and Dr. James Campbell. Thank you to Dr. Cho for graciously offering to be my mentor for the dissertation and providing feedback throughout the process. Thank you to Dr. Birringer-Haig for answering my numerous questions about SPSS and for providing timely feedback throughout. I would also like to acknowledge those professionals who have completed doctorate programs and shared their expertise and experience with the dissertation: Dr. Eric G. Waxman Jr., Dr. Carl A. Semmler, Dr. Rosemary Carroll Farley, Dr. Patrice Tiffany, Dr. William R. Galati, Dr. Peter McCarthy, and Br. Augustine Nicoletti FSC.

Thank you to all of the exceptional professors who taught me at St. John's University through both the administration program and doctoral program: Dr. Randy Clemens (my advisor in the administration program), Professor Joseph Caldone, Dr. Kamala Watt, Dr. Ranier Melucci, Dr. Carla D'Ambrosio, Dr. David Bennardo, Dr. Tatyana Ulubabova, Dr. Robert Brasco, Dr. Roger Bloom, Dr. Ignazio Restivo, Dr. Kathryn Napolitano, Dr. Naomi Landau, Dr. Elizabeth Gil, Dr. Stephen Kotok, Dr. Ceceilia Parnter, Dr. Joan I. Birringer-Haig, Dr. Barbara Cozza, Dr. Jennifer Hoffman, and Dr. Seokhee Cho.

Thank you to the wonderful teachers of the Three Village Central School District who encouraged my pursuit of becoming a high school mathematics teacher and ultimately the doctoral program, especially Mrs. Janet McCauley, Mrs. Deborah Cheney, Ms. Catherine Cobb, Mrs. Patricia Clare, Mr. William S. Bernhard, Mrs. Christine Dillon, and Mrs. Susan Archer. Thank you to all of the outstanding professors and mentors I had at Manhattan College and Stony Brook University, especially the late Fr. George H. Hill. These educators' open-door policy provided me with a welcoming community to learn. Their open minds and empathy towards me as a student allowed me to develop understanding in a variety of ways, and their open hearts always demonstrated kindness, caring, and fairness. Thank you to my former colleague Mr. Stephen Brown who graduated from the administration program at Stony Brook University and encouraged me to enter administration. Thank you to my former assistant principal Mrs. Lisa M. Navarra for allowing me to complete my school building leadership and school district leadership internship hours at Bishop McGann-Mercy Diocesan High School. Thank you to the former and current administration of Loyola School (Mr. Adam Lewis, Mr. Tony Oroszlany, Mr. James F.X. Lyness) for your generous financial support in my completion of the coursework.

Thank you to all of the educators and administrators who were kind enough to share their school's data in the completion of my dissertation. Although I was never part of a cohort, I would like to acknowledge the wonderful cohorts that I had a chance to work with in completion of my coursework: The Medgar Evers Doctoral Cohort, Borough of Manhattan Community College, Hostos Community College, New York City Department of Education I Cohort, and the NBDC VI Cohort. Congratulations to those

graduating in May and good luck to those who will be completing the program soon. I would also like to recognize my former colleague Mr. Cole M. Malsky who started the administration program at the same time I did. We went through several courses together and he is soon to be a graduate of the doctoral program.

Most of all, I would like to thank my family. Thank you to my grandparents for their constant desire to make a better life for their children and grandchildren. My extended family has always been there to celebrate my accomplishments at the different graduations. I would also like to thank my brothers Anthony and John for their continuous support. They both have always been a joy to spend time with and talk to about anything, and that means more to me than they know. Thank you to my beautiful girlfriend Carly Dane Cerbone, who has been a constant source of support to me in these last stages of the dissertation writing, and was with me when I finished writing the dissertation. I love you so much Carly Dane.

Lastly, the biggest thanks go to my wonderful parents Bruno and Catherine Fiore. They have instilled in me a strong sense of trust in God, and my faith has been a major source of guidance and inspiration throughout my entire educational journey. My parents always emphasized the importance of education since the time I started school. My parents have done so much for me over the years, and without their continuing love and support I would not be here today. Thank you for encouraging me to strive for excellence, to persevere, and to take advantage of what life has to offer. My parents put me through Manhattan College, which was founded by the Brothers of the Christian Schools. The mission of St. John Baptist De La Salle, patron saint of teachers and the founder of the Brothers of the Christian Schools, was to provide young individuals with

an outstanding academic experience which stressed strong values and a desire to achieve great things. My parents always encouraged my vocation of becoming a high school mathematics teacher, and they supported me through every stage of my educational journey. They have taught me more about life and faith than anyone, and I hope to one day have their wisdom. They have had the most profound influence on the person I am today. I love both of them very much, and words cannot convey enough gratitude for all they have done for me. This dissertation is dedicated to them.

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CHAPTER 1

Introduction

The Advanced Placement program allows high school students to learn college-level material which culminates in a standardized exam, usually administered in May (College Board, 2019). Depending on the student's score on that exam, he or she may be eligible for credit from an undergraduate institution and/or be exempt from taking certain courses. The student receives an integer score between 1 and 5, with 5 being the maximum possible score. The Advanced Placement (AP) program is one of the most common ways that the United States provides advanced academic content to motivated and talented high school students (Warne, 2017).

The AP program is important to study because it has been shown to have a number of positive outcomes for participants in comparison to non-AP students. College Board studies demonstrate that AP students score higher on standardized exams than non-AP students (Ewing, Camara, & Millsap, 2006; Mattern, Shaw, & Xiong, 2009; McKillip & Rawls, 2013). Moreover, AP students have higher college attendance rates (Chajewski, Mattern, & Shaw, 2011; Wyatt & Mattern, 2011). These students also earn higher grades in college (Keng & Dodd, 2008; Morgan & Klaric, 2007; Murphy & Dodd, 2009; Patterson, Packman, & Kobrin, 2011; Shaw, Marini, & Mattern, 2013). AP students are less likely to drop out of college (Mattern et al., 2009; Wyatt & Mattern, 2011) and graduate from college in higher proportions than non-AP students (Mattern, Marini, & Shaw, 2013). Lastly, AP students possess more positive attitudes toward the same academic content covered by their AP course (Patterson, 2009) and are more likely

to study a field pertinent to the AP course than non-AP students (Keng & Dodd, 2008; Mattern, Shaw, & Ewing, 2011; Morgan & Klaric, 2007).

There are several rationales for why school districts do not allocate enough time to Advanced Placement courses. Based on experience in high schools from the researcher in the current study, some schools have partnerships with colleges and universities where students can earn college credits from that college or university without having to earn a qualifying score on an AP exam. In turn, some districts have deemed it more worthwhile for students to take such courses and automatically earn college credit upon successfully passing the course, as opposed to taking an Advanced Placement course for an entire year and possibly not earning a high enough score to qualify for college credit. The Advanced Placement exam is another standardized exam, and some school districts may be looking to move away from the overemphasis on standardized testing (Tai, 2008). Tai (2008) also notes that schools repeatedly reporting low AP exam scores signify a general lack of student preparation for the Advanced Placement exams. A remedy to that lack of student preparation would be to have increased instructional time for Advanced Placement courses before the exams. Tai (2008) further conveys that the acceleration of AP program participation, where students are taking Advanced Placement courses as early as tenth grade, ignores the significance of life experiences in helping students interpret and process course content. Being able to process and interpret content is an essential part of life learning. Once again, the extended instructional time for Advanced Placement courses before the exam would provide students with more opportunity to process and interpret content.

Purpose of the Study

The current study explored the influence of the amount of instructional days and amount of instructional time (in minutes) on high school students' AP Calculus exam scores. The purpose of this non-experimental research was to ascertain the influence of the number of instructional days and the amount of instructional time (in minutes) on achievement on the Advanced Placement Calculus exams for students from various high schools in the United States. Differences in the amount of instructional time (in minutes) or amount of instructional days occurred due to the month that the district started the school year, or the hours/schedule that the high school operated on each day (National Center for Education Statistics, 2018). Instructional time was measured in minutes. Achievement on the mathematics Advanced Placement exam was based on the AP Calculus examinations graded on a numerical scale of 1 to 5. The names of the examinations were AP Calculus AB and AP Calculus BC.

The current study has implications with new instructional methods, as teachers may need to reevaluate their practices in order to foster student success on the exams. Moreover, the current study has implications with policy changes. Specifically, if there is a positive association between the amount of instructional time and scores on the exams, districts may be encouraged to begin their school year earlier or find ways to extend the school day. The present study related to the theoretical framework of constructivism, because the amount of instructional time and amount of instructional days influenced how well students constructed knowledge and consequently performed on the AP Calculus exams.

Theoretical Framework

Constructivism is the lens through which the research problem and research questions were evaluated. Constructivism is a philosophical explanation pertaining to the nature of learning. A number of theories are constructivist in nature: Piaget's theory, Bruner's theory of cognitive growth, and Vygotsky's sociocultural theory.

Constructivism was valid to the researcher's study for a number of reasons. With constructivism, knowledge is not imposed from outside people (e.g. teacher) but rather formed from inside the person (e.g. student). With the traditional classroom (teacher-centered model), the knowledge is being disseminated to the student by the teacher.

Hackmann (2004) articulated that the student-centered principles associated with constructivism could benefit from the additional class time offered by block scheduling. Hackmann also notes the rigidity of the traditional high school schedule, uniform periods that are often 45 to 55 minutes in length. Educators are unable to explain why block scheduling is superior to traditional daily-period formats. There are many points of convergence between the two points of constructivism and block scheduling (Hackmann, 2004). These points of convergence are expanded upon in the literature review. Thus, there is a connection between constructivism and the type of scheduling in the school, which in turn influences the amount of instructional days and amount of instructional time. In the current study, the researcher took note of the amount of instructional days, amount of instructional time, and type of scheduling that the school operated on.

Constructivism mandates that teaching and learning experiences are structured to challenge students' thinking so they will be able to construct new knowledge. Learning processes are developed through settings that are both physical and social. Thus, the

physical and social context of the in-person classroom, meeting for a certain number of days and minutes, will lead students to construct knowledge. Specifically, knowledge is shared between students and teachers. Students and teachers will share authority. The teacher is meant to serve as a guide or facilitator. Moreover, learning groups contain small numbers of heterogeneous groupings (Tam, 2000).

Constructivist leaning environments seek to provide rich experiences encouraging students to learn. Constructivist classes teach major concepts using student-centered learning activities. In the student-centered classroom, student ideas are sought out from teachers, and compared with the traditional classroom, there is less emphasis on superficial learning and greater emphasis on deeper understanding. A number of constructivist teaching behaviors are pertinent to the Advanced Placement Calculus course: Student initiative and autonomy, activating students' prior knowledge, encouraging students to dialogue with the teacher and each other, encouraging student inquiry, having students elaborate on initial responses, and allowing wait time after asking questions (McLeod, 2019).

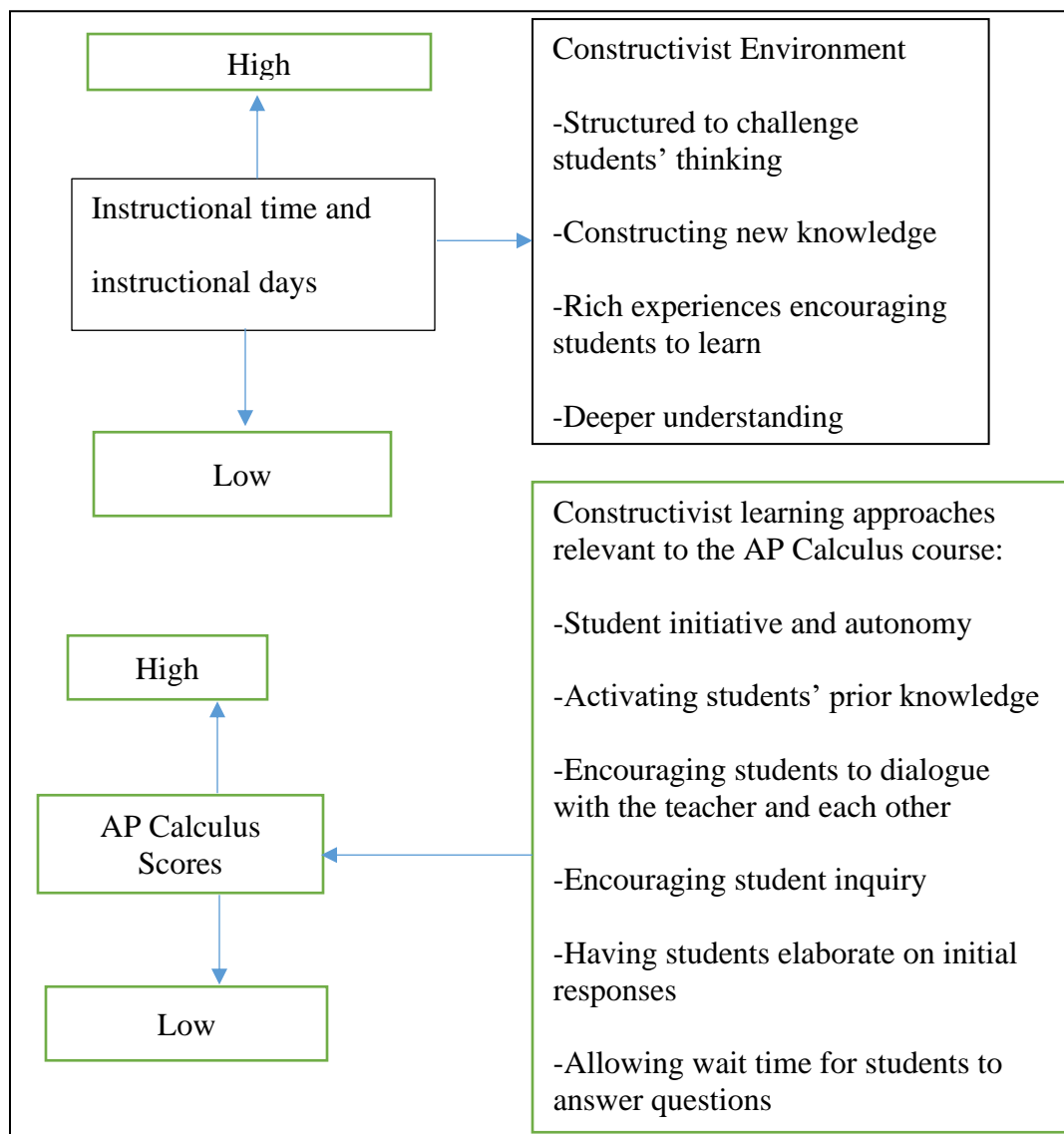
Constructivism provided an interpretive lens to the non-experimental research in the study. More instructional time would facilitate students' construction of knowledge. As the literature review in Chapter 2 will articulate, more instructional time should also be coupled with appropriate interventions. Constructivist learning approaches are examples of such interventions. As described in the sample in Chapter 3, schools operating on a block schedule/non-traditional schedule tend to have fewer instructional days before the Advanced Placement Calculus exam. If these schools significantly

outperform those operating on a traditional schedule with a higher number of instructional days, that would further justify the validity of the constructivist approach.

Conceptual Framework

Figure 1.1

Conceptual Framework of Constructivism



The conceptual framework in Figure 1.1 explains how the amount of instructional days and amount of instructional time influence how students construct knowledge, which in turn impacts performance on the AP Calculus examinations. Insight is needed

to better understand how the quantity of instruction impacts student learning. The researcher's conjecture is that there was an association between the amount of instructional days/amount of instructional time and performance on the AP Calculus exams. However, part of what influences the connection between the independent variables and the dependent variable is constructivism.

Significance/Importance of the Study

An important educational research topic is best instructional methods and practices for high school and undergraduate mathematics courses. As the literature review articulates, an increase in instructional time had either a neutral or positive influence on student performance. There were several practical problems and issues which focused the current study. The national passing rate for AP Calculus AB in 2019 was 58.3%. The mean score was 2.97, which is lower than a qualifying score (Total Registration, 2019). The national passing rate for AP Calculus BC in 2019 was 81.5%, which is one of the highest passing rates among all AP exams from 2019. Moreover, the mean score was about 3.82, which is higher than a qualifying score (Total Registration, 2019). Thus, there is a clear discrepancy as BC Calculus students outscore AB Calculus students by an impressive margin.

Since some states start school in July or August and the AP exam is in May, some states have more instructional days before the AP exam (Prince, 2017). This can lead to more review for the exam, deeper learning, and an increase in student learning and achievement. By having increased instructional time before the AP exam, particularly for AB Calculus students, districts can work towards bridging the achievement gap between those two AP Calculus exams. As the literature review articulates in Chapter 2, there has

been a lack of study specifically on the amount of instructional time before the AP Calculus exam. Tai (2008) cites lack of student preparation as a reason for some schools repeatedly reporting low AP exam scores. In turn, the way to rectify a lack of student preparation is to provide students with more time to process and internalize the material. Thus, schools yielding low scores can be attributed to a lack of student preparation which comes from limited instructional time before the exam. Educators can be paid more and attend additional professional development workshops. Nevertheless, if these teachers do not have enough instructional time before the AP exam to work with students, then those students will still enter the exam without the full preparation necessary for success on the exam.

There is a possible explanation for a lack of strong evidence for the impact of increasing instructional time. First, to benefit from increased instructional time, students may need motivation to pay attention to the instruction, and in turn achieve long-term gains. Doing so necessitates self-control, which is a scarce resource and exhausted when utilized (Andersen, Humlum, & Nandrup, 2016). Consequently, it is more difficult for students to focus their attention, manage emotions, and control thoughts, which can lead to more aggression (Andersen, Humlum, & Nandrup, 2016). Thus, the longer school day may be ineffective since students' self-control has diminished. Other factors impact self-control such as gender and socioeconomic status (Andersen, Humlum, and Nandrup, 2016). These findings further illustrate the complexity of the issue, as there are variables at work affecting student achievement other than the amount of time students are in school. Motivation is an important component of learning (Schunk, 2016). Andersen,

Humlum, and Nandrup (2016) articulated that motivation is an important component to the amount of instructional time.

Gershenson (2018) discusses the concept of grade inflation in high schools, where the subjective grades assigned by teachers do not align with objective performance such as on standardized assessments. Gershenson (2018) also found that more grade inflation happened in schools attended by wealthier students. The researcher's experience from teaching in private schools aligns with such findings. Having an outside assessment measure that is not created or graded by the classroom teacher is an effective way to maintain high standards (Gershenson, 2018), and it also functions as an audit of course progress and grades. Advanced Placement exams serve as these outside assessments for many high school students (Gershenson, 2018). Thus, the author recognizes that in an age of grade inflation, the Advanced Placement exams still serve as a measure of rigor in the United States education system and accurately assesses what students learned in the course. This further illustrates the importance of studying the AP Calculus exams.

Moreover, the current study will hopefully serve as a guide for schools and districts to improve their academic program through practices such as increased instructional time, more appropriate professional development, and increased expectations for teachers and administrators. Doing so will hopefully bolster the national passing rate and average score. The College Board is committed to college and career readiness. It is important for students to get higher scores, because an ambitious student with enough AP credits could feasibly attain sophomore status before even setting foot on a college campus. The financial cost of granting these college credits is relevant to colleges, students taking these courses, and their families (Tai, 2008). The AP program

offers a way for high school students to distinguish themselves. From a larger standpoint, the Advanced Placement program offers a way of bolstering the science, technology, engineering, and mathematics (STEM) workforce in the United States (Tai, 2008). The mission of the College Board is to connect students to college opportunity and success (College Board, 2010). By looking for ways to increase student course performance and exam performance, and in turn obtain college credit, the current study seeks to foster that College Board goal of advocacy.

Connection with Social Justice and Vincentian Mission in Education

A remaining issue which ties to the current study is that not all teachers may be setting high standards for all learners. This is manifested in the discrepancy between the performance of minority groups and the national average (College Board, 2018). The school in the sample from the current study with the highest percentage of minority students had the lowest average score. Such data reflects these unfortunate trends regarding expectations and the discrepancy in performance. The researcher conveyed ethnicity of the participating schools in demographics tables. It was logistically not feasible for the researcher to obtain specific Advanced Placement scores based on an individual student's ethnicity. However, ethnicity is mentioned in the directions and recommendations for future research. The current study has a social justice component, as the College Board is committed to equity and access in the Advanced Placement program (College Board, 2012). There may be high schools in the sample which have made efforts to close the achievement gap by including all students in their Advanced Placement courses.

As a Vincentian institution, part of the mission of St. John's University is to provide an excellent education for all, especially those lacking certain advantages. The causes of injustices are sought out, and practical solutions are encouraged (St. John's University, 2019). The current study sought to discover if there were differences in student performance on the AP Calculus exams based on the amount of instructional time/amount of instructional days. If there are, the current study serves as an encouragement for districts to seek ways to increase the instructional time, and in turn further seek the academic excellence of the students. As mentioned earlier, the discrepancy in performance from underrepresented populations will be mentioned in the discussion and recommendations for future research.

Research Questions

Research Question 1

To what extent will the amount of instructional days, amount of instructional time (in minutes), and types of class (AB or BC) influence the AP Calculus scores?

Hypotheses

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional days (high, medium, low).

H₁: There will be a statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional days (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₁: There will be a statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H_0 : There will be no statistically significant difference in AP Calculus exam scores between the types of class (AB or BC)

H_1 : There will be a statistically significant difference in AP Calculus exam scores between the types of class (AB or BC).

H_0 : There will be no interaction among schools of different amounts of instructional days and among schools of different amounts of instructional time (in minutes).

H_1 : There will be an interaction among schools of different amounts of instructional days and among schools of different amounts of instructional time (in minutes).

H_0 : There will be no interaction among schools of different amounts of instructional days and types of class (AB or BC).

H_1 : There will be an interaction among schools of different amounts of instructional days and types of class (AB or BC).

H_0 : There will be no interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H_1 : There will be an interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H_0 : There will be no interaction among schools of different amounts of instructional days, schools of different amounts of instructional time (in minutes), and types of class (AB or BC).

H_1 : There will be an interaction among schools of different amounts of instructional days, schools of different amounts of instructional time (in minutes), and types of class (AB or BC).

Research Question 2

To what extent will the amount of instructional time (in minutes), school type (public, private), and types of class (AB or BC) influence AP Calculus exam scores?

Hypotheses

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₁: There will be a statistically significant difference in AP Calculus exam among schools of different numbers of instructional minutes (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores based upon school type (public, private).

H₁: There will be a statistically significant difference in AP Calculus exam scores based upon school type (public, private).

H₀: There will be no statistically significant difference in AP Calculus exam scores based upon the types of class (AB or BC).

H₁: There will be a statistically significant difference in AP Calculus exam scores based upon the types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and school type (public, private).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes) and school type (public, private).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₀: There will be no interaction between school type (public, private) and types of class (AB or BC).

H₁: There will be an interaction between school type (public, private) and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes), school type (public, private), and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes), school type (public, private), and types of class (AB or BC).

Research Question 3

To what extent will there be an association between the number of instructional days, amount of instructional time (in minutes), type of school (public, private), types of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam, and performance on the AP Calculus exams?

Hypotheses

H₀: The number of instructional days, amount of instructional time (in minutes), type of school (public, private), type of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam will not be valid predictors of AP Calculus exam scores.

H₁: The number of instructional days, amount of instructional time (in minutes), type of school (public, private), type of class (AB or BC), and percentage of AP Calculus AB and

BC students in the school who took both the course and exam will be valid predictors of AP Calculus exam scores.

For the first research question, the amount of instructional time (in minutes) and amount of instructional days were numerical. The type of class (AB or BC) was categorical. The Advanced Placement Calculus exam score was the dependent variable. Two Three-Way Between-Subjects Analysis of Variance (ANOVAs) were utilized to answer the first two research questions. For the second research question, the amount of instructional time (in minutes) was numerical. The school type (public, private) and type of class (AB or BC) were categorical. The Advanced Placement Calculus exam score was the dependent variable. A multiple linear regression was utilized to answer the third research question. For the third research question, the number of instructional days, amount of instructional time (in minutes), and percentage of AP Calculus AB and BC students in the school who took both the course and exam were quantitative variables. The type of school (public, private) and type of class (AB or BC) were categorical. The Advanced Placement Calculus exam score was the dependent variable.

Definition of Terms

Mathematics Achievement – Scores on May 2019 AP Calculus exams graded on a numerical scale of 1-5. For the current study, all students in the sample took one of the AP Calculus AB exam or AP Calculus BC exam.

Instructional Time – The total amount of time in minutes that the AP Calculus course was in session before students took the AP Calculus exam.

Instructional days – The number of days that the AP Calculus course was in session before students took the AP Calculus exam.

Schools of high, medium, and low instructional days of AP Calculus– Schools in the sample in the top 1/3 of instructional days were considered high with the range of 154-174 days. Schools in the sample in the next 1/3 of instructional days were considered medium with the range of 134-150 days. Schools in the sample in the bottom 1/3 of instructional days were considered low with the range of 30-131 days.

Schools of high, medium, and low instructional time of AP Calculus– Schools in the sample in the top 1/3 of instructional minutes were considered high with the range of 8,106 to 9,744 minutes. Schools in the sample in the next 1/3 of instructional minutes were considered medium with the range of 5,920 to 7,776 minutes. Schools in the sample in the bottom 1/3 of instructional minutes were considered low with the range of 1,200 to 5,796 minutes.

Type of school – Public or private.

Type of class – AP Calculus AB or AP Calculus BC. For the current study, all students in the sample took one of these courses.

Percentage of AP Calculus AB and BC students – Percentage of students enrolled in each of the courses from the total school population. Only students who took both the AP Calculus course offered by the school and the AP Calculus exam were counted in the percentage. As described in the sample, there were fifteen students in total who were not counted in this percentage. Fourteen of these students took the exam but not the course. One of these students took the exam but did an online course instead of a course offered by the school.

CHAPTER 2

Review of Related Research

Introduction

Chapter 2 provides the literature review. There is an emphasis on the connection between the amount of instructional time and student achievement. The literature review also focuses on block scheduling. The theoretical framework is also expanded upon. The gaps in the current literature are also addressed which help justify the need for the current study.

Connection Between the Amount of Instructional Time and Student Achievement

Part of the research focus for the dissertation pertains to the association (if any) between the amount of instructional days/amount of instructional time and scores on the Advanced Placement Calculus exams. There appears to be a gap in peer-reviewed research with respect to the reasons that certain states start school before Labor Day or after Labor Day. In turn, a focus of the literature review for the dissertation was on the amount of instructional time in the school year. The research suggests that increasing the amount of instructional time has either a neutral or positive influence on student achievement (Andersen, Humlum, & Nandrup, 2016; Cattaneo, Oggenfuss, & Wolter, 2016; Kidron & Lindsay, 2014; Lavy, 2015; Mandel & Suessmuth, 2011; Patall, Cooper, and Allen, 2010; Skirbekk, 2006; Woessmann, 2003; Woessmann, 2010).

Since some states start school in July or August, one can assume that those schools have more instructional days before the AP exam in May. In turn, those schools may have more instructional time before the exam. By investigating such research, there was more context for the findings when looking at the scores between each school

(National Center for Education Statistics, 2018). The major research focus that emerged with respect to the topic was on the impact of increasing instructional time on student learning and achievement (Andersen, Humlum, & Nandrup, 2016; Cattaneo, Oggenfuss, & Wolter, 2016; Kidron & Lindsay, 2014; Lavy, 2015; Mandel & Suessmuth, 2011; Patall, Cooper, and Allen, 2010; Skirbekk, 2006; Woessmann, 2003; Woessmann, 2010). The research suggested that increasing instructional time in the classroom had either a neutral or positive influence on student achievement (Andersen, Humlum, & Nandrup, 2016; Cattaneo, Oggenfuss, & Wolter, 2016; Kidron & Lindsay, 2014; Lavy, 2015; Mandel & Suessmuth, 2011; Patall, Cooper, and Allen, 2010; Skirbekk, 2006; Woessmann, 2003; Woessmann, 2010)

Increasing instructional time has been a component of numerous educational reforms in the United States and Europe (Andersen, Humlum, & Nandrup, 2016). All governments responsible for education systems must decide on the amount of instructional time to be provided (Andersen, Humlum, & Nandrup, 2016). The time students spend in the classroom varies by a factor of two across the Organization of Economic Co-operation and Development (OECD) countries in both total compulsory instruction time and within specific disciplines (Andersen, Humlum, & Nandrup, 2016). These international distinctions have created debates regarding whether students profit from having increased instruction, or whether governments can reduce spending on instructional time without adversely impacting student achievement. A review of literature prior to 2009 concludes that there appears to be a neutral to small positive impact of more instructional time on student achievement (Andersen, Humlum, & Nandrup, 2016). Nevertheless, many of those studies were implemented with weak

designs and disputed effects. Critics contend that longer school days create behavioral problems caused by boredom and fatigue (Andersen, Humlum, & Nandrup, 2016).

More recent studies founded on observational data demonstrated positive effects on student achievement (Andersen, Humlum, & Nandrup, 2016). Furthermore, studies looking at the impact of more instructional time in conjunction with more effective teachers, tracking ability, data-driven teaching, and improved pedagogy also showed positive effects (Andersen, Humlum, & Nandrup, 2016). A randomized trial held in the Netherlands did not find a significant difference from increased instructional time. Nevertheless, the trial had a threat to the statistical conclusion validity, namely low statistical power since there were only seven schools (Andersen, Humlum, & Nandrup, 2016). The findings from this study were important because there are other interventions in the school setting that are intertwined with the amount of instructional time. Also, there did not appear to be studies stating that increased instructional time had a negative impact on student achievement. In addition, the studies that did not support increasing instructional time had methodological flaws and limitations (Andersen, Humlum, & Nandrup, 2016).

There were two possible explanations for a lack of strong evidence for the impact of increasing instructional time. First, to benefit from increased instructional time, students may need motivation to pay attention to the instruction, and in turn achieve long-term gains. Doing so necessitates self-control, which is a scarce resource and exhausted when utilized (Andersen, Humlum, & Nandrup, 2016). Consequently, it is more difficult for students to focus their attention, manage emotions, and control thoughts, which can lead to more aggression (Andersen, Humlum, & Nandrup, 2016). Thus, the longer school

day may be ineffective since students' self-control has diminished. Other factors impact self-control such as gender and socioeconomic status (Andersen, Humlum, and Nandrup, 2016). These findings further illustrate the complexity of the issue, as there are variables at work affecting student achievement other than the amount of time students are in school. Motivation is an important component of learning (Schunk, 2016). Andersen, Humlum, and Nandrup (2016) articulated that motivation is an important component to the amount of instructional time.

A second possible explanation is that the impact of increasing school resources is likely to be influenced by how teachers utilize the additional time. There is often a set of rules in the school that regulate the interplay between instruction and assessment (Andersen, Humlum, & Nandrup, 2016). These researchers considered schools with no formal requirements on how the extra time is spent, and those schools that had an increase in instruction time with a detailed teaching program. They conducted a randomized, large-scale trial in Denmark which provided evidence supporting that increasing instructional time in school bolsters student learning. The regime with no formal requirements on the extra time was at least as efficient as the schools with a detailed teaching program for the extra time. There were limitations here with external validity, as the study was conducted for fourth grade in another country. Based on the literature supporting the Advanced Placement program, future research should be conducted in the United States and at the high school level.

Cattaneo, Oggenfuss, and Wolter (2016) also wrote about the ramifications of instructional time on student performance. The researchers noted that empirical contributions on the effectiveness and utilization of instructional time remain rather

limited, thus highlighting another gap in the research relating to the topic. Instructional time is a scarce resource, and with limited educational budgets, instructional costs can take away from other potential inputs. Instructional time and time allocated to specific disciplines varies greatly between countries. For lower secondary education, the average hours per school year varies as greatly as Sweden (754 hours) to Mexico (1167 hours). The Organization for Economic Cooperation and Development (OECD) member nations had an average of 916 hours. These researchers looked to address whether additional instructional time is being used effectively.

Cattaneo, Oggenfuss, and Wolter (2016) acknowledged that instructional time can vary between subjects based on number of lessons taught per week, length of lessons, number of school weeks, and number of school years. Such sources of variation can have quite different impacts on how students learn. The authors could only analyze the impact of yearly or weekly cumulative instruction time on student test scores. Due to data limitations, the authors could not analyze the impact of distinctions in the organization of school weeks and days. In the current study, there was a wide range of instructional days and amount of instructional time (in minutes) for schools in the sample.

Cattaneo, Oggenfuss, and Wolter (2016) viewed student achievement through performance on the Program for International Student Assessment (PISA). Their analysis revealed that one additional instruction hour per week raised the PISA score between .05 and .06 standard deviations. The additional hour of instruction increased the PISA score between .07 and .08 standard deviations for students with advanced requirements. Such findings were important, as generalizing these results suggested that the Advanced Placement students would benefit from the additional time. While the increase in PISA

score was only .04 standard deviations for students with basic requirement tracks, there was still an improvement among all the groups. These distinctions can result from differences in student attitude and time necessary to learn. In turn, students with different abilities benefit to different degrees from the added instructional time. To that end, the researcher was able to obtain some information about special education students in the sample. Once again, the research was showing that additional time can be beneficial, but the other factors that go into that additional time must also be examined. Cattaneo, Oggenfuss, and Wolter's (2016) study was sound as a large, random sample was utilized, $n = 13,605$. It would be helpful for future research to be conducted in the United States.

Lavy (2015) looked at international disparities in student achievement based on instructional time, based on PISA data from 2006. He discovered that instructional time has a significant and positive effect on test scores. However, the effect was much lower in developing countries. Moreover, the productivity of instructional time was greater for countries with school features like autonomy in budgetary decisions and accountability measures. The United States is a country with mandatory education and high levels of the population with a high school education. Many states have taken measures in recent years to increase school and teacher accountability. Thus, Lavy's findings would generally suggest that the Advanced Placement students would benefit from the additional instructional time. Conversely, low scores in individual schools may suggest a lack of accountability. The previous conjecture was supported by Rivkin and Schiman (2015), who studied 2009 PISA data and added controls for school quality. They ascertained that the benefits of more instructional time are determined to a large extent by school circumstances.

Woessmann (2003) studied the international student-level database known as Trends in International Mathematics and Science Study (TIMSS). The results showed that instructional time was positively correlated with student performance. A study within Germany for cumulative instruction time by Mandel and Suessmuth (2011) found positive effects on student performance. The literature did also reveal studies finding no significant difference between instructional time and school outcomes. Woessmann (2010) found no significant difference on student test scores in Germany. In addition, Skirbekk (2006) looked at TIMSS scores from 2006 and found no effect of time in school on student achievement after controlling for student characteristics and school. While these studies did not show a positive correlation between instructional time and student achievement, they also never stated that the increase in instructional time led to a decrease in student achievement.

As alluded to in the research from Cattaneo et al. (2016), another important consideration with the amount of instructional time was the ability and tracking grouping. To that end, the researcher attempted to get information about tracking from each school in the sample. These researchers articulated that there is little research on the relation between instructional time and ability groups. A study in the United States was done by Allensworth and Nomi (2009) using the Chicago Public Schools. The efficacy of an algebra program was estimated by doubling lessons to 9th grade students whose 8th grade test scores fell beneath the national median. The authors found that the lowest-skilled students benefitted less from more lessons as opposed to the higher-skilled students. The students received more instruction, more difficult coursework, and improved instruction, since teachers were informed on how to utilize the additional time. Thus, a strength of

the study was that the authors' estimates accounted for both time and quality of instruction. These findings implied that the additional time would benefit the Advanced Placement students.

In Switzerland, only one study (Angelone and Moser, 2012) before Cattaneo et al. (2016) pertained to instructional time and ability tracks. The authors used a regression to estimate the impact of instructional time on student performance in Switzerland using 2006 data from PISA. The results implied that students on a high-level track benefitted more from increased instruction than students on the lower-level track. Thus, the literature further suggested that Advanced Placement students would be positively affected by the added instructional time.

Kidron and Lindsay (2014) summarized research studies on increased learning time utilizing meta-analysis techniques. The article delineated ways that schools can possibly increase the amount of instructional time: Out-of-school programs (before and after school and weekend programs); schools with longer school days, weeks, or years; summer school; and year-round schools. The meta-analysis looked at over 7,000 studies and ultimately identified 30 that utilized research designs capable of yielding strong evidence pertaining to the outcomes of more learning time. In certain instances, the 30 studies found that the increased learning time had a positive effect on student outcomes. In other instances, the studies found no positive effect. Hence, no single increased learning time program meets the needs of all students. What works well for the Advanced Placement students in one school may be unique to that particular setting and those advanced learners.

The practicality of Kidron and Lindsay's (2014) research was that it can help educators decide how to best choose and implement an approach for increased learning time. The programs improved academic outcomes when the instruction was delivered by certified teachers. Five studies found that mathematics instruction was conducted by certified teachers and found the positive effect on mathematics achievement was statistically significant. However, the authors noted that the effects were small. Programs that utilized a traditional instruction style (teacher-centered model) improved academic outcomes in mathematics (four studies). Once again, the effects were small. Programs that utilized an experiential learning instruction style (e.g. hands-on, inquiry-based instruction) improved student social-emotional skill development (e.g. self-management and self-confidence). The effects were small again.

Kidron and Lindsay's (2014) study aligned with other research in the literature review, namely that it is not just about an increase in instructional time that matters, but also what happens in the classroom in conjunction with the added instructional time. These concepts also pertained to the conceptual framework of constructivism discussed in the first chapter. Students construct knowledge based on the frequency of class time and/or scheduling, and that knowledge is constructed in the physical and social context of the classroom. Here lies the bridge/connection between the independent variables (amount of instructional time/amount of instructional days) and differences in the dependent variable (performance on the AP Calculus exams).

Kidron and Lindsay (2014) also explained how programs that targeted specific student subgroups and utilized explicit instruction to teach well specified skills tended to demonstrate a positive effect on student outcomes. Educators who want to utilize

increased learning time programs may set goals and design activities based on a profound understanding of student interests and needs. The authors noted that their study does not provide information on potential interactions among implementation features, such as the duration and frequency of classes. In the current study, the researcher collected data from each participating school regarding the frequency and duration of the Advanced Placement Calculus classes, thus expanding on a gap in the current research. Kidron and Lindsay (2014) noted that their study will be able to assess the effects of increased learning time using multiple factors simultaneously as the knowledge base grows. The current research study looked at multiple factors and thus filled a research need identified by Kidron and Lindsay (2014).

Lastly, Patall, Cooper, and Allen (2010) studied extending the school day or school year, which is an important consideration for schools and/or states seeking to increase instructional time. Extending school time has been contemplated as a measure to bolster academic achievement. The researcher has attended the Advanced Placement Annual Conference for the past three summers, which is a convention of AP teachers from across the United States and spanning all of the Advanced Placement courses. The school day length and year change over time and across localities, which was a finding supported by the attendees of the Advanced Placement Annual Conference. Proponents claimed that more time will have learning benefits as well as non-academic benefits. Critics suggested that more time could be costly and is not guaranteed to lead to higher quality instruction. Through their research, Patall et al. (2010) ultimately concluded that adding instructional time can be an effective way to foster student learning, particularly when considerations for how the time will be utilized are made. These findings were

congruent with those from other literature in this review. Nevertheless, these researchers did note a limitation that there needs to be more future research on extending school time, which also aligns with the other peer-reviewed literature.

Based on the literature review, looking at scores on the Advanced Placement Calculus exams based on when schools start the year lent itself best to a statistical analysis. The research from the literature review would likely support the alternative hypothesis that there will be a statistically significant difference between AP Calculus exam scores based on the number of instructional days and amount of instructional time in minutes. The amount of instructional time was important to study for the literature review, as it provided insight on additional topics that can be examined relating to education systems. The start date of the school year may end up not having an influence on the scores. The disparity between scores could reveal educational inequities between the states, which aligned with the prior research on the importance of accountability. Charts from the College Board also signified that there was generally a discrepancy between the performance of certain minority groups in comparison to state and national averages (College Board, 2018). In the current study, the school with the highest percentage of minority students had the lowest average score.

The review of literature thus far pertained to the first research question of the current study, which emphasized the number of instructional days and amount of instructional time (in minutes). The type of school (public, private) is pertinent to the second research question in the current research study. In 2014, private school students accounted for 11% of the AP exams taken by United States students in private and public schools (Council for American Private Education, 2015). A 3 is the minimum score on

an AP exam that can possibly earn a student college credit. The percentage of public-school students who scored 3 or higher on an AP exam in 2014 was about 57 percent. By contrast, the percentage of private school students who earned at least a 3 on an AP exam was higher at 71 percent. Moreover, the average AP score for private school students was 3.24 in 2014, and the mean score was 2.82 for public school students (Council for American Private Education, 2015). Thus, the research here would likely support the alternative hypothesis that there will be a statistically significant difference in AP Calculus exam scores based on the amount of instructional time and school type.

The percentage of AP Calculus AB and BC students in the school who took both the course and exam is pertinent to the third research question. In 2014, the ratio of AP exams to students was 37 percent for private schools and 24 percent for public schools (Council for American Private Education, 2015). From 2008 to 2018, the number of United States public high school graduates who took an AP exam during high school increased by 65 percent. Furthermore, the number of United States public high school graduates who scored at least a 3 on at least one AP exam increased by 63% over the same ten-year period (College Board, 2018). For the class of 2018, about 1.24 million United States public school high school graduates (38.9% of the class) took at least one AP exam, a rise from 752,255 (25.1%) in the class of 2008 (College Board, 2018). While there is plenty of national and state data available on AP exam scores, there does not appear to be much peer reviewed literature on the percentage of students taking an AP exam from within individual schools. Since the current study focused on the percentage of AP Calculus AB and BC students who took both the course and exam out of the entire school population, the study helps fill in another gap in the current research.

Constructivism

The AP Calculus AB and BC courses have four main mathematical practices:

Implementing mathematical processes, connecting representations, justification, and communication and notation (College Board, 2019). One of the skills for connecting representations which aligns with constructivism is identifying common underlying structures in problems involving distinct contextual scenarios (College Board, 2019).

Another constructivist learning strategy which falls under the skill of justification is providing rationales or reasons for conclusions and solutions (College Board, 2019).

This further explains why the theoretical framework of constructivism was appropriate to use for the research questions pertaining to the AP Calculus course.

Block Scheduling/Theoretical Framework

The LAB (1998) noted that the use of time is the most influential factor in what happens in America's schools. Time structures the curriculum, determines class schedules, influences teaching, and shapes the interactions between students and teachers. Thus, the type of scheduling is directly tied to the conceptual framework of constructivism. Specifically, the interactions between students and teachers based on the time frame in the school influences how students construct knowledge in the physical and social context of the classroom. Once again, constructivism demonstrates the connection between the independent variables (amount of instructional time/amount of instructional days) and differences in the dependent variable (performance on the AP Calculus exams).

The LAB (1998) also noted that block scheduling allows students to take fewer classes during a 90-day semester, stay in class for a longer amount of time during the day, and complete the coursework in one semester. Ideally, block scheduling makes it

possible for students to complete 8 to 10 courses in a school year. If a school district was to adopt the semester model, it would probably be more beneficial for the students to take the Advanced Placement Calculus course in the second semester. In turn, the students would be learning the material and subsequently reviewing closer to the time of the exam in May. Block scheduling alters the way the school day is organized and how instructional time is utilized. A student takes four classes per semester during an average day. Fewer disruptions and fewer class changes allow for more time spent in the content area.

The LAB (1998) noted that with block scheduling, some schools maintain the full-year schedule for Advanced Placement (AP) classes, as opposed to having the AP course be crammed into one semester. It was also conveyed that with block scheduling students receive increased instructional time. Instructional time was one of the independent variables being considered in the current research study. Thus, the researcher was extending past research by examining the impact of students receiving increased instructional time on scores on the AP Calculus exams. Moreover, several schools in the sample in the current study followed a block schedule.

Reames and Bradshaw (2009) conducted quantitative research on the effectiveness of block scheduling. The case study dealt with an urban school system in Georgia by considering whether the block schedule resulted in an increase in test scores on several measures including Advanced Placement Tests (AP). In the school system under investigation, Advanced Placement Tests (AP) passing rates showed an upward development over a ten-year period. The researchers suggested school districts should consider the impact of block scheduling on student achievement. In the current research

study, the author found that many schools in the sample operated on a traditional schedule where the students meet for a shorter period of time every single day. The research from Reames and Bradshaw (2009) would likely support the alternative hypothesis that there will be a significant difference in Advanced Placement Calculus exam scores based on the amount of instructional time. Thus, if schools are operating on a traditional schedule and looking to bolster Advanced Placement scores, block scheduling may be worthwhile to implement.

Relationship Between Prior Research and Present Study

The literature review conveyed that increasing instructional time did not have an adverse impact on student achievement. The literature showed that in some instances the effects were neutral, but in the remaining studies the results were positive. There were no findings in the literature suggesting that increased instructional time led to a decrease in student achievement. Moreover, the literature review conveyed that the effectiveness of the increased instructional time worked in conjunction with a number of other factors. Such factors include, but are not limited to, gender, motivation, socioeconomic status, accountability measures, budget autonomy, instructional quality, and teachers' ability to make use of the additional time.

As discussed in Chapter 3, several of the schools in the sample operated on a block schedule. Some of those schedules aligned with the research findings that a school may choose to have classes meet every other day for the entire year but for a longer time frame. The theoretical framework of constructivism pertained to the amount of instructional days and amount of instructional time. The previous studies from the literature review do not specifically address the amount of instructional time, which is

why the current study is being conducted. The current research study looked at multiple variables (instructional days, instructional minutes, class type, school type, percentage of students in the school taking an AP Calculus course and exam) and thus filled a research need identified by Kidron and Lindsay (2014).

CHAPTER 3

Method

Hypotheses/Specific Research Questions

Research Question 1

To what extent will the amount of instructional days, amount of instructional time (in minutes), and types of class (AB or BC) influence the AP Calculus scores?

Hypotheses

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional days (high, medium, low).

H₁: There will be a statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional days (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₁: There will be a statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores between the types of class (AB or BC)

H₁: There will be a statistically significant difference in AP Calculus exam scores between the types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional days and among schools of different amounts of instructional time (in minutes).

H₁: There will be an interaction among schools of different amounts of instructional days and among schools of different amounts of instructional time (in minutes).

H₀: There will be no interaction among schools of different amounts of instructional days and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional days and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional days, schools of different amounts of instructional time (in minutes), and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional days, schools of different amounts of instructional time (in minutes), and types of class (AB or BC).

Research Question 2

To what extent will the amount of instructional time (in minutes), school type (public, private), and types of class (AB or BC) influence AP Calculus exam scores?

Hypotheses

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₁: There will be a statistically significant difference in AP Calculus exam among schools of different numbers of instructional minutes (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores based upon school type (public, private).

H₁: There will be a statistically significant difference in AP Calculus exam scores based upon school type (public, private).

H₀: There will be no statistically significant difference in AP Calculus exam scores based upon the types of class (AB or BC)

H₁: There will be a statistically significant difference in AP Calculus exam scores based upon the types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and school type (public, private).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes) and school type (public, private).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₀: There will be no interaction between school type (public, private) and types of class (AB or BC).

H₁: There will be an interaction between school type (public, private) and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes), school type (public, private), and types of class (AB or BC).

H₁: There will be an interaction among schools of different amounts of instructional time (in minutes), school type (public, private), and types of class (AB or BC).

Research Question 3

To what extent will there be an association between the number of instructional days, amount of instructional time (in minutes), type of school (public, private), types of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam, and performance on the AP Calculus exams?

Hypotheses

H₀: The number of instructional days, amount of instructional time (in minutes), type of school (public, private), type of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam will not be valid predictors of AP Calculus exam scores.

H₁: The number of instructional days, amount of instructional time (in minutes), type of school (public, private), type of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam will be valid predictors of AP Calculus exam scores.

For the first research question, the amount of instructional time (in minutes) and amount of instructional days were numerical. The type of class (AB or BC) was categorical. The Advanced Placement Calculus scores were the dependent variable. A Three-Way Between-Subjects Analysis of Variance (ANOVA) was utilized to answer the first two research questions. Before the Three-Way ANOVA was conducted twice, descriptive statistics were calculated for AP Calculus scores based on the amount of instructional days, number of instructional minutes, school type, and class type. While

mean differences can easily be computed from a table, a One-Way ANOVA was conducted to determine if any of the pairwise comparisons for the amount of instructional days and number of instructional minutes were statistically significant. In addition, independent sample t tests were conducted to ascertain if the mean differences between class type or between school type were statistically significant. A multiple linear regression was utilized to answer the third research question.

Research Design

Based on the sixteen schools in the sample in the current study, the researcher classified schools into high, medium, and low instructional days. In alignment with the definitions from Chapter 1, schools in the sample in the top 1/3 of instructional days were considered high with the range of 154-174 days. Schools in the sample in the next 1/3 of instructional days were considered medium with the range of 134-150 days. Schools in the sample in the bottom 1/3 of instructional days were considered low with the range of 30-131 days. The researcher categorized schools in the sample into high, medium, and low instructional minutes in a similar manner. Schools in the sample in the top 1/3 of instructional minutes were considered high with the range of 8,106 to 9,744 minutes. Schools in the sample in the next 1/3 of instructional minutes were considered medium with the range of 5,920 to 7,776 minutes. Schools in the sample in the bottom 1/3 of instructional minutes were considered low with the range of 1,200 to 5,796 minutes.

It was necessary to create these groupings for instructional days and instructional minutes because the researcher chose a Three-Way Between Subjects Analysis of Variance (ANOVA) for the first two research questions. In such an analysis, the independent variables need to be based on groups and cannot be quantitative. The

researcher treated the instructional days and instructional minutes as quantitative variables in the third research question. Thus, a strength of the current study is that instructional days and instructional minutes were considered both in terms of groupings and as quantitative variables.

Sample

The participants in the study were students enrolled in AP Calculus at high schools throughout the United States. The researcher ensured that the minimum sample size requirement for a correlational study were satisfied. The researcher collected data from each school in the sample, which is presented in demographic tables. The course is usually taken by eleventh and twelfth graders, so the students are normally between 16 and 18 years of age at the time of the AP examination.

The target population was high schools with similar demographics, and AP Calculus students. The accessible population was the AP Calculus students in the schools that the researcher was able to gather data from. Since the participants had special qualifications, namely taking both an AP Calculus course and exam, purposive sampling was used. In addition to personal networking connections, the researcher contacted the College Board and posted on an AP Calculus forum for teachers. Teachers responded from different states around the country and were willing to share data.

The first high school in the sample was a public school in the southwestern United States. The school began in mid-July and had 174 instructional days (high) before the Advanced Placement Calculus examinations, with 56 minutes on each of the instructional days. Thus, there were 9,744 instructional minutes (high) and the school operated on a traditional schedule. The traditional schedule means that for each day school was in

session, the AP Calculus course would meet for one period of 56 minutes. Of the 46 AP Calculus AB students, 18 (39%) were female and 28 (61%) were male. Of the 36 AP Calculus BC students, 11 (31%) were female and 25 (69%) were male. The AB exam was taken in the media center and the BC exam was administered in a classroom (not in the math building). The AP Calculus exams were given to all students at the same time.

Table 3.1

Demographics/Important Characteristics of High School 1 (Public School)

Demographics	(<i>n</i>)	%
Asian	66	4
Hispanic	344	21
Black	98	6
White	1,082	66
Two or more races	49	3
Students who took AP Calculus AB and BC exams	82	5

The next high school in the sample was a public high school in the northwestern United States. The academic year began after Labor Day and had 74 class days (low). The class periods varied from 45 to 87 minutes. Only about 10% of the class periods during the year were 45 minutes. The mean class length was 80 minutes, and thus the total number of instructional minutes was 5,920 (medium). The school operated on a block schedule. There were 4 class periods meeting each day. The AP Calculus exams were administered in the high school library and all students took the exam at the same

time.

Table 3.2

Demographics/Important Characteristics of High School 2 (Public School)

Demographics	(<i>n</i>)	%
American Indian	104	7
Asian	45	3
Hispanic	282	19
Black	15	1
White	965	65
Two or more races	74	5
Students who took AP Calculus AB and BC exams	21	1.4

The third high school in the sample was a public school in the western United States. A typical week had students attend all periods 1-6 on Monday (50-minute classes), 2-4-6 blocks on Tuesdays and Thursdays, and 1-3-5 blocks on Wednesdays and Fridays (each block class is 110 minutes). The AP Calculus AB and BC classes were year-long classes, with students required to have completed Calculus AB before taking Calculus BC as a second year of AP Calculus. Before the AP exam, AP Calculus students experienced 24 “Monday” classes and 64 “block” classes, plus one 120-minute semester exam session. Thus, the total number of instructional days was 89 (low), and the total number of instructional minutes was 8,360 (high). The AP Calculus AB exams

were given in the large gym on campus, and the AP Calculus BC exams were given in the “Bingo Room” on campus. All students took the exam at the same time.

Table 3.3

Demographics/Important Characteristics of High School 3 (Public School)

Demographics	(<i>n</i>)	%
Asian	316	11
Hispanic	689	24
Black	172	6
White	1,321	46
Two or more races	373	13
Students who took AP Calculus AB and BC exams	175	6

The fourth high school in the sample was a rural, public high school in the northeastern United States. The school began the week before Labor Day and only offered AP Calculus AB. There were 154 class days (high) of AP Calculus AB before students took the examination. There were 46 minutes per class on the school’s traditional seven period day. Thus, the total number of instructional minutes was 7,084 (medium). The AP Calculus AB exam was administered in the large group instruction room. All exams were given at the same time in the same room.

Table 3.4*Demographics/Important Characteristics of High School 4 (Public School)*

Demographics	(<i>n</i>)	%
Hispanic	24	3
White	787	97
Students who took AP Calculus AB exams	14	1.7

The fifth high school in the sample was a public school in Indiana that only offers AP Calculus AB. There were 172 instructional days (high) before the examination. Classes meet for 49 minutes a day on four days of the week and 44 minutes a day on one day of the week. The total number of instructional minutes in the school's traditional schedule was 8,258 (high). The teacher required her students to take the exam. The school policy is not to allow students whose course grade is below C- to take the exam. One student did not take the exam because she was failing the class. She was an exchange student and she was not overly proficient in English. In alignment with the definition from chapter 1, this student was not included in the percentage of AP Calculus AB students as she took the course but not the exam.

One of the students who scored a 5 was a student with an Individualized Education Plan (IEP) who received extended time to take the exam. That student tested in another location. The student did not need the extra time, but the student decided in conjunction with the teacher to take the extra time since it was available. The course instructor noted that the two students who scored a 5 on the exam were constantly

competing for the highest grade in the class. The teacher noted that the student with the extended time would have still received a 5 without the extra time. Six of the students tested in a large group instruction room in a single sitting. The one student with an IEP tested in a separate room in the guidance office in a single sitting.

Table 3.5

Demographics/Important Characteristics of High School 5 (Public School)

Demographics	(<i>n</i>)	%
Hispanic	557	22
Black	304	12
White	1,569	62
Two or more races	101	4
Students who took AP Calculus AB exam	7	.28

The sixth school in the sample was a public high school in the northeastern United States. The school operated on a traditional schedule of 48-minute periods for 162 days (high) before the exam. Thus, the total number of instructional minutes was 7,776 (medium). Out of the 20 AP Calculus AB students, 7 (35%) were female and 13 (65%) were male. There was one Hispanic student and one Indian student. There was one student with an IEP. There was only one snow day used. There was also a day missed for PSAT testing. The exam was administered in the library with the PA system turned off during the day so it was quiet. Everyone took the exam on the same day. The students' average score on the multiple choice was 33.6/54 points with an 18/30 question

average on the non-calculator multiple choice, and a 10.1/15 question average on the calculator multiple choice. The free response average was 27.1/54 points.

For the 8 BC Calculus students, 5 (62.5%) were female and 3 (37.5%) were male. There were 3 males who did not take the exam as their colleges were not going to accept it. In alignment with the definition from Chapter 1, these three students were not included in the percentage of AP Calculus AB and BC students, as they took the course but not the exam. The BC Calculus class had one Indian student, no ELL students, and 1 student with an IEP. The amount of days and minutes for this class were the same as the AB class. All students took the exam in the library. The multiple-choice average was 35.1/54 points. The average was 19/30 questions on the non-calculator multiple choice and 10.3/15 questions on the calculator multiple choice. The free response average was 23.6/54 points. The AP Calculus exams were administered at the time assigned by the College Board.

Table 3.6

Demographics/Important Characteristics of High School 6 (Public School)

Demographics	(n)	%
Asian	44	3
Hispanic	59	4
Black	89	6
White	1,275	86
Two or more races	15	1
Students who took AP Calculus AB and BC exams	28	1.9

The seventh school in the sample was a public high school in the northeastern United States. There were 155 days (high) of class prior to the exam. The school followed traditional scheduling. The AP Calculus AB course and some AP Calculus BC classes met for one 41-minute period per day. For these students, the total number of instructional minutes was 6,355 (medium). The most advanced students take AP Calculus BC after a high-level Algebra 2 Honors class without a precalculus course in between. In turn, these students took AP Calculus BC with a double period lab every other day. For these students, the total number of instructional minutes was 9,512 (high). Students were bused to the administration building to take the AP Calculus exams, and all students took the exam at the same time. There were ten AP Calculus BC students who did not take the AP exam. In alignment with the definition from chapter 1, these ten students were not counted in the percentage of AP Calculus AB and BC students, as they took the course but not the exam.

Table 3.7

Demographics/Important Characteristics of High School 7 (Public School)

Demographics	(<i>n</i>)	%
Asian	180	10
Hispanic	72	4
Black	18	1
White	1,528	85
Students who took AP Calculus AB and BC exams	109	6

The eighth school in the sample was a private high school in the southern United States. There were 16 weeks of instruction, with 5 days per week, and the course met for 50 minutes each day. Thus, the total number of instructional days was 80 (low), and the total number of instructional minutes was 4,000 (low). The school followed a traditional schedule. All AP Calculus exams were administered at the school and at the same time. The school offered only the AP Calculus AB exam.

Table 3.8

Demographics/Important Characteristics of High School 8 (Private School)

Demographics	(<i>n</i>)	%
Black	60	8.2
Hispanic	89	12.2
Asian	6	.8
White	574	78.8
Students who took AP Calculus AB exam	13	2

The ninth school in the sample was a private Catholic high school in the northeastern United States. The school offers only the AP Calculus AB exam. There were 149 instructional days (medium) before the administering of the exam. The school followed a traditional schedule with 40-minute periods. Thus, the total number of instructional minutes was 5,960 (medium). The exams were administered on campus in a lecture hall. The exams were given at the same time to each student and the school does not allow students to opt out of the AP exams.

Table 3.9*Demographics/Important Characteristics of High School 9 (Private School)*

Demographics	(<i>n</i>)	%
Asian	171	11
Hispanic	171	11
Black	93	6
White	1,074	69
Two or more races	31	2
Students who took AP Calculus AB exam	36	2.3

The tenth high school in the sample was also a private Catholic high school in the northeastern United States. For the AP Calculus AB exam, there were 150 instructional days (medium) before the exam. The school follows a traditional schedule with rotating periods and 40 minutes per instructional period. Thus, the total number of instructional minutes was 6,000 (medium). For the AP Calculus BC exam, students took the course as an independent study and were tutored once a week for 40 minutes. Thus, the total number of instructional days was 30 (low) and the total number of instructional minutes was 1,200 (low). Both exams were administered in the school in a testing room, and all students took the exam at the same time.

Table 3.10*Demographics/Important Characteristics of High School 10 (Private School)*

Demographics	(<i>n</i>)	%
Asian	50	5
Hispanic	120	12
Black	221	22
White	572	57
Hawaiian Native/Pacific Islander	30	3
Students who took AP Calculus AB and BC exams	25	2.5

The eleventh school in the sample was also a private Catholic high school in the northeastern United States. The school follows a traditional 8-period, 6-day cycle schedule. Classes meet for 42 minutes on a regular day. The AP Calculus exams were administered in the auxiliary gym. The exams were given to all students at the same time in strict adherence to the College Board's testing rules. There were 138 instructional days (medium) of instruction before the AP Calculus exams. Thus, the total number of instructional minutes was 5,796 (low).

Table 3.11*Demographics/Important Characteristics of High School 11 (Private School)*

Demographics	(<i>n</i>)	%
Indian	50	5.8
Asian	7	0.8
Hispanic	4	0.5
Black	7	0.8
White	721	83.6
Pacific Islander	5	0.6
Two or more races	68	7.9
Students who took AP Calculus AB and BC exams	40	4.6

The twelfth high school in the sample was another private Catholic high school in the northeastern United States. The school is all boys. There were 134 instructional days (medium) before the AP Calculus AB exam with 42 minutes per class. Thus, the total number of instructional minutes was 5,628 (low). The school follows a rotating schedule. The test was administered in a classroom in the school and the exams were given to all students at the same time.

Table 3.12*Demographics/Important Characteristics of High School 12 (Private School)*

Demographics	(<i>n</i>)	%
Asian	31	8.8
Hispanic	211	59.8
Black	71	20.1
White	40	11.3
Students who took AP Calculus AB exams	9	2.6

The thirteenth school in the sample was a public high school in the northeastern United States. There were 136 instructional days (medium). The AP Calculus AB course meets for 1 period a day which is 41 minutes in length. Thus, the total number of instructional minutes was 5,576 (low). The AP Calculus BC course meets for 1 period a day plus an additional block of having 2 periods on alternating days. Thus, the total number of instructional minutes was 8,364 (high). The school follows a traditional schedule. The AP Calculus exams were administered in the gym and at the same time.

Table 3.13*Demographics/Important Characteristics of High School 13 (Public School)*

Demographics	(<i>n</i>)	%
Asian	118	11
Hispanic	150	14
Black	75	7
White	718	67
Two or more races	11	1
Students who took AP Calculus AB and BC exams	32	3

The fourteenth school in the sample was a private Catholic high school in the southern United States. The school only offers the AP Calculus AB course. There were 155 instructional days (high) before the exam with 42 minutes in each period. The school follows a mixed schedule, with three days of one period and one day of a block (double period). Thus, the total number of instructional minutes was 8,106 (high). The AP Calculus exams were administered in the school gymnasium and at the same time in one block.

Table 3.14*Demographics/Important Characteristics of High School 14 (Private School)*

Demographics	(<i>n</i>)	%
Asian	7	3
Hispanic	10	4
Black	7	3
White	214	89
Students who took AP Calculus AB exams	10	4.2

The fifteenth school in the sample was a private Catholic high school in the northeastern United States. The total number of instructional days was 131 (low) and the school only offers the AP Calculus AB course. Students may take AP Calculus BC online or as an independent study with a teacher. The school operated on a six-day rotating schedule, with AP Calculus meeting on five of the six days. On one day of the cycle the course met for a double period, and thus there were six meetings over a six-day cycle. Depending on the type of schedule for a given day, the class would meet for either 45 minutes, 44 minutes, 40 minutes, 32 minutes, or 37 minutes. The total number of instructional minutes was 5,480 (low). All students took the exam at the school at the same time, as is mandated by College Board. The extended time students took the exam in a different room. One student took the AP Calculus BC course online as an independent study. In alignment with the definition from chapter one, that student was not counted in the percentage of AP Calculus AB and BC students as he took the exam

but did not take an AP Calculus BC course offered by the school.

Table 3.15

Demographics/Important Characteristics of High School 15 (Private School)

Demographics	(<i>n</i>)	%
Asian	19	9
Hispanic	25	12
Black	12	6
White	139	67
Two or more races	10	5
Students who took AP Calculus AB exams	20	9.6

The sixteenth and last school in the sample was an all-boys private Catholic high school in the northeastern United States. There were 128 instructional days (low) before the AP Calculus exams. The school followed a traditional schedule with five 50-minute classes and one 60-minute class per 7-day cycle. The average number of instructional minutes on each of the instructional days was 51.55, and thus there were 6,598.4 instructional minutes (medium) before the AP Calculus exams. The AP Calculus exams were administered to all students at the same time in classrooms in the high school.

Table 3.16*Demographics/Important Characteristics of High School 16 (Private School)*

Demographics	(<i>n</i>)	%
Asian	63	4
Hispanic	63	4
Black	110	7
White	1290	82
Two or more races	47	3
Students who took AP Calculus AB and BC exams	134	8.5

Table 3.17 is a summary of all high schools in the sample. The table conveys that over two-thirds of the students from all the schools in the sample are White. Thus, these schools in the sample that offered the Advanced Placement Calculus courses do not reflect a great deal of diversity. Moreover, less than 4% of all students from these high schools took both an AP Calculus course and exam. In turn, more work needs to be done towards the College Board's commitment to equity and access in the AP program (College Board, 2012). The total population from all sixteen high schools in the sample was $n = 20,182$.

Table 3.17*Demographics/Important Characteristics of all High Schools in the Sample*

Demographics	(n)	%
Asian	1123	5.56
American Indian	104	.52
Hawaiian Native/Pacific Islander	35	.17
Indian	50	.25
Hispanic	2870	14.22
Black	1352	6.70
White	13,869	68.72
Two or more races	779	3.86
Students who took AP Calculus AB and BC exams	755	3.74

Instruments

Assessments were used. The AP Calculus examination score was the dependent variable being analyzed. They were cumulative and summative examinations graded on a numerical scale of 1 to 5. The assessments could be considered norm-referenced as the AP exam is curved, and the College Board tries to ensure that roughly the same percentage of students are earning a qualifying score each year (3 or higher). The target goal was for the student to pass (3 or higher). The assessments align with the curriculum and standards set forth by the College Board. The AP Calculus AB assessment tests the student's knowledge on limits and continuity, the derivative and applications, the

indefinite integral and applications, and the definite integral and applications. AP Calculus AB is considered the equivalent of Calculus I in college. The AP Calculus BC assessment covers all the topics from the Calculus AB exam, as well as parametric equations, polar coordinates, vector-valued functions, and infinite sequences and series (College Board, 2019). AP Calculus BC is considered the equivalent of Calculus I and II in college. The assessments help to test standards needed for success in college Calculus courses.

The breakdown of the AP Calculus AB and BC examinations is the same: Section I is multiple choice. Students have 60 minutes to complete 30 questions (no calculator permitted). Then students have 45 minutes to complete 15 questions (graphing calculator allowed). Section I is worth 54 points. Section II is constructed response. Students have 30 minutes to complete two questions (graphing calculator allowed). Students then have 60 minutes to complete four questions (graphing calculator not allowed). Section II is also worth 54 points, and therefore Section I and Section II are each 50% of the final grade (College Board, 2019). The score out of 108 points is then converted to the student's AP exam score from 1 to 5. Students who take the BC calculus exam also receive a sub score from 1 to 5 for the AB exam. The range of scores that constitute a 1, 2, 3, 4, or 5 varies slightly from year to year. Once again, the College Board tries to ensure that a similar percentage of students are earning a qualifying score each year (3 or higher).

Similar format examinations for AP Calculus AB and BC have been used for years by the College Board. The exam has been considered a valid predictor of student performance in college Calculus courses. The assessment has also been a good indicator

for where students should be placed in mathematics in college: Students scoring at least a 3 on the AP Calculus AB exam may end up placing out of Calculus I and into Calculus II. Those students with a 3 or higher on the AP Calculus BC exam may end up placing out of Calculus II and into Calculus III. The AP Calculus AB and BC exams are reliable as there have been similar passing percentages for each exam in recent years (Total Registration, 2019). One study (Young & Yoon, 1986) looked at a number of assessments including the 1986 AP Calculus AB and AP Calculus BC exams. These two exams were similar in format to the examinations currently given, consisting of 45 multiple choice and 6 constructed response questions. The 1986 exam was 180 minutes which is 15 minutes shorter than the exams currently given. Young and Yoon (1986) found the reliability of the 1986 AP Calculus AB exam and AP Calculus BC exams to be .93+ and .91+, respectively.

Procedures

The AP exam scores are disseminated to the schools in early July. The multiple choice is scored by a machine. Teachers meet during a set week in June to grade the constructed response questions. Teachers must apply to be graders for the exam, must have taught the course for at least three years, and must have taught the course in the previous school year. The teachers go through an extensive training process to ensure that the scoring rubric is being correctly followed. Doing so helps ensure consistency and accuracy with scoring for each student. If a teacher is unsure about the score that should be assigned to a student, he or she may consult with a colleague grading the same question. Each constructed response question has a “table leader” who is an expert on the rubric for that particular question. The teacher can also ask a question about the grading

to the table leader. Thus, there is a professional who is there to provide support to the teachers during the grading process.

The researcher gathered the AP exam scores from schools who were willing to share the data. The researcher gathered scores for both the AP Calculus AB and AP Calculus BC exams. Any data files were kept on the researcher's password protected email account to help ensure security. The assessment and administration met the guidelines for protecting human subjects. Approval to use the assessment data was given to the researcher by a building or district administrator. Confidentiality was maintained as no names or other identifying information was used in the collection of data. The assessment was appropriate for measuring the intended variables. The assessment was selected because it is considered valid and reliable by both the schools using it and the College Board. In addition, the data was conveniently available to the researcher to analyze for the dissertation.

Data Analysis

For the first two research questions, a Three-Way Between-Subjects Analysis of Variance (ANOVA) was the statistical analysis that was utilized to determine the significance for the null hypothesis. The Three-Way Between-Subjects ANOVA was selected as the statistical analysis because it examined if there was an interaction effect between three independent variables on the dependent variable (Laerd Statistics, 2018). For the first research question, the three independent variables were amount of instructional days, amount of instructional time (in minutes), and type of class (AB or BC). For the second research question, the three independent variables were amount of instructional time (in minutes), school type (public or private), and type of class (AB or

BC). For the three research questions, the AP Calculus exam score was the dependent variable. For the third research question, a multiple linear regression was the statistical analysis that was utilized to determine the significance for the null hypothesis. A multiple linear regression was used to understand whether AP Calculus exam performance could be predicted based on several independent variables (Laerd Statistics, 2018). In the current study, the strength of the linear relationship was determined between the amount of instructional days, the amount of instructional time (in minutes), school type (public or private), type of class (AB or BC), percentage of AP Calculus AB and BC students who took both the course and exam, and scores on the AP Calculus exams. An alpha level of .05 was used for the analysis in each research question. The purpose of this non-experimental research was to determine the influence of the amount of instructional days/amount of instructional time on AP Calculus exam scores. The design was non-experimental since the researcher utilized data from an exam that already took place, the AP Calculus exams from May 2019.

CHAPTER 4

Results

Introduction

The purpose of this non-experimental research was to determine the influence of the amount of instructional days and amount of instructional time (in minutes) on achievement on the AP Calculus examinations for high school students across the United States. The design was non-experimental since the researcher utilized data from an exam that already took place, the AP Calculus exams from May 2019. This chapter presents findings from the three research questions in the current study. These results and findings provide context for the discussion and conclusion in the last chapter.

Research Question 1

To what extent will the amount of instructional days, amount of instructional time (in minutes), and types of class (AB or BC) influence the AP Calculus scores?

Hypotheses

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional days (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores between the types of class (AB or BC)

H₀: There will be no interaction among schools of different amounts of instructional days and among schools of different amounts of instructional time (in minutes).

H₀: There will be no interaction among schools of different amounts of instructional days and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional days, schools of different amounts of instructional time (in minutes), and types of class (AB or BC).

For the first research question, a Three-Way Between-Subjects Analysis of Variance (ANOVA) was the statistical analysis that was utilized to determine the significance for the null hypothesis. The Three-Way Between-Subjects ANOVA was selected as the statistical analysis because it examined if there was an interaction effect between three independent variables on the dependent variable (Laerd Statistics, 2018). For the first research question, the three independent variables were amount of instructional days, amount of instructional time (in minutes), and type of class (AB or BC). The AP Calculus exam score was the dependent variable. An alpha level of .05 was chosen to test the significance of each null hypotheses.

The data were screened and there were no missing values and no coding errors found. No cases were deleted. Prior to running the Three-Way Between-Subjects ANOVA, the six assumption tests for the analysis were conducted (Laerd Statistics, 2018). The dependent variable (AP Calculus exams scores) was measured at the continuous level from 1 to 5. The three independent variables (instructional time in minutes, instructional days, and type of class) consisted of two or more categorical, independent groups: Instructional time in minutes (high, medium, low), instructional days

(high, medium, low), and type of class (AB or BC). There was also independence of observations. Every student in the sample had a set amount of instructional days, set amount of instructional time in minutes, and took either the AB exam or BC exam. Thus, no participant was in more than one group.

The AP Calculus exam scores were integers from 1 to 5, and therefore there were no significant outliers. In addition, the researcher conducted the test for outliers using SPSS and found that none of the z scores were greater than 2.58 or less than -2.58. The researcher ran a normality test for each level of each independent variable in order to assess the normality for each analysis. ANOVAs are robust with regard to moderate departures from normality (Winer, Brown, & Michels, 1991). When looking at the histograms, the mode was 5, which demonstrates that the data were skewed but reflects the scores reported. The Shapiro-Wilk test was significant which shows a non-normal distribution, and some of the histograms demonstrated a negative skewed distribution. For the Q-Q plots, the scatter of dots lies close to the line with no obvious pattern coming away from the line. Thus, the Q-Q plots showed a normal distribution.

Lastly, homogeneity of variances for each combination of the groups of the three independent variables was tested using Levene's test for homogeneity of variances. Levene's test for homogeneity of variances was statistically significant. The AP Calculus scores were transformed using log base ten, square root, analyzing the residuals, and the Box-Cox test. There were still no changes in the normality tests or the homogeneity tests. The data were naturally skewed, which can be considered a limitation of the current study.

A One-Way ANOVA was conducted as a follow up statistical analysis to determine any significant mean differences in AP Calculus scores based on the amount of instructional days. Table 4.1 presents descriptive statistics for AP Calculus scores based on the amount of instructional days and the One-Way ANOVA results. Students of schools with high instructional days outperformed students of schools with low instructional days, although the difference was not statistically significant ($MD = .155$, $SE = .092$, $p = .214$).

Table 4.1

Descriptive Statistics for AP Calculus Exam Scores for Schools of High, Medium, and Low Instructional Days and One-Way ANOVA Results for Significant Mean Differences

Days	<i>M</i>	<i>SD</i>	<i>(n)</i>	<i>MD (I - J)</i>	<i>SE</i>	<i>p</i>
High	4.08	.992	250			
Medium	3.19	1.301	140			
Low	3.93	1.141	365			
High (I) Medium (J)				.898	.119	.000
Low (I) Medium (J)				.743	.112	.000

A One-Way ANOVA was conducted as a follow up statistical analysis to determine any significant mean differences in AP Calculus scores based on the number of instructional minutes. It was found that students from the schools of high instructional minutes outperformed the students from the schools of middle and low instructional

minutes. In addition, students from the schools of middle instructional minutes outperformed the students from low instructional minutes schools. Table 4.2 presents descriptive statistics for AP Calculus scores based on the amount of instructional time (in minutes) and the One-Way ANOVA results.

Table 4.2

Descriptive Statistics for AP Calculus Exam Scores for Schools of High, Medium, and Low Instructional Time (In Minutes) and One-Way ANOVA Results for Significant Mean Differences

Minutes	<i>M</i>	<i>SD</i>	<i>(n)</i>	<i>MD (I - J)</i>	<i>SE</i>	<i>p</i>
High	4.26	.965	319			
Medium	3.66	1.160	337			
Low	3.11	1.293	99			
High (I) Medium (J)				.605	.086	.000
High (I) Low (J)				1.152	.127	.000
Medium (I) Low (J)				.548	.126	.000

A t test was conducted as a follow up statistical analysis to determine any significant mean differences in AP Calculus scores based on the school type. It was found that public schools in the sample significantly outperformed private schools in the sample. Table 4.3 presents descriptive statistics for AP Calculus scores based on the

school type and results of the t test. A t test was conducted as a follow up statistical analysis to determine any significant mean differences in AP Calculus scores based on the class type. It was found that BC Calculus students significantly outperformed AB Calculus students. Table 4.4 presents descriptive statistics for AP Calculus scores based on the class type and results of the t test.

Table 4.3

AP Calculus Exam Scores Means for Private Schools Versus Public Schools and t Test Results

School Type	<i>M</i>	<i>SD</i>	(<i>n</i>)	<i>t</i>	<i>df</i>	<i>MD (I – J)</i>	<i>p</i>
Private (J)	3.51	1.257	287	-6.361	753	.540	.000
Public (I)	4.05	1.063	468				

Table 4.4

AP Calculus Exam Scores Means for AB Calculus Classes Versus BC Calculus Classes and t Test Results

Class Type	<i>M</i>	<i>SD</i>	(<i>n</i>)	<i>MD (I – J)</i>	<i>t</i>	<i>df</i>	<i>p</i>
AB Calculus (J)	3.61	1.198	494	.680	-7.899	753	.000
BC Calculus (I)	4.29	.972	261				

Results of the Three-Way Between-Subjects ANOVA demonstrated that there was a statistically significant difference in AP Calculus exam scores based on the amount

of instructional days before the exam, $F_{(2, 741)} = .9710, p < .001$. Thus, students with a high number of instructional days scored higher on the AP Calculus exams. The Eta Squared effect size was .02 which is considered small. The first null hypothesis was rejected.

There was a statistically significant difference in AP Calculus exam scores based on the number of instructional minutes before the exam, $F_{(2, 741)} = 15.370, p < .001$. Thus, students with a high number of instructional minutes scored higher on the AP Calculus exams. The Eta Squared effect size was .03 which is considered small. The second null hypothesis was rejected.

There was a statistically significant difference in AP Calculus exam scores based on class type, $F_{(1, 741)} = 19.088, p < .001$. Thus, BC Calculus students performed higher than AB Calculus students. The Eta Squared effect size was .02 which is considered small. The third null hypothesis was rejected.

There was an interaction between the amount of instructional days and amount of instructional time (in minutes), $F_{(2, 741)} = 4.327, p < .01$. The Eta Squared effect size was .01 which is considered small. Thus, the fourth null hypothesis was rejected. There was no significant interaction between the amount of instructional days and class type (AB or BC). Thus, the fifth null hypothesis was retained. There was no significant interaction between the amount of instructional time in minutes and class type (AB or BC). Thus, the sixth null hypothesis was retained. Lastly, there was no significant interaction between amount of days, amount of instructional time in minutes, and class type (AB or BC). Thus, the three-way interaction null hypothesis was retained. The Tukey post hoc

results and simple effects showed a number of statistically significant mean differences in the pairwise comparisons as illustrated in Table 4.5 and Table 4.6.

Table 4.5

Significant Mean Differences for Instructional Minutes in Research Question 1

Minutes	Class	Days	<i>MD</i> (I – J)	<i>SE</i>	<i>p</i>
Low	AB Calculus	Low (I) Medium (J)	.991	.236	.000
Low	BC Calculus	Low (I) Medium (J)	2.077	.801	.010

Table 4.6*Significant Mean Differences for Instructional Days in Research Question 1*

Days	Class	Minutes	<i>MD</i> (I – J)	<i>SE</i>	<i>p</i>
High	BC Calculus	High (I) Medium (J)	.672	.186	.000
Medium	AB Calculus	Medium (I) Low (J)	.684	.202	.001
Medium	BC Calculus	High (I) Low (J)	1.195	.388	.002
Low	AB Calculus	High (I) Medium (J)	.539	.139	.000
Low	BC Calculus	High (I) Medium (J)	.800	.212	.001
High	BC Calculus (I) High AB Calculus (J) High		.798	.187	.000
High	BC Calculus (I) Medium AB Calculus (J) Medium		.376	.190	.049
Low	BC Calculus (I) High AB Calculus (J) High		.715	.171	.000
Low	BC Calculus (I) Medium AB Calculus (J) Medium		.454	.188	.016

Research Question 2

To what extent will the amount of instructional time (in minutes), school type (public, private), and types of class (AB or BC) influence AP Calculus exam scores?

Hypotheses

H₀: There will be no statistically significant difference in AP Calculus exam scores among schools of different numbers of instructional minutes (high, medium, low).

H₀: There will be no statistically significant difference in AP Calculus exam scores based upon school type (public, private).

H₀: There will be no statistically significant difference in AP Calculus exam scores based upon the types of class (AB or BC)

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and school type (public, private).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes) and types of class (AB or BC).

H₀: There will be no interaction between school type (public, private) and types of class (AB or BC).

H₀: There will be no interaction among schools of different amounts of instructional time (in minutes), school type (public, private), and types of class (AB or BC).

For the second research question, a Three-Way Between-Subjects Analysis of Variance (ANOVA) was utilized to determine the significance of the main and interaction effects of instructional minutes, school types, and class types on AP Calculus exam scores. An alpha level of .05 was chosen to test the significance of each null hypotheses.

The data were screened and there were no missing values and no coding errors found. No cases were deleted. Prior to running the Three-Way Between-Subjects ANOVA, the six assumption tests for the analysis were conducted (Laerd Statistics,

2018). The dependent variable (AP Calculus exams scores) was measured at the continuous level from 1 to 5. The three independent variables (instructional time in minutes, school type, and type of class) consisted of two or more categorical, independent groups: Instructional time in minutes (high, medium, low), school type (public, private), and type of class (AB or BC). There was also independence of observations. Every student in the sample had a set amount of instructional time in minutes, one school type, and took either the AB exam or BC exam. Thus, no participant was in more than one group.

The AP Calculus exam scores were integers from 1 to 5, and therefore there were no significant outliers. In addition, the researcher conducted the test for outliers using SPSS and found that none of the z scores were greater than 2.58 or less than -2.58. The researcher ran a normality test for each level of each independent variable in order to assess the normality for each analysis. ANOVAs are robust with regard to moderate departures from normality (Winer, Brown, & Michels, 1991). When looking at the histograms, the mode was 5, which demonstrates that the data were skewed but reflects the scores reported. The Shapiro-Wilk test was significant which shows a non-normal distribution, and some of the histograms demonstrated a negative skewed distribution. For the Q-Q plots, the scatter of dots lies close to the line with no obvious pattern coming away from the line. Thus, the Q-Q plots showed a normal distribution. Lastly, homogeneity of variances for each combination of the groups of the three independent variables was tested using Levene's test for homogeneity of variances. Levene's test for homogeneity of variances was statistically significant. The data were naturally skewed, which can be considered a limitation of the current study.

Results of the Three-Way Between-Subjects ANOVA demonstrated that there was a statistically significant difference in AP Calculus exam scores based on the number of instructional minutes before the exam, $F_{(2, 745)} = 13.115, p < .001$. Thus, students with a higher number of instructional minutes performed better on the AP Calculus exams. The Eta Squared effect size was .03 which is considered small. The first null hypothesis was rejected.

There was no statistically significant difference in AP Calculus exam scores based on school type. Thus, the second null hypothesis was retained. There was a statistically significant difference in AP Calculus scores based on class type, $F_{(1, 745)} = 16.730, p < .001$. Thus, BC Calculus students performed higher than AB Calculus students. The Eta Squared effect size was .02 which is considered small. The third null hypothesis was rejected.

There was no significant interaction between the amount of instructional time in minutes and school type (public, private). Thus, the fourth null hypothesis was retained. There was no significant interaction between the amount of instructional time in minutes and class type (AB or BC). Thus, the fifth null hypothesis was retained. There was no significant interaction between school type (public, private) and class type (AB or BC). Thus, the sixth null hypothesis was retained. For the three-way interaction, SPSS could not calculate it due to the sum of squares and degrees of freedom being zero. Thus, it could not be determined whether to reject or retain the last null hypothesis, which can be considered a limitation of the current study.

The Tukey post hoc results and simple effects showed a number of statistically significant mean differences in the pairwise comparisons. For AB Calculus classes,

private schools with high minutes significantly outperformed private schools with low minutes ($MD = 1.242, SE = .363, p < .01$). For AB Calculus classes, private schools with medium minutes significantly outperformed private schools with low minutes ($MD = .500, SE = .155, p < .01$). For AB Calculus classes, public schools with high minutes significantly outperformed public schools with medium minutes ($MD = .581, SE = .149, p < .001$). For BC Calculus classes, private schools with medium minutes significantly outperformed private schools with low minutes ($MD = .800, SE = .326, p = .014$). For BC Calculus classes, public schools with high minutes significantly outperformed public schools with medium minutes ($MD = .657, SE = .157, p < .001$).

In schools with a high amount of instructional time in minutes, students in public-school BC Calculus classes significantly outperformed students in public-school AB Calculus classes ($MD = .683, SE = .123, p < .001$). In schools with a medium amount of instructional time in minutes, private-school BC Calculus classes significantly outperformed private-school AB Calculus classes ($MD = .442, SE = .192, p = .022$). Lastly, students in schools with a medium amount of instructional time in minutes, public-school BC Calculus classes significantly outperformed public-school AB Calculus classes ($MD = .607, SE = .179, p < .01$).

Research Question 3

To what extent will there be an association between the number of instructional days, amount of instructional time (in minutes), type of school (public, private), type of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam, and performance on the AP Calculus exams?

Hypothesis

H_0 : The number of instructional days, amount of instructional time (in minutes), type of school (public, private), type of class (AB or BC), and percentage of AP Calculus AB and BC students in the school who took both the course and exam will not be valid predictors of AP Calculus exam scores.

For the third research question, a multiple linear regression analysis was conducted to determine the significance for the null hypothesis. A multiple linear regression was used to understand whether AP Calculus exam performance could be predicted based on several independent variables (Laerd Statistics, 2018). In the current study, the strength of the linear relationship was determined among the amount of instructional days, the amount of instructional time (in minutes), school type (public or private), type of class (AB or BC), percentage of AP Calculus AB and BC students who took both the course and exam, and scores on the AP Calculus exams. An alpha level of .05 was used to test for the significance of the null hypothesis.

The data were screened and there were no missing values and no coding errors found. No cases were deleted. School type was a dichotomous variable so it was dummy coded 0 (private) and 1 (public). Class type was a dichotomous variable so it was dummy coded 0 (BC Calculus) and 1 (AB Calculus). The number 0 was assigned to private schools and to BC Calculus because the researcher believed that BC Calculus students would outperform AB Calculus students and private-school students would outperform public-school students. Number of instructional days, number of instructional minutes, and percentage of students who took both an AP Calculus course and exam were all quantitative variables.

Prior to running the Multiple Linear Regression, the assumption tests for the analysis were conducted (Laerd Statistics, 2018). The n quota assumption was satisfied, as there were 755 scores in the study. Scatterplots showed that the relationship between each independent variable (days, minutes, school type, class type, and percentage of students who took the AP Calculus course and exam) and the dependent variable (AP Calculus scores) was linear. There was no multicollinearity in the data. None of the correlations were higher than 0.8. Moreover, analysis of collinearity statistics shows this assumption had been met, as VIF scores were well below 10 (Days = 1.153, Minutes = 2.004, School Type = 2.249, Class Type = 1.143, Student Percentage = 1.299), and all tolerance scores were above 0.2 (Days = .867, Minutes = .499, School Type = .445, Class Type = .875, Student Percentage = .770). For the values of the residuals being independent, the Durbin-Watson statistic was less than 1 (Durbin-Watson = .401), which can be considered a limitation of the current study. The reason that this probably happened is because the individual data points needed to be independent from one another (or uncorrelated). The data points and the resulting residuals were only 5 different points, so many of the residuals were the same.

The variance of the residuals was constant. The plot of standardized residuals versus standardized predicted values showed no obvious signs of funneling, suggesting the assumption of homoscedasticity had been met. The P-P plot for the model suggested that the values of the residuals were normally distributed as the dots were close to the diagonal line. Only extreme deviations from normality are likely to have a significant impact on the findings. Lastly, there were no influential cases biasing the model. Cook's

Distance values were all under 1, suggesting individual cases were not unduly influencing the model.

A multiple regression was carried out to investigate whether number of instructional days, amount of instructional time in minutes, school type (private or public), class type (AB or BC), and percentage of students in the school who took both an AP Calculus course and exam could significantly predict students' AP Calculus exam scores. The results of the regression indicated that the model explained 15.6% of the variance of AP Calculus scores and that the model was a significant predictor of exam performance, ($R = .401$, $F(5, 749) = 28.768$, $p < .001$, $R^2_{Adj} = .156$). The number of instructional minutes contributed significantly to the model ($B = .000$, $p < .001$) with a unique contribution of $sr^2_{minutes} = .0289$, accounting for 2.89% of the variance. The class type (AB or BC) also contributed significantly to the model ($B = -.514$, $p < .001$) with a unique contribution of $sr^2_{class\ type} = .038416$, accounting for approximately 3.84% of the variance. The percentage of students in the school who took both an AP Calculus course and exam also contributed significantly to the model ($B = .061$, $p < .01$) with a unique contribution of $sr^2_{student\ percentage} = .010609$, accounting for approximately 1.06% of the variance. The number of instructional days did not contribute significantly to the model ($B = -.002$, $p = .175$). Lastly, school type (public or private) did not contribute significantly to the model ($B = .110$, $p = .364$). This indicates that the number of instructional minutes, class type, and percentage of students who took both an AP Calculus course and exam were significant predictors of AP Calculus scores. The number of instructional days and school type were not significant predictors of AP Calculus scores. The final predictive model was:

Predicted AP Calculus Exam Score = $2.602 + .000(\text{Number of instructional minutes}) - .514(\text{Class Type}) + .061(\text{Student Percentage who took AP Calculus course and exam})$.

The null hypothesis was rejected.

CHAPTER 5

Discussion

Introduction

This chapter discusses the findings from the three research questions in the current study. The results and findings from Chapter 4 provide context for the discussion and conclusion in this last chapter. The discussion of findings will also connect back to the theoretical and conceptual framework from Chapter 1. Moreover, the discussion is connected back to the literature review from Chapter 2. Lastly, there will be a discussion of limitations, as well as recommendations for future research and future practice.

Implication of Findings

The data analysis from the first research question revealed that there was a statistically significant difference in AP Calculus scores based on the amount of instructional days, amount of instructional time (in minutes), and type of class (AB or BC). Students with a high number of instructional days performed higher on the AP Calculus exams. Students with a high number of instructional minutes outperformed students with a medium and low number of instructional minutes. These findings can be explained by the conceptual framework, as the amount of instructional days and amount of instructional time influenced how students constructed knowledge, which in turn impacted performance on the AP Calculus examinations. BC Calculus students performed higher than AB Calculus students. This finding was in alignment with national passing rates on the AB Calculus and BC Calculus exams (Total Registration 2019).

There was a significant interaction between the amount of instructional days and amount of instructional time (in minutes). Once again, since the conceptual framework demonstrates how the amount of instructional days and instructional time influenced how students constructed knowledge, it makes sense that there was a significant interaction between these two independent variables. For instance, discovery learning is one of the instructional methods that works well with constructivism (Schunk, 2016). In the AP Calculus class, once students have learned the quotient rule, they can appropriately discover the derivatives of different trigonometric functions. Students need adequate instructional time and instructional days in order to derive these formulas on their own, as opposed to the teacher merely giving the derivative rules to the students. The other two-way interactions between days and class type and between minutes and class type were not statistically significant. The three-way interaction between days, minutes, and class type was not statistically significant. One possible explanation is that the additional days and instructional time allowed students more opportunities to learn through constructivist strategies. Such learning through constructivism should be able to occur in any rigorous course, and therefore the type of calculus class did not interact with the amount of instructional days or amount of instructional time.

For both AB Calculus and BC Calculus courses with a low number of minutes, students with a low number of instructional days significantly outperformed students with a medium number of instructional days. One plausible explanation is the type of scheduling implemented in the schools in the sample. Some schools in the sample implemented block scheduling, where the AP Calculus class met every other day for a longer period of time. In turn, a school with a low number of instructional days could

end up with more instructional minutes than a school with a medium number of instructional days.

The findings from the preceding paragraph contradict the theoretical framework of constructivism. However, these findings do lend support to the number of instructional days not being a significant contributor to the linear regression model in the third research question. For schools with high days, BC calculus students with high minutes outperformed students with medium minutes. For schools with medium days, AB Calculus students with medium minutes outperformed students with low minutes, and BC Calculus students with high minutes outperformed students with low minutes. For schools with low days, AB Calculus students with high minutes outperformed students with medium minutes, and BC Calculus students with high minutes outperformed students with medium minutes. In all of these cases of significant differences, the larger amount of instructional time was beneficial to student performance. Once again, the theoretical framework of constructivism is justified, as students had more time to practice with constructivist learning strategies.

For schools with a high number of instructional days, BC Calculus students with high minutes outperformed AB Calculus students with high minutes, and BC Calculus students with medium minutes outperformed AB Calculus students with medium minutes. For schools with a low number of instructional days, BC Calculus students with high minutes outperformed AB Calculus students with high minutes, and BC Calculus students with medium minutes outperformed AB Calculus students with medium minutes. These findings are consistent with national statistics on BC Calculus students performing higher than AB Calculus students (Total Registration, 2019). Since schools

normally require certain prerequisite courses and performance in mathematics to place into the BC Calculus course, the BC Calculus students tend to be more advanced in mathematics than the AB Calculus students. The BC Calculus students are essentially one year ahead in mathematics of the AB Calculus students. Thus, in terms of the theoretical framework, it is plausible that the BC Calculus students were able to construct knowledge more effectively in a manner that was needed for success on the AP Calculus exams.

A surprising finding from Table 4.1 was that students with a low number of instructional days significantly outperformed students with a medium number of instructional days. One plausible explanation is that some of the schools in the sample operated on a block schedule, where the class met every other day but for a longer period of time. In turn, a school with a low number of instructional days could have more instructional minutes than a school with a medium number of instructional days. Since there was a statistically significant difference in AP Calculus scores based on the number of instructional minutes, it makes sense that students with a low number of instructional days could outperform students with a medium number of instructional days.

The data analysis from the second research question revealed that there was a statistically significant difference in AP Calculus scores based on the amount of instructional time (in minutes) and type of class (AB or BC). Students with a high number of instructional minutes performed better on the AP Calculus exams than students with medium or low instructional minutes. Once again, the conceptual framework justified how such differences occurred. Teachers must provide the instructional support (scaffolding) to help students maximize their learning in their

unique zone of proximal development (Schunk, 2016). One example of scaffolding with the AP Calculus course is a five-step process when teaching related rates. The process involves drawing a picture, listing known and unknown quantities, listing an appropriate equation, differentiating on both sides of the equation, and plugging in and solving algebraically for the unknown quantity. Adequate instructional time is needed for the teachers to provide such scaffolding and allow students to engage with the material. Eventually, those scaffolds can be removed as students become more mathematically confident.

Mathematics is not a spectator sport (Phillips, 2005). While a student can understand a textbook and lecture, the best way to learn mathematics is by practicing. The more instructional time a student has, the more he or she is able to practice mathematics and thus learn what is necessary to be successful on assessments. Moreover, by increasing the amount of instructional time, there is more opportunity for students to learn in their zone of proximal development. Since doing mathematics requires time, the amount of instructional time is more influential than the quality of instruction. While a teacher can provide excellent explanations and lessons, ultimately the student must be able to replicate those same kinds of problems through adequate practice, which requires time.

BC Calculus students performed higher than AB Calculus students, which was consistent with national statistics (Total Registration, 2019). The main effect of school type was not statistically significant. One possible explanation for school type not being statistically significant was the purposive sampling and voluntary response in the current study. The researcher had connections with several strong public schools that were

willing to share their scores. Moreover, those public-school teachers who voluntarily responded may have chosen to do so since their school's scores were above average. In turn, the public schools outperformed the private schools. There were only sixteen schools in the current study. Based on statistics from Chapter 2 regarding AP private-school students outperforming AP public-school students (Council for American Private Education, 2015), the researcher suspects that if there were a larger number of schools in the sample, the private schools would have outperformed the public schools. None of the two-way interactions were statistically significant. Based on the theoretical framework, constructivist learning strategies should be able to occur regardless of the type of class or the type of school that a student was in. Thus, it makes sense that none of the two-way interactions were statistically significant. The three-way interaction could not be calculated using SPSS.

For AB Calculus classes, private schools with high minutes significantly outperformed private schools with low minutes, and private schools with medium minutes significantly outperformed private schools with low minutes. For AB Calculus classes, public schools with high minutes significantly outperformed public schools with medium minutes. For BC Calculus classes, private schools with medium minutes significantly outperformed private schools with low minutes, and public schools with high minutes significantly outperformed public schools with medium minutes. In all of these significant mean differences, the theoretical framework justifies how increased instructional time allowed students to practice more with constructivist strategies and in turn perform higher on the AP Calculus exams. An important principle of constructivism is the construction of knowledge, where the successful learner can connect new

information with existing knowledge in significant ways (Schunk, 2016).

For the AP Calculus exam, the free response questions often cover the same array of topics. The AB Calculus free response usually tests area and volume, a definite integral in the context of a word problem, related rates, calculus theorems, and the first and second derivative test. The BC Calculus free response usually tests polar functions, parametric equations, and series. By having more instructional time, there is more opportunity for review where students can practice with free response questions from exams in recent years. By going through these problems, students get a sense of the kinds of questions that are asked and what the expectation is with receiving credit. In turn, while students may be presented with a new scenario on the AP Calculus exam, they have had enough instructional time with the material, where they are able to appropriately apply their existing knowledge to the new problems.

In schools with a high amount of instructional time in minutes, students in public-school BC Calculus classes significantly outperformed students in public-school AB Calculus classes. In schools with a medium amount of instructional time in minutes, private-school BC Calculus classes significantly outperformed private-school AB Calculus classes. Lastly, students in schools with a medium amount of instructional time in minutes, public-school BC Calculus classes significantly outperformed public-school AB Calculus classes. These findings are consistent with national statistics on BC Calculus students performing higher than AB Calculus students (Total Registration, 2019). Since schools normally require certain prerequisite courses and performance in mathematics to place into the BC Calculus course, the BC Calculus students tend to be more advanced in mathematics than the AB Calculus students. The BC Calculus students

are essentially one year ahead in mathematics of the AB Calculus students. Thus, in terms of the theoretical framework, it is possible that the BC Calculus students were able to construct knowledge more effectively in a manner that was needed for success on the AP Calculus exams.

The data analysis from the third research question revealed that the model was a significant predictor of AP Calculus exam performance. The number of instructional minutes, class type (AB or BC), and percentage of students in the school who took both an AP Calculus course and exam significantly contributed to the model. The theoretical framework demonstrates how students with a high number of instructional minutes had more opportunity to practice with constructivist learning strategies, which is why these students performed higher on the AP Calculus exams. The findings on class type are consistent with national statistics on BC Calculus students performing higher than AB Calculus students (Total Registration, 2019). Since schools normally require certain prerequisite courses and performance in mathematics to place into the BC Calculus course, the BC Calculus students tend to be more advanced in mathematics than the AB Calculus students. The BC Calculus students are essentially one year ahead in mathematics of the AB Calculus students. Thus, in terms of the theoretical framework, it is possible that the BC Calculus students were able to construct knowledge more effectively in a manner that was needed for success on the AP Calculus exams. A higher percentage of students who took both an AP Calculus course and exam means that more students in the school were enrolled in these rigorous and constructivist classes, which is why this independent variable was a significant contributor to the linear regression model. The number of instructional days and school type (public, private) did not

contribute significantly to the model. One plausible explanation for the number of instructional days was that students with low instructional days outperformed students with medium instructional days (Table 4.1). Lastly, constructivist learning strategies should take place in an Advanced Placement class regardless of the school type.

The instructional minutes were statistically significant in all three research questions, which represents a consistent finding. The results on the influence of instructional days were mixed. While the amount of instructional days was statistically significant in the first research question, the number of instructional days was not a significant contributor to the linear regression model in the third research question. The results were consistent with national trends of BC Calculus students outperforming AB Calculus students (College Board, 2018). Thus, it makes sense that the class type was statistically significant in research questions 1 and 2, and a significant contributor to the linear regression model in research question 3. The school type (public, private) was not statistically significant in research question 2, and was not a significant contributor to the linear regression model in research question 3.

The findings supported the theoretical framework of constructivism. The instructional time (in minutes) influenced how well students constructed knowledge and consequently performed on the AP Calculus exams. The instructional time (in minutes) was statistically significant in all three research questions. The amount of instructional days also influenced how well students constructed knowledge and performed on the AP Calculus exams. Constructivism provided an interpretive lens to the non-experimental research in the study. Specifically, students were able to construct knowledge due to having more time to practice constructivist instructional strategies.

The following constructivist strategies are applicable to the AP Calculus course and require additional instructional time: Student initiative and autonomy, activating students' prior knowledge, encouraging students to dialogue with the teacher and each other, encouraging student inquiry, having students elaborate on initial responses, and allowing wait time for students to answer questions. A case of activating students' prior knowledge is having them recall derivative rules before showing them the anti-derivative rules that are associated with integration. Instructional time is needed to activate such prior knowledge. Having students dialogue with the teacher and each other requires more instructional time outside of the direct instruction from the teacher. An example of having students elaborate on initial response is having students not only state whether a function has a relative maximum or minimum, but to write out the explanation in terms of a sign change in the first derivative. More instructional time is also needed if students are going to be provided with wait time to process the teacher's questions and provide an appropriate response.

The current study also supported the conceptual framework in Figure 1.1, as the instructional days and instructional time influenced how students constructed knowledge, which in turn impacted performance on the AP Calculus examinations. Insight was needed to better understand how the quantity of instruction impacts student learning. The researcher's conjecture that there was an association between amount of instructional time and performance on the AP Calculus exams was supported by the results from Chapter 4. Part of what influenced the connection between the independent variables and the dependent variable was constructivism. The researcher has direct familiarity with some of the teachers from the schools in the sample and had observed their

implementation of constructivist instructional strategies. Moreover, the researcher looked at class pages from teachers in other schools in the sample, and observed that constructivist strategies such as discovery learning were included in each teacher's lessons.

Relationship to Prior Research

As the literature review articulated, an increase in instructional time could have a positive influence on student performance (Cattaneo et al., 2016; Lavy, 2015; Mandel & Suessmuth, 2011; Woessmann, 2003). The current research study extended past research by demonstrating that there was a statistically significant difference in AP Calculus exam scores based on the instructional time in minutes. The current study refuted previous studies cited in Chapter 2 that an increase in instructional time has a neutral impact on student achievement (Skirbekk, 2006; Woessmann, 2010). Woessmann (2010) found no significant difference on student test scores in Germany based on the amount of instructional time. Skirbekk (2006) looked at TIMSS scores from 2006 and found no effect of time in school on student achievement after controlling for student characteristics and school. The current study found that there was a significant difference in AP Calculus scores based on the amount of instructional time in minutes. Moreover, the current research study filled in a gap in the existing literature by focusing on the impact of instructional time on the AP Calculus exams, which was not a focus in prior research.

A surprising finding was that school type was not statistically significant. Based on previous research from the literature review (Council for American Private Education, 2015), the researcher believed that private school students would significantly outperform

the public-school students. The Council for American Private Education (2015) found that AP students from private schools outperformed AP students from public schools in 2014. The results from the current study contradicted those findings, as there was no statistically significant difference in AP Calculus scores based on the school type. It is possible that private school students outperform public school students on AP exams as a whole, but not specifically on the two AP Calculus examinations. Lastly, Kidron and Lindsay (2014) noted that their study would be able to assess the effects of increased learning time using multiple factors simultaneously as the knowledge base grows. The current research study looked at instructional days, instructional time in minutes, school type, class type, and percentage of students who took both an AP Calculus course and exam. Thus, the current study filled a research need identified by Kidron and Lindsay (2014).

The LAB (1998) noted that the use of time is the most influential factor in what happens in America's schools. The current study justifies such research, the amount of instructional time was statistically significant in all three research questions. Thus, the use of time influenced how well students performed on the AP Calculus examinations. The LAB (1998) also noted how block scheduling can provide schools with more instructional time. This comment was important to the current study, as it was possible for a school in the sample to have a lower number of instructional days than another school in the sample, but still have a higher number of instructional minutes. Such a scenario could help explain how schools with low instructional days outperformed schools with medium instructional days.

Limitations

A limitation of the current study was that purposive sampling was used. Imprecision of measurement would have occurred if a teacher sent over the incorrect number of instructional days or the incorrect number of instructional minutes per class period, which would bias the pattern of results observed. The researcher used prior networking connections to help obtain scores from different schools. The sample was also non-random since the students already took the AP Calculus course, and each school already had a set amount of instructional days and instructional time (in minutes). The sampling limitation was that the purposive sample may involve a judgment error from the researcher (Fraenkel, Wallen, & Hyun, 2017). Voluntary response was another limitation of the current study. The researcher posted to an online AP Calculus forum asking if teachers were willing to share data from their respective schools. Thus, educators only responded to the forum if they wanted to share their school's scores. The researcher noted that only one school in the sample had poor scores (where the mode was a 1). Thus, educators may have only responded to the forum if they knew that their school's scores were above average.

One possible extraneous variable that may have influenced the outcome of the dependent variable was the environment (e.g. noise level, temperature of room, time of day the test is given, distractions). Due to logistics and scheduling reasons, the schools may not be able to administer the AP Calculus exam to all students in the same location, such as the auditorium or gymnasium. The researcher inquired with those schools that were willing to share data where the exam was administered. Such inquiry shed light on whether students were away from any noticeable source of noise, and if walls and boards

were cleared to help eliminate distractions to the students. The researcher also verified that the exam was administered on the same day and time for all students. The researcher asked the same questions to all the schools in the sample to verify that each school was treated the same with inquiry data.

The participant/person variable was another extraneous variable that can influence the outcome of the dependent variable. This variable refers to the ways each participant varies from the other and how this could affect the results (i.e. mood, intelligence, anxiety, nerves, concentration) (McLeod, 2018). The participant variable can also encompass prior academic preparation. For instance, most of the students in the sample likely took precalculus before taking an AP Calculus course. Some of these precalculus courses include an introduction to calculus, which means that some students in the sample had calculus training before taking the Advanced Placement course. In one school in the sample, it was reported that students took the AB Calculus course before taking the BC Calculus course.

To limit threats to internal validity, the researcher gathered data from as many schools as possible, which helped yield a large sample size. Schools controlled for threats to internal validity by standardizing the conditions under which students took the AP examinations. Moreover, teachers did not grade their own students' AP examinations. The multiple choice was scored by a machine, and a group of teachers graded the constructed response questions over the course of a week after going through an extensive training process. The student's name was unknown to the teachers grading each exam. Teachers applied the same grading rubric when assigning credit to students on the constructed response, so the ways in which data (test scores) were collected was

also standardized. Moreover, since the entire curriculum was supposed to be delivered to all students taking the course, all students in the sample were capable of correctly answering all questions on the AP examination. Another possible threat to internal validity was history. It is possible that a noteworthy event could have happened in the school community on the day of the AP exam or shortly before the AP exam. Such events could influence the dependent variable (Kirk, 2012).

One possible threat to the external validity of the study was the interaction of selection and treatment, since all of the participants were AP Calculus students. Kirk (2012) stated that the constellation of factors that affect the availability of subjects to participate in an experiment may restrict the generalizability of results to populations that share the same constellation of factors. Another threat to the external validity of the study was the interaction of setting and treatment, since the availability of participants was dependent on the number of students taking AP Calculus in each school. The unique characteristics of the setting in which results were obtained may restrict the generalizability of the results to settings that share the same characteristics (Kirk, 2012). Lastly, the interaction of testing and treatment was a possible threat to external validity due to all the tests that students took throughout the year before the AP examination.

One threat to the statistical conclusion validity of this study was low statistical power. Kirk (2012) explains that a researcher may fail to reject a false null hypothesis because the sample size is inadequate, irrelevant sources of variation are not controlled or isolated, or inefficient test statistics are used. The effect sizes noted in the first two research questions were small, and it would have been more ideal for the data to yield larger effect sizes. Kirk (2012) also notes violated assumptions of statistical tests as a

threat to statistical conclusion validity. The data were naturally skewed, which could be considered a limitation of the current study. Levene's test for homogeneity of variances was statistically significant in the first two research questions. In the second research question, SPSS was unable to calculate the statistical significance for the three-way interaction between number of instructional minutes, school type, and class type. Thus, the researcher was unable to determine whether the three-way interaction null hypothesis should be rejected or retained. For the multiple linear regression, the Durbin-Watson statistic was less than 1.

Another threat to the statistical conclusion validity of this study was the random heterogeneity of respondents. Kirk (2012) describes this threat as idiosyncratic characteristics of the subjects (students) that may inflate the estimate of the error variance and result in not rejecting a false null hypothesis. In some instances, students were taking the exam in different classrooms, so random irrelevancies in the experimental setting was another possible threat to the statistical conclusion validity of the study. An improvement that would make the reader more confident of the findings would be to have an even larger sample size. Another way to make the reader more confident is to have data collected from the upcoming 2020 AP Calculus examinations and see if similar results are obtained.

Recommendations for Future Research

Recommendations to add some credibility to the study results are to utilize additional schools, which would possibly yield a larger sample size. It would also be interesting to know how the independent variables from the current study influence other dependent variables such as the New York State Regents examinations in mathematics.

It would also be interesting to know if the results from the current study extend to other Advanced Placement courses. School setting (public, suburban, rural) is another important independent variable to consider. Thus, another important area that can be investigated is statistically significant differences in Advanced Placement Calculus scores based on school setting.

Another suggestion is to use more forms of data analysis aside from the Three-Way Between Subjects Analysis of Variance (ANOVA) and the multiple linear regression. Other factors may be impacting students' achievement on mathematics assessments. For example, to what extent does gender, ethnicity, or socioeconomic status affect students' achievement on math assessment tests? In the sample in the current study, the school that had the lowest performance from the students had the highest percentage of students of color. Only one of the nine students from that school earned a qualifying score of 3 or higher. Such findings shed light on the need for future research regarding the achievement gap on tests such as the Advanced Placement exams. There is a discrepancy between the performance of minority groups and the national average on AP Calculus exams (College Board, 2018).

In terms of prior academic preparation, it was noted that some students take AP Calculus AB before taking AP Calculus BC. In a future study, the researcher would separate the BC Calculus exam scores into two groups: Those who took AB Calculus first, and those who went from precalculus into the BC Calculus course. Internationally, the United States stands in the middle of the pack on mathematics, science, and reading scores (DeSilver, 2017). Recent PISA results from 2015 place the United States at 38th out of 71 countries in mathematics (DeSilver, 2017). In turn, the researcher would focus

future research on data from international mathematics examinations. Specifically, the researcher would investigate why the United States performance is so poor, and what instructional strategies other countries are implementing to have successful mathematics scores.

While the current study focused on Advanced Placement Calculus scores, there appears to be a gap in peer-reviewed research with respect to the qualitative factors influencing Advanced Placement Calculus scores. In turn, the focus of a future research project pertinent to the researcher's educational interests would be on teachers' instructional approaches towards the Advanced Placement Calculus course. Instructional methods and practices would be ascertained through classroom observations, interviews, and student course surveys. One goal of this research would be that teachers will be reflective of their experiences and change any practices that do not work towards the best interests of the students. Moreover, the study will hopefully serve as a guide for schools and districts to improve their academic program through practices such as increased instructional time, more appropriate professional development, prerequisite courses and summer work, and increased expectations for teachers and administrators.

Recommendations for Future Practice

The findings from the three research questions indicated that the instructional time in minutes was statistically significant. Thus, school districts and administrators should seek to extend the instructional minutes as a measure to bolster student achievement. Recommendations to practitioners and policy-makers in the field that emanate from the data are to encourage educators to implement more constructivist and student-centered forms of teaching. Many teachers may be used to the traditional

teacher-centered classroom. In turn, professional development will be needed for teachers and administrators if schools are going to effectively implement constructivism in the classroom. For districts that have no control over the start date of school and are looking to improve Advanced Placement scores, they should consider increasing instructional time in conjunction with other appropriate interventions to make effective use of that additional time.

Class type was also statistically significant in the three research questions. The current study reinforced the trend of BC Calculus students outperforming AB Calculus students (College Board, 2018). Thus, teachers and administrators need to work to bridge that disparity in scores. Moreover, the percentage of students in the school who took both an AP Calculus course and exam was a significant contributor to the linear model. Thus, schools should seek measures to expand access and participation in the AP Calculus courses. For instance, the AP for All program strives to expand access and equity in New York City. Expanding access and participation can help reduce the achievement gap. Furthermore, the College Board is committed to equity and access in the AP program (College Board, 2012).

Conclusion

This non-experimental research aimed at examining the influence of the amount of instructional days and amount of instructional time in minutes on Advanced Placement Calculus exam scores. The findings are novel and interesting because a study at the high school level justified the statistical significance of the instructional time in minutes. The findings regarding the instructional days were mixed. The current study further illustrated BC Calculus students outperforming AB Calculus students. An interesting

finding was that school type was not statistically significant. The percentage of students who took both an AP Calculus course and exam was a significant contributor to the linear regression model. The findings from the current study led to a number of recommendations for future research and practice.

Any future research in the area should work towards the purpose of improving mathematics instruction and bolstering student achievement in the Advanced Placement Calculus courses. The research can also lead to improvements in future college coursework. Specifically, those students who are successful on the AP Calculus exam will be able to start college at the next level of calculus. Those students who were not successful on the exam will still have a working knowledge and background of calculus when taking the introductory calculus course again. School districts are encouraged to increase instructional time.

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Appendix A – IRB Approval



ST. JOHN'S UNIVERSITY

Federal Wide Assurance: FWA00009066

Nov 25, 2019

PI: Robert Fiore
CO-PI: seokhee Cho
Dept: Ed Admin & Instruc Leadership

Re: Initial - IRB-FY2020-260 THE INFLUENCE OF THE AMOUNT OF SCHOOL DAYS AND AMOUNT OF INSTRUCTIONAL TIME ON HIGH SCHOOL STUDENTS' ADVANCED PLACEMENT (AP) CALCULUS EXAM SCORES

Dear Robert Fiore:

The St John's University Institutional Review Board has rendered the decision below for THE INFLUENCE OF THE AMOUNT OF SCHOOL DAYS AND AMOUNT OF INSTRUCTIONAL TIME ON HIGH SCHOOL STUDENTS' ADVANCED PLACEMENT (AP) CALCULUS EXAM SCORES.

Decision: Exempt

PLEASE NOTE: If you have collected any data prior to this approval date, the data needs to be discarded.

Selected Category: Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

- (i) The identifiable private information or identifiable biospecimens are publicly available;
- (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot

readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Sincerely,

Raymond DiGiuseppe, PhD, ABPP
Chair, Institutional Review Board
Professor of Psychology

Marie Nitopi, Ed.D.
IRB Coordinator

VITA

Name: *Robert M. Fiore*

Baccalaureate Degree: *Bachelor of Science, Manhattan College,
Riverdale, NY
Major: Secondary Education,
concentration in mathematics*

Date Graduated: *May, 2013*

Other Degrees: *Master of Arts, Stony Brook University,
Stony Brook, NY, Major: Mathematics*

Date Graduated: *May 2015*

*School Building Leadership/School
District Leadership, Advanced Certificate,
St. John's University, Jamaica, NY*

Date Graduated: *May 2018*