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Factors Correlated to the Success of Stem Students in Calculus 2

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FACTORS CORRELATED TO THE SUCCESS OF STEM STUDENTS

IN CALCULUS 2

A Thesis

By

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The thesis entitled FACTORS CORRELATED TO THE SUCCESS OF STEM STUDENTS IN CALCULUS 2 presented by KATHLEEN MCCORMACK, a candidate for the degree of Master of Science in Mathematics, has been approved and is worthy of acceptance.

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ABSTRACT

This study examines the academic success of math-intensive STEM students enrolled in Calculus 2. As the need for qualified STEM professionals continues to grow in the United States, universities seek to understand factors that impact academic success and student retention in STEM majors. Success in first-year college calculus courses is critical for students to succeed in upper-level courses needed to graduate in math-intensive STEM majors like mathematics, the physical sciences, and engineering. As more students enter universities with Calculus 1 credit from Advanced Placement (AP) or Dual Enrollment courses in high school or from another post-secondary institution, a higher number of students are beginning their college mathematics education in college Calculus 2. This study examined how student success in Calculus 2 was impacted by the student's Calculus 1 background and math-intensive STEM major and identified factors predictive of student success in Calculus 2 for several student backgrounds. The results suggest students with AP experience are well-prepared for Calculus 2 and students with credit for Calculus 1 from another institution may need additional academic support to succeed in Calculus 2. In addition, while Calculus 2 success varies little between students in most math-intensive STEM majors, students majoring in Forensic Science may also need additional academic support to successfully complete the course. The study results support continuing to encourage student participation in STEM learning communities at the university and the expansion of STEM learning communities to include transfer students. The results also suggest higher Calculus 1 grades, AP Calculus exam scores, and SAT math scores are predictive of STEM student success in Calculus 2 and students are less likely to succeed in Calculus 2 when they need to complete several pre-requisite courses prior to enrolling in Calculus 1. Finally, the impact of ethnicity on student success in Calculus 2 at this university is minimal according to the results of this study.

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CHAPTER I
INTRODUCTION

There is an increasing demand for professionals in science, technology, engineering, and mathematics (STEM) fields in the United States. As a result, many universities have implemented programs to expand recruiting efforts and increase the retention and graduation rates of STEM students. Many of these programs focus on supporting STEM students academically and socially early in college when attrition rates have been reported to be nearly 50% (Chen, 2013). Universities have developed a variety of strategies to support students including access to extra tutoring services, the formation of STEM learning communities, the development of programs that facilitate student access to STEM faculty, the fostering of interactions with both professional and peer mentors, and early opportunities for students to participate in research. Since studies have shown that the successful completion of the first-year required STEM courses is vital to the retention of post-secondary STEM students, many student programs focus on improving student academic success in the first year. In particular, student success in the series of college calculus courses required for math-intensive STEM majors, such as engineering, the physical sciences, and mathematics and statistics, has been shown to be predictive of a student's decision to persist and graduate in a STEM major (Bressoud, 2011, Kopparla, 2019).

Many studies have examined the factors that affect STEM student academic success in college Calculus 1 courses. Factors contributing to student success in these courses include high school math preparation, high school teaching methods in math courses, mathematical attitudes, intended career, year in college, parental education, ethnicity, and gender (Sonnert, et al., 2020, Wade, et al., 2018, Wade, et al., 2017, Sadler & Sonnert, 2018). Studies of STEM students in majors requiring extensive math have identified similar factors that are predictive of STEM retention and graduation. These factors include high school math and science background and success, mathematical attitudes, career goals and intentions, institutional systems, parental education, ethnicity, and gender (Dagley, et al., 2016, Redmond-Sanogo, et al., 2016, Belser, et al., 2016, Ellis, et al., 2016, Geisinger & Raman, 2013).

Prior research has focused heavily on student success in Calculus 1 since prospective STEM students have traditionally entered universities into a college pre-calculus or Calculus 1 course. However, as high schools increase the number of Advanced Placement (AP) and Dual Enrollment courses offered to students and as some students choose to begin or supplement their post-secondary education at another institution, more students are entering their first year at universities with credit for Calculus 1 from AP Calculus courses, Dual Enrollment courses, or Calculus 1 completed at another 2-year or 4-year institution. These students are beginning their college mathematical education at the university taking college Calculus 2. While there has been extensive research related to the factors that contribute to the academic success of STEM students in Calculus 1 courses, there has been little research related to factors that contribute to academic success in Calculus 2 courses. As the number of students taking Calculus 2 without having taken Calculus 1 at the same university increases, it is vital that student success factors for this course are better understood. Therefore, this study will examine the success of students in math-intensive STEM majors in college Calculus 2 based on the entry pathway of the student from Calculus 1 and will also investigate factors predictive of student success in college Calculus 2 courses.

1.1 Background of the Problem

The last 50 years have seen monumental steps in science and technology, from the developments in electronics and communications including personal computers, supercomputers, the World Wide Web, and smartphones to the deployment of fiber optic networks, the internet, GPS, and communication satellites, to technological leaps in space including the International Space Station, the Mars rover, reusable rockets, and the Hubble Space Telescope to life-changing advances in biology with the Human Genome Project, drugs to treat HIV and Ebola viruses, pacemakers, and MRI machines. Innovation in new areas of science and engineering have led to unprecedented progress in rechargeable and portable batteries, hybrid and electric vehicles, 3D printing, DNA fingerprinting for crimes, genomics and DNA targeted treatments of diseases, robotics, the Large Hadron Collider, and even Bluetooth and gaming systems ("The greatest invention...", 2020). None of these scientific and engineering advances of the last 50 years would be possible without qualified science, technology, engineering, and mathematics (STEM) professionals.

As the significant technological leaps of the last 50 years and continued expected growth in these and many developing fields fuels high demand for STEM professionals in the United States, there is a national focus on recruiting, retaining, and matriculating students in these fields. Many STEM majors are considered math-intensive majors, requiring mathematics beyond first-year college level calculus courses (Bressoud, 2011). It is not surprising, then, that the successful completion of first-year college calculus courses, including Calculus 1 and Calculus 2, is vital for the success of post-secondary STEM students.

There have been extensive studies to examine the factors that contribute to student success in college Calculus 1. These studies suggest that high school mathematics preparation, mathematics attitudes, intended career, year in college, parental education, ethnicity, and gender are predictive of success in Calculus 1 (Sonnert, et al., 2020,). In addition, high school mathematics instruction that focuses on a rigorous conceptual understanding of material has been found to be predictive of success in post-secondary mathematics courses (Wade, et al., 2018, Wade, et al., 2017, Sadler & Sonnert, 2018).

Similar studies related to success in math-intensive STEM majors indicate several similarities exist between the factors contributing to Calculus 1 success and the factors predictive of STEM student retention and graduation. In addition to high school math and science exposure and success, mathematical attitudes, parental education, ethnicity, and gender, research has shown that the institutional academic and social systems and the student's intentions and goals are critical factors in retaining and graduating students in STEM majors (Dagley, et al., 2016, Belser, et al., 2016, Ellis, et al., 2016, Geisinger & Raman, 2013).

Often, it is specifically noted that the first-year experience of STEM students is predictive of their persistence and eventual graduation. For instance, students who pass Calculus 1 with a grade of C or higher have been shown to have significantly higher STEM persistence rates than students with lower grades in Calculus 1 (Kopparla, 2019). In fact, students in math-intensive majors such as engineering (not including engineering technologies), the physical sciences (physics, chemistry, and forensics), and mathematics and statistics often must earn a C or higher in required introductory science and mathematics courses before continuing into the major or to fulfill degree requirements. Therefore, first-year mathematics and science courses are often considered "gateway" courses for STEM students since students who do not succeed in them are unable to continue in math-intensive majors.

As high schools seek to offer more challenging course options to their students, there has been an expansion in the number of high schools offering Advanced Placement (AP) and Dual

Enrollment courses. The number of high school graduates who took at least one AP exam has increased 38.9% from 2009 to 2019 (College Board, 2020). Dual Enrollment saw a growth rate of more than 65% between 2002 and 2010 with anticipated continuing increases (Shiyji & Wilson, 2019). These additional course offerings allow many students to take courses that provide college credit before graduating from high school.

Two commonly offered AP classes are AP Calculus AB and AP Calculus BC. Concepts in the AP Calculus AB course include material from the entire college Calculus 1 course and the start of the college Calculus 2 course. AP Calculus BC includes the concepts for both college Calculus 1 and Calculus 2. In 2020, more than 266,000 students completed the AP Calculus AB exam with 61.4% of the students scoring a 3 or higher and more than 127,000 students took the AP Calculus BC exam with 81.6% of the students scoring a 3 or higher on the exam (College Board, 2020). Although some universities require a higher score to apply AP credit, many universities require that students earn a 3 or higher on the AP Calculus AB exam in order to obtain credit for college Calculus 1 and earn a 3 or higher on the AP Calculus BC exam to obtain credit for college Calculus 1 and Calculus 2.

Dual Enrollment courses are often a cooperative offering between a high school and a local university, college, or community college. The format of a Dual Enrollment class can vary significantly from classes on a college or university campus with post-secondary students to purely remote course offerings to classes taught by high school teachers in the high school environment. These courses provide credit for a college-level course and this credit is often accepted by universities when a student earns a C or higher in the Dual Enrollment class.

It is evident that as high schools have expanded AP and Dual Enrollment options for students and students take pre-requisite courses at other post-secondary institutions, 4-year universities have seen an increase in the number of students with credit for college level courses, including Calculus 1. These students, many with intentions of pursuing math-intensive STEM majors, are now beginning their college mathematical education at the home university in Calculus 2. Data from a number of large research-focused STEM universities indicates a higher number of students are now taking Calculus 2 courses than Calculus 1 courses during their first year. Thus, more students are entering with credit for college Calculus 1 courses at many large universities (Georgia Tech, 2018, Purdue University, 2017). These students come from a myriad of backgrounds with varying experiences in Calculus 1 courses that do not necessarily encompass the same educational experiences of students who complete the course at the same university where they take Calculus 2. In addition, data shows that many students who take college Calculus 2 at large research-focused universities do not pass the course (Georgia Tech, 2018, Purdue University, 2019).

Evidence from previous studies suggests there is a strong relationship between mathematical background and mathematical teaching methods in determining STEM student success in Calculus 1 courses. Therefore, many believe there is a similar relationship related to academic success in Calculus 2. Some researchers argue that the smaller class sizes of high school AP courses and often offered in Dual Enrollment and at smaller 2-year and 4-year institutions, provide more personal attention and instructional flexibility that leads to better student mastery of calculus concepts (Rasasco, 2013). However, others suggest that the high school AP teachers and Dual Enrollment and other post-secondary institutional instructors do not always teach the foundational mathematical concepts needed by students to be successful in the advanced calculus courses required for math-intensive STEM majors (Wade, et al., 2017, Bressoud, 2010).

1.2 Statement of the Problem

College-level Calculus 1 and Calculus 2 courses for STEM students teach essential mathematical concepts and advanced problem-solving techniques that are vital to student success in upper level mathematics, science, and engineering courses (Bressoud, 2011, Badr, 2013, Veenstra, et al., 2009). Thus, it is important that students in math-intensive STEM majors have a strong foundation in both first-year calculus courses before continuing onto more advanced core courses related to their major. Efforts to increase STEM student retention and graduation have led to many studies that provide counselors, administrators, and instructors information about factors contributing to student success in Calculus 1 and to the development of programs that provide academic support to increase student success rates in Calculus 1 courses.

To date, there has been little research related to the success rates of STEM students in math-intensive majors entering universities in college Calculus 2 from alternative pathways or of the factors that influence student success in college Calculus 2 courses. This study seeks to examine math-intensive STEM student success in college Calculus 2 across varying entry pathways including credit from AP Calculus, credit from another 2-year or 4-year institution for Calculus 1 as part of a Dual Enrollment program or as transfer credits, and credit from a Calculus 1 course at the university where Calculus 2 is taken. In addition, this study examines student success in Calculus 2 in relation to the student's intended STEM major. Finally, this study investigates the role of student pre-entry attributes, goals and intentions, and institutional experiences on math-intensive STEM students' academic success in a college Calculus 2 course.

1.3 Purpose of the Study

The purpose of this study is to examine the academic success, as measured by final course grade, of students enrolled in college Calculus 2 with varying experiences for college Calculus 1.

Additionally, factors related to student pre-entry attributes, goals and intentions, and institutional experiences will be investigated to determine which factors predict success in college Calculus 2 for students in math-intensive STEM fields.

This will be a quantitative study which will examine the final grades from Calculus 2 (MAC 2312) of up to 7000 students in math-intensive STEM majors at the University of Central Florida (UCF) during the academic semesters from Summer 2017 through Fall 2020. The final Calculus 2 grades of students will be translated to a 4.0 point scale for analysis. The time frame for data collection was chosen to minimize variations in SAT test scores and in AP Calculus course experiences for students taking Calculus 2. The SAT tests were revised to an updated exam format in March 2016. There was also an update to the AP Calculus curriculum and exam during the 2016-2017 school year. Thus, students entering as first-year university students at UCF for the Summer 2017 academic semester will be likely to have taken both the new format of the SAT exam and the updated AP Calculus course. This leads to increased consistency in student scores and in the material included in AP Calculus courses that were used as credit for Calculus 1.

A logistic regression analysis will also be performed to identify factors that predict math-intensive STEM student success, measured as a final grade of C or higher, in Calculus 2 (MAC 2312). Factors examined include the Calculus 1 grade for students who completed Calculus 1 (MAC 2311) at UCF or another institution, AP Calculus AB score, if applicable, SAT Math score, SAT Verbal score, the number of terms since admission to UCF, student involvement in a learning community, the standardized number of credit hours taken concurrently with Calculus 2, the number of semesters between taking Calculus 1 and enrolling in Calculus 2, the student's intended STEM major, ethnicity, and gender. These factors all relate to a STEM student's pre-entry attributes, goals and commitments, and institutional experiences.

1.4 Significance of Study

With the limited existing information regarding student success in Calculus 2, this study will offer critical information about factors influencing math-intensive STEM student success in this course. The results of this study will be valuable to the STEM colleges at the University of Central Florida. In addition, it can be utilized by university administers, counselors, and instructors to better understand the factors that lead to the success of math-intensive STEM students enrolling in college Calculus 2 courses with varying experiences for college Calculus 1. Finally, factors that significantly predict Calculus 2 success for students in math-intensive STEM majors can be used to determine how to better support students.

1.5 Research Questions

The following research questions will be examined to determine what preparation and institutional support influences and predicts math-intensive STEM students' academic success in Calculus 2:

<u>Research Question 1</u>: Is there a significant relationship between the source of a student's Calculus 1 class credit, including high school AP Calculus, Calculus 1 at another post-secondary institution, and Calculus 1 at UCF, with student academic success in Calculus 2 for math-intensive STEM students?

<u>Research Question 2</u>: Is there a significant relationship between a student's prior Calculus 1 background experiences and student academic success in Calculus 2 for math-intensive STEM

students? Student experiences include the completion of an AP Calculus course and use of AP credit for Calculus 1, completion of and credit for a Calculus 1 course from another post-secondary institution, completion of and credit for Calculus 1 at UCF after forgoing credit from AP Calculus AB with an AP AB exam score of 3 or higher, completion of and credit for Calculus 1 at UCF after forgoing credit earned from AP Calculus BC with an AP BC exam score of 3 or higher, completion of and credit for Calculus 1 at UCF after taking AP Calculus AB or BC with an AP exam score of 1 or 2, and completion of and credit for Calculus 1 at UCF with no known AP or other post-secondary Calculus 1 experience.

<u>Research Question 3</u>: Is there a significant relationship between a math-intensive STEM student's major and academic success in Calculus 2?

<u>Research Question 4</u>: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

A. math-intensive STEM students who began college mathematics at UCF in Calculus 2 with AP Credit for Calculus 1?

B. math-intensive STEM students who began college mathematics at UCF in Calculus 2 having a recorded AP Calculus AB exam score and using with AP Credit for Calculus 1?

C. math-intensive STEM students who began college mathematics at UCF in Calculus 2 after completing Calculus 1 at another post-secondary institution?

D. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus AB with an AP exam score of 3 or higher?

E. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus BC with an AP exam score of 3 or higher?

F. math-intensive STEM students who began their college mathematics education at UCF in Calculus 1 who scored a 1 or 2 on the AP Calculus exam after completing AP Calculus AB or BC in high school?

G. math-intensive STEM students who completed Calculus 1 at UCF with no known AP Calculus or other post-secondary calculus experience?

1.6 Hypotheses

Hypothesis 1: Given the extensive work done to ensure that AP Calculus, Dual Enrollment Calculus and other college-level Calculus 1 courses are designed to meet the mathematical standards for college Calculus 1, it is not expected that there is a significant relationship between a student's Calculus 1 class format and academic success in college Calculus 2 courses for math-intensive STEM students.

Hypothesis 2: It is hypothesized that a math-intensive STEM student's previous Calculus 1 class experience does not impact student academic success in Calculus 2 since courses providing college Calculus 1 credit are designed to meet the same mathematical standards and objectives regardless of format.

Hypothesis 3: Given the uniformity of instructional material included in a Calculus 2 course at a given institution, it is not expected that there is a relationship between a math-intensive STEM student's major and academic success in Calculus 2.

Hypothesis 4:

A. It is expected that pre-entry attributes including SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended

STEM major, and institutional experiences including learning community participation, the standardized number of credit hours taken concurrently with Calculus 2, and the number of terms at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

B. It is expected that pre-entry attributes including AP Calculus AB score, SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended STEM major, and institutional experiences including learning community participation, the standardized number of credit hours taken concurrently with Calculus 2, and the number of terms at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

C. It is expected that pre-entry attributes including grade in Calculus 1, SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended major, and institutional experiences including the student's learning community participation, the standardized number of credit hours taken concurrently with Calculus 2, the time between the completion of Calculus 1 and enrollment in Calculus 2, the number of terms at UCF, and whether the student took Calculus 1 before or after enrolling at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

D. It is expected that pre-entry attributes including AP Calculus AB score, SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended STEM major, and institutional experiences including learning community participation, grade in Calculus 1 at UCF, the standardized number of credit hours taken concurrently with Calculus 2, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the number of terms at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

E. It is expected that pre-entry attributes including a student's AP Calculus BC score, SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended STEM major, and institutional experiences including learning community participation, grade in Calculus 1 at UCF, the standardized number of credit hours taken concurrently with Calculus 2, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the number of terms at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

F. It is expected that pre-entry attributes including SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended STEM major, and institutional experiences including learning community participation, grade in Calculus 1 at UCF, the standardized number of credit hours taken concurrently with Calculus 2, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the number of terms at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

G. It is expected that pre-entry attributes including SAT Math score, SAT Verbal score, gender, and ethnicity/race, goals and commitments including a student's intended major, and institutional experiences including learning community participation, grade in Calculus 1 at UCF, the standardized number of credit hours taken concurrently with Calculus 2, the number of semesters between the completion of

Calculus 1 and enrollment in Calculus 2, and number of terms at UCF will be predictive of student success measured by a grade of C or higher in Calculus 2.

1.7 Research Design

Data will be obtained from the University of Central Florida (UCF). Specifically, Institutional Knowledge Management (IKM) at UCF will supply the data with all personal identifying information removed. The data acquisition will also be supported by Dr. Melissa Dagley, Executive Director, Initiatives in STEM, University of Central Florida.

The data will include information about a group of up to 7000 STEM students who have taken Calculus 2 (Calculus with Analytic Geometry II - MAC 2312) at the UCF from the Summer 2017 to the Fall 2020 academic semesters. Participants will be students in math-intensive STEM majors including Mathematics, Statistics, Actuarial Science, Physics, Chemistry, Forensic Science, Computer Science, Aerospace Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Environmental Engineering, Industrial Engineering, Materials Science and Engineering, Mechanical Engineering, Photonics Science and Engineering, and Undecided Engineering/Science as identified at the start of the semester they were enrolled in Calculus 2. Sampling will strive to include as many students as possible in the analysis.

Students will be divided into groups based on where they earned credit for Calculus 1 (Calculus with Analytic Geometry I – MAC 2311) or the equivalent class. The student's Calculus 2 grade and information regarding the previous Calculus 1 or equivalent class including the class completed, the grade, if available, and the AP Calculus score, if available, will be collected. In addition, data collected will include the entry semester of the student at the university, the student's participation in a learning community including the EXCEL, COMPASS, University Honors, or LEAD Scholars Learning Communities at any time during their enrollment at UCF, the student's intended major, the total number of credit hours taken concurrently with Calculus 2, the student's UCF Math Placement Test sub-scores, if available, the student's SAT Math and SAT Verbal scores, and the student's gender and ethnicity. All data will be cleansed of identifying information prior to release for analysis.

It should be noted that the Spring 2020 contingent of students will be examined to determine if there are significant differences in success rates based on modifications to grading options to include a Satisfactory/Unsatisfactory (S/U) option that was available until the final week of the semester and the extension of the withdrawal date until the final week of the semester due to the impact of the Covid-19 pandemic. Students choosing the S/U option will not be included in this study.

The statistical analysis will be completed using EXCEL software and R software for statistical computing (R Core Team, 2020).

1.8 Theoretical Framework

The factors relating to post-secondary student retention and success are often described using Tinto's Institutional Departure Model (French, et al., 2005, Tinto, 2012). Tinto's model focuses on the importance of student integration through academic and social communities in determining whether a student decides to persevere or leave a post-secondary institution. Integration into those communities is affected by a student's pre-entry attributes, such as family background, skills and abilities, and previous school experience, a student's goals and commitments, and a student's formal and informal experiences both academically and socially at the institution. Modifications to Tinto's model have also been made to focus on factors that specifically affect STEM student retention and graduation (Baisley, 2019, Rosasco, 2013). Here, the STEM community can be modeled as an independent institution where a student's experiences can be used to describe student departure from the community when a student transfers to a non-STEM major or when a student leaves the institution entirely.

As is expected, studies have shown the first-year experience of many STEM students is predictive of their persistence and eventual graduation in a STEM major. For instance, students who pass Calculus 1 with a grade of C or higher have been shown to have significantly higher STEM persistence rates than students with lower grades in Calculus 1 (Kopparla, 2019). In fact, students in math-intensive majors such as engineering (not including engineering technologies), the physical sciences (physics, chemistry, and forensics), and mathematics and statistics often must earn a C or higher in required introductory science and mathematics courses before continuing into the major or to fulfill degree requirements. Therefore, first-year mathematics and science courses are often considered "gateway" courses for STEM students since students who do not succeed in them are unable to continue in math-intensive majors.

1.9 Assumptions, Limitations, and Scope

Assumptions

It is assumed that success in Calculus 2 can be characterized by the student's final grade the last time the student took Calculus 2. It was not possible to obtain data to indicate whether a student was repeating the course.

Limitations

Limitations of this study include the use of participants from one university. Demographics and student academic attributes at this university may not represent student populations at other universities. Student participants are also limited to math-intensive STEM majors as identified at the start of the academic semester for which students are enrolled in Calculus 2.

There are also variations in teaching styles and methods across instructors that are not included as factors in this study. This could include variations in exams given to students and differences in grading systems by semester, course section, and/or course instructor.

Finally, the requirements to earn credit for AP Calculus at UCF were changed for students beginning the Fall 2019 semester. Students taking Calculus 2 before the Fall 2019 semester needed an AP Calculus AB exam score of 5 to earn credit for Calculus 1 whereas those taking Calculus 2 in the Fall of 2019 or later needed an AP Calculus AB exam score of 3 or higher to earn credit.

Scope

The study was designed to determine whether the Calculus 1 experiences and differing entry pathways to Calculus 2 result in variations in student academic success in Calculus 2. The student's academic success is measured by the student's final Calculus 2 grade.

The investigation of factors predictive of STEM student success in Calculus 2 is designed to examine pre-entry attributes, goals and commitments, and institutional experiences that are expected to impact student success and retention in STEM majors. The student's academic success is defined as earning a final Calculus 2 grade of C (2.0) or higher for the predictive portion of the study.

1.10 Definition of Terms

Calculus 1 (Calculus with Analytic Geometry I – MAC 2311) Course Description: This is a 4-unit course on calculus with analytic geometry. The course includes concepts of analytic geometry; limits, continuity, differentiation of algebraic and trigonometric functions; applications of derivatives; integration and the Fundamental Theorem of Calculus; and applications of definite integrals.

Calculus 2 (Calculus with Analytic Geometry II – MAC 2312) Course Description: This is a 4-unit course on calculus with analytic geometry. The course includes concepts of differentiation and integration of exponential, logarithmic, and inverse trigonometric functions; techniques of integration; further applications of integration; parametric equations; polar coordinates; and infinite sequences and series.

Advanced Placement (AP) Calculus AB Course Description: This is a 2-semester high school course governed by guidelines from the College Board. The course includes concepts of limits and continuity, differentiation: definition and fundamental properties, differentiation: composite, implicit, and inverse functions, contextual and analytical applications of differentiation, integration and accumulation of change, differential equations, and applications of integration.

Advanced Placement (AP) Calculus BC Course Description: This is a 2-semester high school course governed by guidelines from the College Board. The course includes the concepts of limits and continuity, differentiation: definition and fundamental properties, differentiation: composite, implicit, and inverse functions, contextual and analytical applications of differentiation, integration and accumulation of change, differential equations, and applications of integration, parametric equations, polar coordinates, and vector valued functions, and infinite sequences and series.

Advanced Placement (AP) Score: The AP Exam scores are designed to represent student achievement in an equivalent college level course. AP scores range from 5 to 1 with the following breakdown: 5 – extremely well qualified – equivalent college grade: A; 4 – well qualified – equivalent college grade: A-, B+, B; 3 – qualified – equivalent college grade: B-, C+, C; 2 – possibly qualified – no equivalent grade; 1 – no recommendation – no equivalent grade.

SAT Score: The SAT exam is administered by the College Board. The total score range is 200-1600. This total score is split between a math section sub-score with a range of 200-800 and a verbal section sub-score with a range of 200-800.

Number of semesters at university: The number of semesters will be defined as the total number of academic semesters since a student enrolled in classes at the University of Central Florida, including summer semesters.

EXCEL Learning Community: EXCEL is a STEM learning community program with the goal of increasing the total number of Bachelor's Degrees earned in STEM majors for U.S. citizens at UCF. EXCEL recruits up to 300 incoming freshmen each year and focuses on improving student learning in math and science courses and connecting students with opportunities in research and industry.

COMPASS Learning Community: COMPASS is a program at UCF for students who enjoy math and science, are interested in exploring opportunities related to a STEM career, but who are not certain of committing to a specific STEM major. COMPASS recruits 100 first-year students and focuses on providing guidance to students about career opportunities, facilitating interactions with mentors and improving student learning in math and science courses.

LEAD Scholars Academy: The LEAD Scholars Academy is a 2-year leadership development program that focuses on academic, community service, and leadership opportunities. This program is available to UCF students of all majors, not only STEM students.

University Honors Learning Community: The Burnett Honors College has a learning community which recruits high-achieving incoming first-year students at in the top 10% of the incoming class at UCF and also accepts applications from established UCF students during the spring semester of their first year and transfer students with State College Honors A.A. degrees. This program offers smaller class sizes and rigorous honors courses available only to students in the college.

Math-intensive STEM major: Majors identified as math-intensive STEM majors require mathematics beyond first-year college calculus courses. All math-intensive majors identified for this study require at least a C or higher in both first-year college calculus courses at UCF (MAC 2311 and MAC 2312). All require a minimum of three semesters of mathematics courses to meet degree requirements. Majors identified as math-intensive at UCF include Mathematics, Statistics, Actuarial Science, Physics, Chemistry, Forensic Science, Computer Science, Aerospace Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Environmental Engineering, Industrial Engineering, Materials Science and Engineering, Mechanical Engineering, and Photonics Science and Engineering.

Math Placement Test (MPT): At UCF, the MPT consists of three math placement tests covering algebra, trigonometry, and pre-calculus as well as practice tests for each of the three tests. Students must earn a 35% or higher on the practice exam for algebra before they are able to take the placement test for algebra. If the student scores 350 or higher on the algebra test, they can continue to the trigonometry test series. Students must again earn a 35% or higher on the practice exam for trigonometry before being able to take the placement test for trigonometry. Students who earn a 350 or higher on the trigonometry test can continue to the practice pre-calculus test and actual pre-calculus test. If students do not earn a score of 350 on any of the 3 sections of the MPT, they are unable to take the next test. The MPT is used to determine the appropriate course for incoming first-year students at UCF. Students who have existing AP and Dual Enrollment credits may or may not complete the MPT.

Academic Success: Academic success will be determined by the grade a student earns in a course. The grade will be converted to GPA values where A = 4.00, A- = 3.75, B+ = 3.25, B = 3.00, B- = 2.75, C+ = 2.25, C = 2.00, C- = 1.75, D+ = 1.25, D = 1.00, D- = 0.75, and F = 0.00. A grade of C or higher is considered academic success in the predictive portion of this study since students must earn a grade of C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive STEM majors which are included in this study.

1.11 Summary

The demand for qualified science, technology, engineering, and mathematics professionals is increasing in the United States and universities are working to educate the workforce of the future. Many students in STEM majors are required to complete a set of academically rigorous math and science courses during the first year of college, including a minimum of two semesters of college-level calculus. These courses have been found to be ‘gateway’ courses and students who do not succeed in these courses often leave STEM fields.

Extensive studies have been completed to investigate the factors which affect STEM student academic success in college Calculus 1 and factors that influence STEM student retention and graduation rates. These studies have found that student academic success in college Calculus 1 courses and STEM student retention and graduation rates share many common factors.

As more students enter universities with credit for Calculus 1 courses from AP Calculus, Dual Enrollment Calculus, or Calculus 1 at another 2-year or 4-year institution, the number of students enrolled in Calculus 2 during their first semester at a university and without mathematics experience at the same university are increasing. Statistics from large, research-focused universities indicate that more students are now taking Calculus 2 classes than are taking Calculus 1 classes and that a high number of these students are not passing Calculus 2 during their first year at the university.

To date, there have been few studies related to student success in college Calculus 2 courses. This research study seeks to examine the impact of a student's Calculus 1 entry pathway to Calculus 2 on academic success in college Calculus 2 for students in math-intensive STEM majors. In addition, the impact of factors related to math-intensive STEM student pre-entry attributes, goals and commitments, and institutional experiences will be investigated to identify factors predictive of success in Calculus 2.

CHAPTER II
LITERATURE REVIEW

From its earliest days, the United States has had an extraordinary history of innovation and invention leading to transformative scientific and technological advances that impact not only the nation, but the world. Today, with the development of technologies such as artificial intelligence (AI), quantum information science, advanced manufacturing, and biotechnology, the world is on the cusp of a Fourth Industrial Revolution that will change the way people live, work, and communicate (Institute of Entrepreneurship Development [iED], 2020). A growing need for professionals educated in the fields of science, technology, engineering, and mathematics (STEM) comes with these advancements. Recent projections indicate that STEM opportunities are expected to grow by 8.0% between 2019 and 2029 (U.S. Bureau of Labor Statistics, 2020). Therefore, there is a national focus on educating and graduating qualified STEM professionals in the United States (PCAST, 2020).

The focus of this literature review relates to bachelor’s program students in STEM programs, with attention to math-intensive STEM majors. The review begins with a brief history of science and technology and the development of STEM post-secondary education in the United States. This is followed by a discussion of the high student attrition rates from STEM fields and a description of the factors affecting STEM student attrition related to Tinto’s Model of Institutional Departure. After establishing the importance of post-secondary mathematics courses on STEM retention, factors predictive of Calculus 1 success are identified and compared to those contributing to college STEM student retention. Since there are many shared factors contributing to STEM retention and college Calculus 1 success, the impact of university programs implemented to improve STEM retention and Calculus 1 success are examined. While Calculus

1 success and STEM retention have often been studied simultaneously, the profile of incoming first-year students has significantly changed with the growth of Advanced Placement (AP) and Dual Enrollment programs in U.S. high schools. The growth of these programs, along with students completing coursework at other post-secondary institutions, has resulted in a large number of students beginning their post-secondary mathematics education at the home university in Calculus 2 after earning AP credit or credit from another institution for Calculus 1. Studies of student success in Calculus 2 and the need for the current study of Calculus 2 for STEM majors is then provided.

2.1 History of STEM Innovation and Education

The United States has a long history of educating students for careers in the sciences. As early as George Washington's first State of the Union Address to Congress in 1790, it has been recognized that it is vital to have educated scholars in the sciences that can contribute to innovation. It was Washington's assertion that this knowledge would result in public happiness and a stronger nation. (Washington, 1790).

As the United States was founded, the First Industrial Revolution was beginning. In the late 1700's inventions focused on process improvements in the areas of agriculture, textiles, and steam and communication technologies. In agriculture, inventions such as the Cotton Gin and the McCormick Reaper resulted in substantial productivity increases on farms. In the textiles industry, the invention of cotton spinning machines and sewing machines led to the development of industries able to supply textiles in larger quantities for lower costs. Innovations in steam technologies led to the construction of the railroads and steamships and revolutionized the way people and products were transported across the expanding country. Additionally, the invention of the telegraph and Morse Code in 1837 allowed for faster communication between distant locations ("Industrial revolution inventions", 2018).

In the second half of the 19^{th} century and early 20^{th} century, the Second Industrial Revolution produced technological improvements with the introduction of new fuels and materials and increases in productivity with innovative processes. Notably the advances in the manufacturing process of steel, which could be produced less expensively and which is stronger and lighter than iron, coupled with the discovery of oil and the development of an electrical supply, were pivotal in the development of a large number of transformative inventions. Just a few of the inventions of this period were the automobile, the airplane, the telephone, skyscrapers, electric lights, cameras, and motion pictures. In addition, the first assembly lines changed the way products from clothing to automobiles were manufactured ("Industrial revolution inventions", 2018).

As technology and processes became more sophisticated, the need for skilled workers increased. As a result, another important development during this time was the passing of the Morrill Land Grant College Act in July of 1862. This legislation granted states land and provided funds for the construction of agricultural and mechanical arts schools. These land grant schools are the basis for many of the state colleges and universities that, today, educate many students in a myriad of fields including science, technology, engineering, and mathematics (STEM) (Our Documents, n.d.).

While it is evident that the United States made significant contributions to innovation during the Industrial Revolutions of the 19^{th} and early 20^{th} centuries, the focus on technological advances would again increase in the United States as World War II began in 1939. As fighting escalated, so did the pace of scientific innovation which supported the war effort. Many of the technologies that have seeded current STEM fields evolved quickly as the war was fought. These include the development of radar that was used in monitoring for air raids, the advancement of aircraft to include larger and faster planes that could fly farther and carry heavier loads, the expansion in the use of antibiotics to treat injured soldiers and civilians, the development of rocket science to produce ballistic missiles, the creation of code-breaking machines and techniques which were used to break German encryption systems, and, of course, the discovery of nuclear science which was used to create the atomic bombs that ended the war in the Pacific (Alexander, 2020).

As the end of the war neared, education again came to the forefront in the United States. In an effort to assist veterans, expand the middle class, and avert an economic downturn, the Servicemen's Readjustment Act, better known as the GI Bill, was signed into law. This bill provided loans, medical care, and tuition-free college and vocational education to those who served in World War II. While there were issues related to discrimination against African Americans, especially in the South, and women, these educational benefits resulted in veterans composing nearly 49% of college admissions in 1947 (History.com, 2010). By 1956, nearly 5.7 million World War II veterans had used the GI Bill for education at a college or vocational institution (Kutz Elliot, n.d.). As a result, college education was no longer just for the wealthy and elite in the United States and the number of college degrees increased from around 200,000 in 1940 to almost 500,000 just ten years later. In addition, colleges that had primarily focused on a liberal arts education diversified by adding programs which included specialties in business, science, and engineering (Kutz Elliot, n.d.).

While scientific innovation and invention continued after the end of World War II as the country returned to a peacetime life, the next giant leap was spurred by a Cold War adversary, the USSR. With the launch of Sputnik-1 and the dawn of the space age in 1957, the United States found an urgent need to focus not only on winning the space race, but also on creating a system that would foster the education of students who would contribute to the advancement of technologies allowing the United States to lead the world in STEM fields (Kelly, 2012, Abramson, 2007). To address the need for students who could contribute in the STEM arena, the National Defense Education Act of 1958 allocated more than a billion dollars of funding toward science education and resulted in improved teacher training in science and increases in lab equipment and other supplies for classrooms (Abramson, 2007).

Along with an increased focus on education, innovation and invention skyrocketed as the United States worked to reach the moon. Most evident during the space race, from the seeds of ballistic rockets came rockets powerful enough to escape Earth's gravity. These rockets not only put man into orbit and eventually on the moon, but also propelled satellites into orbit. The early satellites were used to send communication and TV signals across oceans for the first time (Creighton, 2019). The early use of multiple Enigma machines to break codes during World War II led to the development of more sophisticated computers and integrated circuits that were used to control the complex systems on spacecraft (Ceruzzi, 2015). Additional advancements were made in a multitude of fields including battery-powered devices, solar technology, seismology, advanced materials, insulation, food safety, water filtration, wireless devices, and even CAT scans (NASA, 2014, Popular Mechanics, 2020).

Advancements and innovation continued in STEM fields in what some call the Third Industrial Revolution during the late second half of the 20th century. During this time, the field of computers, electronics, and communications evolved quickly parallel with increased use of new energy sources such as nuclear, solar, and wind power (iED, 2020). The development of technologies like supercomputers, personal computers, rechargeable batteries, fiber optics, GPS, and the world wide web changed how people lived, worked, and communicated. The evolution of digital technologies has also had impacts in the arena of space and physics, allowing humans to live in low earth orbit, sending robots to visit other planets, and exploring beyond our solar system and back in time with powerful telescopes. Advances in biology and medicine have improved preventative measures, diagnostic tools, and treatments and cures for countless life-threatening diseases (Popular Mechanics, 2020). The Third Industrial Revolution has shown that in order to achieve the scientific and engineering advances like those of the last 50 years, educated STEM professionals are a vital asset (National Science & Technology Council, 2018).

Peering into the future, it is evident that that need for educated STEM professionals is of critical importance to the United States and, indeed, the world. Many suggest the world is on the cusp of a Fourth Industrial Revolution that will, again, change how people live, work, and communicate (iEd, 2020). Projections related to Industries of the Future, such as artificial intelligence (AI), quantum information science, advanced manufacturing, advanced communications, and biotechnology, dictate that a well-trained supply of STEM professionals will be needed (PCAST, 2020). Additionally, employment projections from the U.S. Bureau of Labor indicate that STEM opportunities are expected to grow by 8.0% between 2019 and 2029, more than double that projected in other areas Since the need to educate students in STEM fields at the post-secondary level of education is a vital component of creating a capable STEM workforce, it is crucial that post-secondary institutions identify practices to recruit, retain, and graduate students with STEM majors.

2.2 STEM Retention Factors

In order to meet the growing demand for STEM professionals in the United States, there have been many research studies that have focused on factors that influence the retention and graduation rates of STEM students. The attrition rate of students in STEM majors is reported to be nearly 50% with significant attrition occurring in the student's first year (Chen 2013, Chen, 2015). Several studies show that student attrition is highest early in post-secondary education while students are adjusting to new academic and social environments away from the familiar support structures that were in place prior to attending a college or university (Tinto, 1993, Tinto, 2012, Chen, 2013).

Tinto's Institutional Departure Model has been used to model student departure from post-secondary institutions in many studies (French, et al., 2005, Tinto, 2012, Veenstra, et al., 2009). Tinto's model emphasizes the importance of student academic and social integration at the institution on the retention of students. The student's pre-entry attributes, goals and commitments, and institutional experiences, both academic and social, are considered critical factors that impact student perseverance (Figure 2.1).

In Tinto's model, student pre-entry attributes include family background, pre-entry skills and abilities, and prior schooling. Pre-entry attributes typically include factors such as the student's social status, parental level of education, financial resources, intellectual skills, social skills, level of motivation, high school GPA, sex, and ethnicity. Goals and commitments include factors related to the student's intentions, the student's commitment to their goals and the institution, and the student's external commitments. Intentions or goals often include the educational and career objectives of the individual while student commitments refer to the level of commitment the student has to achieving their goals and their commitment to the institution. External commitments include outside commitments a student may have to family or the community. Finally, academic and social institutional experiences are categorized both formally and informally and occur when the student begins attending the university or college. These experiences include the student's interactions with peers, instructors, advisors, and other members of the institutional community. Positive institutional experiences are often associated with increased student integration and improved retention rates.

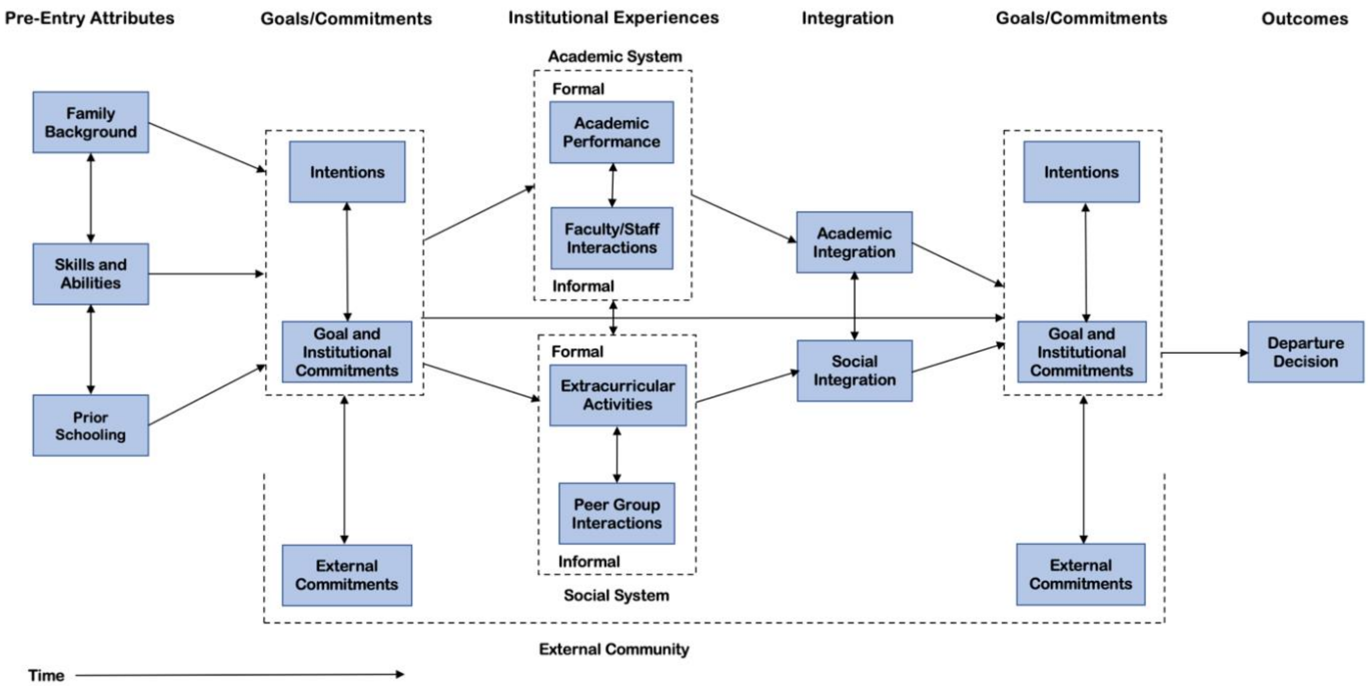


Figure 2.1: Tinto's Institutional Departure Model (Tinto, 1993)

Students entering math-intensive STEM majors, such as engineering (not including engineering technologies), the physical sciences (physics, chemistry, and forensics), and mathematics fields are often required to take a large number of mathematics and science courses beginning in the first year of college. This curriculum is very different than students enrolled in pre-med or health care majors, who take fewer math and science courses in the first year, or students in a liberal arts major, who take almost no math and science courses in the first year

(Veenstra et al., 2009, Badr, 2013). Therefore, it is not surprising that several studies have indicated that the demanding math and science courses required in the first-year curriculum of students in these STEM majors are gateway courses and create unique retention factors related to Tinto's model. Thus, Tinto's model has often been used and modified to focus more specifically on factors that affect retention and graduation rates of math-intensive STEM students (Baisley, 2019, Rosasco, 2013, Veenstra et al., 2009, Badr, 2013).

2.2.1 Student Pre-entry Attributes

While many pre-entry attributes that are traditionally included in Tinto's model have been found to be predictive of math-intensive STEM student persistence, there are also several additional factors that have been found to be specifically predictive of persistence for these students.

Parental Education Level

Tinto suggests that parental education level is an attribute that impacts student attrition with lower parental education leading to lower perseverance at post-secondary institutions (Tinto, 1993, Tinto 2012). Results of a study by Moakler & Kim (2014) noted that parental education level also influences a student's likelihood to have interest in and enroll in a STEM field. In addition, parental education has been found to have an impact on STEM student attrition with students whose parents have a high school education or less having a much higher attrition rate, at 58.9%, versus students with a parent who earned a bachelor's degree or higher, at 44.5% (Chen, 2013).

Family Financial Status

Tinto's model also includes the student's financial status as a factor contributing to student attrition (Tinto, 1993, Tinto, 2012). Studies indicate that as family income level increases, the percentage of students leaving STEM decreases from 57.8% in the lowest income quartile to 43.4% for the uppermost income quartile. In addition, students who have received the financial need-based Pell Grants are 1.2 times more likely to leave STEM fields than those who have never received a Pell Grant (Chen, 2013).

High School GPA

Tinto included prior academic experiences in his model as an individual component of the pre-entry attributes (Tinto, 1993, Tinto, 2012). Studies into STEM attrition have shown that students with higher high school GPAs are more likely to be interested in and persevere in STEM fields than those with lower GPAs (Baisley, 2019, Geisinger & Raman, 2013, Moakler & Kim, 2014, Veenstra, et al., 2009). In fact, students with a high school GPA between 2.5 and 2.99 were 1.8 times more likely to leave a STEM major than those with a high school GPA of 3.5 or higher. (Chen, 2013).

SAT Math Score

The SAT exam is generally taken sometime during the junior year of high school. While both SAT scores are highly predictive of overall student performance and retention from the first year to the second year of college, the SAT Math score has also specifically been found to be predictive of student retention in STEM majors (Westrick, et al., 2019, Belser, et al., 2018, Baisley, 2019, Geisinger & Raman, 2013, French, et al., 2005, Kopparla, 2019).

Ethnicity

Student ethnicity is also a component of the pre-entry attributes included in Tinto’s model (Tinto, 1993, Tinto, 2012). Many studies classify students into some or all of the following ethnicities: Asian, Black/African American, Hispanic, White, and Other. In addition, many studies have found a correlation between student attrition and ethnicity in STEM majors. In general, Asian students tend to have the lowest attrition rates and Black/African American students tend to have the highest attrition rates from STEM fields (Geisinger & Raman, 2013, Griffith, 2010, Belser, et al., 2018, Chen, 2013).

Gender

The model developed by Tinto included gender as a student attribute that may impact attrition (Tinto, 1993, Tinto, 2012). While the number of women entering STEM degree programs continues to be significantly lower than the number of men, there is no agreement related to whether gender has an influence on STEM retention (CRS, 2018). Studies relating to STEM retention show varying effects due to gender with some results indicating that women are up to 1.5 times more likely to leave STEM majors and others indicating there is no correlation between student gender and STEM attrition (Ellis, et al., 2016, Rasmussen & Ellis, 2013, Baisley, 2019, Griffith, 2010, Hagman, et al., 2017, Redmond-Sango, et al., 2016, Geisinger & Raman, 2013, Chen, 2013, French, et al., 2005)

High School Math Courses

Several studies have concluded that the number of high school math classes that a student takes is correlated with STEM retention. The quality of mathematical preparation students receive in high school has also been shown to be a predictor of STEM retention (Wade, et al., 2017). In addition, students who have taken a calculus class of any kind have higher retention rates than those who took no calculus in high school. However, there has not been a definitive result indicating a correlation exists with STEM retention and completing a standard level calculus course versus an honors or Advanced Placement (AP) level calculus course (Redmond-Sango, et al., 2016, Geisinger & Raman, 2013). Some studies show only the number of math classes and/or exposure to calculus in high school is predictive of STEM retention while others claim that the total number of AP classes taken is correlated to STEM persistence (Hagman, et al., 2017, Griffith, 2010).

High School Science Courses

Research has identified a correlation between increased STEM retention and students who have taken more than one year of chemistry and/or at least one year of physics at any level in high school (Geisinger & Raman, 2013, Redmond-Sango, et al., 2016) . Again, while subject to debate, there is support in some studies that AP level science classes improve STEM retention over non-AP level classes (Griffith, 2010).

2.2.2 Student Goals and Commitments

The goals and commitments of math-intensive STEM students have also been shown to significantly influence the persistence of these students in STEM fields. These factors vary only marginally for STEM persistence from those identified in Tinto's model.

Career Goals

Tinto specifically notes that a student's career objectives are a critical part of the goals and intentions that impact student retention. Studies have found that students who have clear career goals have lower rates of student attrition, both in STEM majors and from post-secondary institutions overall (Tinto, 1993, Tinto, 2012, Geisinger & Raman, 2013, Belser, et al., 2018, Veenstra, et al., 2009)

Declared STEM Major

Student commitments both educationally and toward a career are also a critical part of Tinto's model that influence student attrition (Tinto, 1993, Tinto, 2012). Studies of STEM students reveal increased retention rates for students who have declared a specific STEM major versus students who are undecided regarding a STEM major (Geisinger & Raman, 2013, Belser, et al., 2018).

2.2.3 Student Institutional Experiences

Finally, extensive research has identified several factors related to institutional experiences for math-intensive STEM students at post-secondary institutions. They include factors commonly present in overall post-secondary retention models and factors unique to STEM student retention.

Overall GPA

A cornerstone of Tinto's model is the academic system. In order for students to academically integrate in post-secondary education, they must succeed in college-level courses. Often student academic success is measured by the student's GPA (Tinto, 1993, Tinto, 2012). It is, therefore, no surprise that overall GPA is predictive of student retention both for STEM majors and overall at post-secondary institutions (Chen, 2013, Geisinger, et al., 2013, French, et al., 2005).

STEM GPA

Specific to STEM fields, a student's GPA in STEM courses has also been found to be predictive of student perseverance in a STEM major. On average, students persevering in a bachelor's STEM major had a significantly higher average first-year STEM GPA than those who left (Geisinger, et al., 2013, Redmond-Sango, et al., 2016, Griffith, 2010, Chen, 2015, Chen, 2013).

Level of First-Year Math Courses

The 2013 study by Chen investigating STEM attrition identified the level of the mathematics courses that students completed in their first year as a factor affecting STEM attrition. Of the students who persevered in STEM majors, 63% took calculus or another advanced mathematics course in the first year compared to just 28-36% of students who left (Chen, 2013, Kopperla, 2019).

<u>Calculus 1 Class Experience</u>

Calculus 1 is often the first mathematics class for a STEM student at the university level. The experience and performance of a student in this class is highly correlated to STEM retention. Students who perform poorly or do not understand the material are more likely to leave STEM fields than those who perform well and have a strong understanding of the mathematical concepts. (Kopparla, 2019, Hagman, et al., 2017, PCAST, 2012, Geisinger, et al., 2013, Redmond-Sango, et al., 2016, Baisley, 2019). This is especially true for math-intensive STEM students who must take additional calculus classes beyond Calculus 1 and Calculus 2 in order to graduate (Bressoud, 2011).

<u>Mathematical Self-Efficacy</u>

Several studies of STEM student retention have also identified the student's level of mathematical self-efficacy as being a factor in the determination of whether a student stays or leaves a STEM major. Lack of mathematical self-efficacy, regardless of calculus grades, has been found to be a substantial predictor of STEM attrition especially for female students (Hagman, et al., 2017, Geisinger & Raman, 2013, Veenstra, et al., 2009)

<u>Number of STEM Courses</u>

The number of STEM credit hours earned by a student in the first year is identified as being predictive of student persistence in many studies. Bachelor's degree students who earned less than 12 STEM credits in the first year, accounting for approximately 40% of the total credits they earned, were more likely to leave than those who earned more than 18 STEM credits in the first year, accounting for approximately 58% of the total credits they earned (Chen, 2015, Chen, 2013).

Percentage of DFW from STEM Courses

The number of STEM courses that a student fails or withdraws from, defined as a grade of D, F, or W respectively, is also an indicator of STEM attrition rates. Those who leave STEM majors have higher DFW rates in STEM courses than students who persist. STEM persisters in bachelor's degree programs withdrew or failed only 3% of STEM courses attempted whereas those who left the STEM major failed or withdrew from 6-11% of the STEM courses attempted (Chen, 2015, Chen, 2013).

Social Integration

Tinto's model emphasizes the importance of social integration as a vital component leading to student persistence (Tinto, 1993, Tinto, 2012). Many studies of STEM student attrition do not investigate student social integration as an important factor. Some studies go so far as to conclude that social engagement is not vital to STEM student persistence and suggest that the focus should remain on factors leading to academic integration (Xu, 2016).

It should be noted that Tinto's model indicates that students must have some level of academic or social integration at a post-secondary institution in order to persist. Since there is often little to no evidence of formal or informal social integration into the STEM field in the first year, it is critical that students integrate academically in order to persevere. In addition, this review of the literature related to factors that influence math-intensive STEM student retention reveals that preparation for and success in college-level mathematics is a vital component in determining whether a student academically integrates and is retained. This is not surprising since math-intensive STEM majors require a minimum of one full year of single-variable calculus courses that are crucial to success in later mathematics, science, and/or engineering courses (Bressoud, 2011, Badr, 2013, Veenstra, et al., 2009).

2.3 Calculus 1 Success

Recognizing that success in mathematics is an integral component of increasing STEM retention for math-intensive majors, researchers have focused extensively on the identification of factors that lead to mathematics success. Reports indicate that approximately 53% of students taking Calculus 1 intend to pursue a math-intensive STEM degree (Bressoud, 2013). Since the majority of STEM students have traditionally begun their college mathematics coursework by taking college Calculus 1 and they make up a large part of the Calculus 1 population, there has been a focus on the identification of factors that affect student success in Calculus 1 (Hagman, et al., 2017).

College Calculus 1 courses typically include the concepts of limits, continuity, the definition of the derivative, differentiation of algebraic and trigonometric functions, applications of derivatives, integration, and applications of definite integrals (Baisley, 2019, Rasmussen, et al., 2014b). Students enter this class from a myriad of backgrounds; some have taken pre-calculus in high school, some have completed a standard calculus class in high school, some have completed an AP Calculus class in high school, and some have completed mathematics prerequisite courses including pre-calculus at the university level (Sadler & Sonnert, 2018). This range of student experiences has led to the identification of many factors which impact student success in the college Calculus 1.

2.3.1 Calculus 1 Success Factors

Parental Education Level

Parental education level has been identified as a factor that contributes to student success in Calculus 1. There is a positive correlation between students whose parents have a higher level of education and improved student grades in Calculus 1 (Sadler & Sonnert, 2018, Sonnert, et al., 2020). Therefore, parental education level has a positive impact on both STEM student retention and success in Calculus 1 courses.

SAT Math Score

The SAT exam is generally taken sometime during the junior year of high school. While some studies do not include the SAT Math score as a factor, these scores have been found to be predictive of student academic performance in college Calculus 1 in some studies (Sonnert, et al., 2020). Thus, the SAT Math score is predictive of both STEM student retention and Calculus 1 success.

Ethnicity

Many studies classify students into some or all of the following ethnicities: Asian, Black/African American, Hispanic, White, and Other. Student ethnicity is often identified as a factor in Calculus 1 student success, as measured by the class grade. In general, Asian students tend to have the highest Calculus 1 grades and Black/African American students tend to have the lowest Calculus 1 grades (Sadler & Sonnert, 2018, Sonnert, et al., 2020). This factor mirrors the ethnicity factor for retention rates in STEM majors.

Gender

Student gender is sometimes found to correlate to performance in Calculus 1. Studies show that female students have equal or higher grades in Calculus 1 courses than male students (Sadler & Sonnert, 2018, Sonnert, et al., 2020). This correlation is at odds with the results relating to

STEM retention, which shows that females have similar or lower STEM retention rates than males.

Mathematical Self-Efficacy

Mathematical attitudes of students entering college Calculus 1 have been found to have a significant impact on the course grade (Sonnert, et al., 2020). In addition, studies indicate that students' mathematical attitudes relating to confidence, enjoyment, and the desire to take additional math classes changes over the course of Calculus 1. While most students enter Calculus 1 with very positive mathematical attitudes, all three attitudes decreased by the end of the class. These results are also troubling since the students who responded for both the beginning and end of course survey for the study were primarily students who earned grades of C or higher (Bressoud, 2013). The effects of high mathematical self-efficacy on Calculus 1 success mirrors the effects of mathematics self-efficacy that also predicts increased STEM retention.

High School Math Courses

High school mathematics preparation prior to Calculus 1 includes the topics of algebra, geometry, trigonometry, and pre-calculus. For many students high school math education culminates by taking a standard, honors, or AP Calculus course. Research reveals that having a strong mathematical foundation and mastering topics considered prerequisite to calculus is critical to student success in Calculus 1. And, while a strong understanding of prerequisite topics is important, students who took calculus in high school performed as well as or better than their peers who did not take a calculus class in high school (Sadler & Sonnert, 2018, Sonnert, et al., 2020). This factor corresponds well with the impact of a high number of mathematics courses and exposure to calculus in high school on STEM retention.

High school Teaching Methods in Mathematics Courses

Studies have shown that high school mathematics teachers and college professors do not share some important objectives regarding the preparation of students for college calculus courses. High school math teachers and professors agree that to prepare for college calculus, students should have a strong understanding of algebra and pre-calculus with limited use of calculators, that students should have a strong individual understanding of mathematical content, that it is often beneficial for students to understand the context in which math can be used, and that students should know how to read a math textbook. However, high school teachers tend to focus on the pedagogy of teaching math by including group work and real world applications while professors desire a focus on the comprehension of mathematical concepts (Wade, et al., 2017). This disconnect between secondary and post-secondary instructors has an impact on student success in college calculus with students who have been taught to understand mathematical concepts performing better than those without conceptual mastery (Wade, et al., 2018). In addition, students who were allowed only limited use of calculators in prerequisite high school classes had higher grades in college Calculus 1 than those who frequently used calculators (Mao, et al., 2016, Sadler & Sonnert, 2016). There is not a STEM retention factor similar to this factor which contributes to Calculus 1 success.

Intended Career

Studies have concluded that students with career interests in the STEM fields of engineering, computer science, and medicine have higher grades in college Calculus 1 than students with other career interests (Sadler & Sonnert, 2018, Sonnert, et al., 2020). This factor corresponds well with the “Student Goals and Commitments to a Career” factor which is correlated to increased retention rates in STEM fields.

Year in College

The timing of when a student takes college Calculus 1 has been shown to correlate to the student's success in the class, as measured by grade. Students who take college Calculus 1 in the first year of college have higher grades than those who take the course after the first year. Thus, students who need to take more than one semester of remedial math classes prior to enrolling in Calculus 1 and do not enroll in the class until after their first year of college have lower overall grades (Sadler & Sonnert, 2018, Sonnert, et al., 2020). This is a similar result to that demonstrated in the "Level of First-Year Math Courses" factor which indicated that taking calculus in the first year led to increased STEM retention.

Calculus 1 Experience

Calculus 1 is often the first mathematics class for students at the university level and approximately 50% of the students in the class plan to major in a STEM field (Bressoud, 2013). The student experience and grade in Calculus 1 can vary widely depending on where students take the class and the instructor. A model of 6,207 students with 216 different instructors across 133 post-secondary institutions indicated that approximately 18% of the variation in Calculus 1 grade could be explained by differences in instructors and institutions (Sadler & Sonnert, 2018). Hence, a student's experience in college Calculus 1 correlates not only with the grade in the course but also with STEM persistence.

Social Integration

A study of students taking Calculus 1 shows that the students have no social integration to the STEM major of engineering during the class (Baisley, 2019). Thus, social integration is not identified as a factor that affects STEM retention or Calculus 1 success in the studies investigated.

A review of literature indicates that many of the factors that affect student success in college Calculus 1 also affect STEM student retention. With the continued national focus on improving STEM retention and the correlation between STEM retention and Calculus 1 success, there has been a coordinated effort to identify and implement programs that support STEM students and improve student success in Calculus 1 courses.

2.4 Characteristics of Successful Mathematics Programs

As researchers and educators identified the factors that impact STEM retention, they also turned their attention to developing programs that would increase STEM retention. Because of the similar factors for both STEM retention and mathematical success, there has also been an effort to improve the math education experience in colleges and universities, especially in college Calculus 1 courses.

The Characteristics of Successful Programs in College Calculus (CSPCC) which was conducted by the Mathematical Association of America (MAA) was a large national study of students in college Calculus 1 attending two- and four-year institutions in the United States. One of the goals of CSPCC related to the identification of the most successful mathematics programs at PhD granting institutions. These programs shared several characteristics including the production of a high number of science and engineering majors, maintenance of high-quality research programs, increased student retention rates, higher student grades in Calculus 1, and lower DFW rates (Bressoud & Rasmussen, 2015). The study of systems at these institutions identified seven institutional practices related to Calculus 1 courses that led to high levels of student success and retention.

Proper Math Placement

Proper placement of students into math classes was an important component of successful programs. Successful institutions not only focused on accurate placement testing, but also provided supports to students who placed into Calculus 1 but were near the lower cutoff and worked with students who did not place into Calculus 1 to ensure that areas of weakness were addressed in coursework (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Support Services

Access to support services such as learning centers and other out of class support, such as workshops, were provided to all students at the most successful institutions on some level. These learning centers offered student access to trained tutors, whether the student was academically at risk of difficulties or not (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Active Learning

Active student involvement during the learning process has been found to lead to better and more complete understanding of mathematical concepts. The successful institutions made use of smaller recitation sections when the lecture class size was too large to accommodate effective active learning strategies (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Graduate Teaching Assistant Training

At many large PhD granting universities, graduate teaching assistants may teach recitation sections or may be instructors for their own classes. The most successful programs provided ongoing training, mentoring, feedback, and support from experienced faculty for graduate teaching assistants (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Coordination of Instruction

The most successful mathematical programs had a course coordinator for pre-calculus,

Calculus 1, and Calculus 2 courses who facilitated communication and uniformity between instructors. This led to a consistent course pace, a uniform set of exams, and a more standardized educational experience for students across all sections (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Rigorous Courses

The mathematics instructors at the most successful institutions did not believe that retention could be improved by making classes easier. Instead, instructors focused on challenging students. This led to increased conceptual understanding by students and, eventually, increased retention (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Use of Local Data

The most successful mathematics departments reviewed data that was collected locally to determine which processes and methods were working well and which needed to be improved. These institutions reviewed the data regularly by semester and annually so that changes could be made promptly when needed (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015).

Various programs have developed in parallel to those discussed above at universities and colleges that also include many of the characteristics of successful mathematics programs and have led to improved student retention in STEM majors. In addition, as a result of concerns by many researchers and educators related to the lack of social integration of STEM students, many of these programs also include a social component to facilitate student social integration within the STEM community and within the institution at large. It should be noted that substantial variation exists between institutions, students, faculty, and academic programs between individual post-secondary institutions. Thus, there is not one solution that can be implemented at all institutions to improve STEM retention and student success in college calculus courses (Tinto, 1993, Tinto, 2012).

2.5 Programs to Improve STEM Retention and Calculus Success

First-Year Seminars

First-year seminars, which strive to provide students the tools needed to successfully adjust to the academic and personal challenges at a university or college, have been found to increase student success and retention (Tinto, 2012, Permzadian & Credé 2016, Black, et al., 2015). In particular, results show that the impact on retention rates is highest for students taking a specialized first-year course that is discipline or major specific (Black, et al., 2015). As such, some institutions are offering first-year seminars focused on STEM students. A study of STEM students enrolled in a first-year seminar showed a significant increase in first semester GPA and first-year persistence, excluding females, among the students taking the seminar over those who did not (Ward, et al., 2020).

Bridge Programs/Extended Orientations

Like the first-year seminar courses, bridge programs or extended orientations are often designed to provide additional support for students to academically and socially adapt to the environment at the institution. Many, but not all, bridge programs focus on under-represented and/or at risk students (Howard & Sharpe, 2019, "TU STEM Bootcamp", 2020, "STEM Summer Bridge Program", 2020). Research has shown that STEM bridge programs lead to higher student retention rates in STEM majors and higher student grades (Howard & Sharpe, 2019).

Math Learning Centers/Workshops

A significant percentage of post-secondary institutions in the United States offer formal or informal math learning centers where students can receive peer tutoring during set times throughout the week during the semester. There is evidence that nearly all institutions offering calculus have a tutoring/learning center for mathematics and that these tutoring centers lead to increased positive student attitudes toward mathematics (Bressoud & Rasmussen, 2015).

A more formal program similar to a learning center is a workshop. At Cal State LA, workshops were instituted after an investigation of student performance in successive calculus classes revealed that the modal grade of students was decreasing by one or more letter grades with each class in the calculus series. These workshops were mandatory for students who had earned a C in the prerequisite course or who were repeating the current course and optional for all other students (Subramanian, et al., 2008). The workshops provided students the opportunity to solve several problems in a group setting with the support of a qualified teaching assistant. Student performance has increased and more students have been able to successfully navigate the series of calculus classes at the university as a result of these workshops (Subramanian, et al., 2008).

Mentoring/Undergraduate Research/Career Exploration

The impact of mentoring, undergraduate research, and career exploration programs at post-secondary institutions is especially pronounced for first-generation students, underrepresented minorities, and women in STEM fields. Many students in these programs report increased positive feelings related to STEM and their desire to continue in STEM fields (Belser, et al., 2017, Wilson, et al., 2012, Hernandez, et al., 2017). It is believed that these programs increase STEM retention because students gain experience in their field and create social connections with faculty and peers. In addition, participation in undergraduate research has been found to not only improve STEM student retention, but to also improve GPA (Brown, et al., 2020).

Learning Communities

STEM learning communities are focused academic and social communities at post-secondary institutions which seek to increase the rate of retention by impacting several of the factors that affect STEM retention and Calculus 1 success. Learning communities often share a theme, have a common curricular component for student members, and provide opportunities for students to interact with peers, faculty, and even mentors (Solanki, et al., 2019, Tinto, 2012).

STEM learning communities have been shown to improve first-year GPA and student grades in STEM classes, strengthen student career goals in STEM and student commitments to STEM education and careers, increase self-efficacy in STEM classes, and facilitate social integration within the STEM community and at the institution (Solanki, et al., 2019, Carrino & Gerace 2016). Many successful STEM learning communities incorporate several of the previously discussed programs to provide support to student participants.

For instance, one successful learning community is the EXCEL program at the University of Central Florida. The EXCEL program is a 2-year program for first-time students in STEM majors. Academically, the program focuses on supports that primarily lead to student success in mathematics courses including a smaller Calculus 1 class size with a corresponding recitation led by a graduate teaching assistant (GTA), an application-based class related to Calculus 1 and Calculus 2, ongoing monitoring of student performance by GTAs, 0 – 6 hours per week of tutoring based on mathematics course performance, and access to peer tutoring in STEM science and math classes. Socially, the program also provides EXCEL members access to dedicated residential housing, if desired, optional monthly social activities, and access to undergraduate research in the spring of the second year. (Dagley, et al., 2016). A study of the EXCEL Learning Community concluded that overall retention rates in STEM majors increased 43% over comparison groups. In addition, there were significant improvements in retention and graduation rates for women and under-represented minorities who participated in EXCEL. Finally, while not a statistically significant result, both the first-semester and first-year GPA of EXCEL students, at 3.0 and 3.04 respectively, was higher than that of the comparison non-EXCEL group, at 2.96 and 2.95 respectively (Dagley, et al., 2016).

Another successful learning community is the Engineering Living Learning Community at Roger Williams University. Students in this learning community take a class together, live in dedicated housing with a Resident Assistant who organizes several student events during the semester, and have a faculty mentor who organizes various activities to facilitate student interaction with faculty and peers. A study of this learning community indicated that students had a higher first-year GPA and 82% of the learning community students were retained in the engineering program while only 66% of the first-year students who did not participate in the learning community were retained (Palm & Thomas, 2015).

As can be seen, the literature indicates that post-secondary institutions have employed a variety of strategies and combined numerous programs to increase STEM student persistence and improve academic achievement in mathematics, particularly Calculus 1. However, as high school academic programs have become increasingly competitive over the last 20 years, the pre-entry attributes of first-year STEM students have also changed.

2.6 Advanced Placement and Dual Enrollment

In an effort to better prepare high school students for the rigors of post-secondary courses, many schools have expanded programs to provide more challenging classes to students in high school. This has led to a drastic increase in the number of Advanced Placement (AP) and Dual

Enrollment classes available to high school students (Diaz, 2019). For example, the number of high school graduates who have taken at least one AP exam has increased 38.9% between 2009 and 2019 (College Board, 2020). Dual Enrollment experienced a growth rate of 68% between 2002 and 2010 with more than 70% of high schools offering Dual Enrollment options to students in 2015 and localized growth in some states reported to be 753% between 2000 and 2017 (Field, 2021, Shiyji & Wilson, 2019). In addition to preparing students for post-secondary courses, these class offerings allow many students to earn college credit before graduating from high school.

One way students earn college credits in high school is by taking AP courses. Two commonly offered high school mathematics courses are AP Calculus AB and AP Calculus BC. Often high schools choose to offer these AP mathematics classes because the necessary prerequisite mathematics courses of Algebra, Geometry, Algebra 2, and Pre-calculus are available at the school (AP Calculus AB and BC Course and Exam Description, 2020). Growth in these courses has outpaced the 7% annual growth overall in Advanced Placement courses, with a combined growth rate of 132% in AP Calculus between 2001 and 2019 (College Board, 2020).

The programs for AP Calculus courses were updated for the 2016-17 academic year to include an updated curriculum framework rather than an outline of topics. The current curriculum framework emphasizes student understanding of content, implementation of learning objectives, and an understanding of basic concepts to fundamental calculus concepts. Currently, AP Calculus AB includes the topics of limits, derivatives, integrals, and the Fundamental Theorem of Calculus and AP Calculus BC includes all the topics of AP Calculus AB in addition to concepts related to series (AP calculus UPDATES: Key changes, 2017). Students earn scores between 1 and 5 on AP exams and the College Board predicts a student with a score of 3, 4, or 5 on the exam will succeed in successive college-level courses. However, universities are not all aligned with the AP Calculus scores required to receive credit for college calculus courses. While many institutions require a 3 or higher on the AP exam, some require a score of 4 or higher score on the AP exam to receive credit for the equivalent college-level course (Patterson & Ewing, 2013). According to the College Board, students who score well on the AP Calculus AB exam are considered to have a strong understanding of the concepts included in college calculus 1 and students who score well on the AP Calculus BC exam are considered to have a strong understanding of the concepts included in both college Calculus 1 and Calculus 2 (AP Calculus AB and B…, 2020).

In 2020, more than 266,000 students completed the AP Calculus AB exam with 61.4% of the students scoring a 3 or higher and 40.4% of the students scoring a 4 or higher. In the same year, more than 127,000 students took the AP Calculus BC exam with 81.6% of the students scoring a 3 or higher and 62.2% of students scoring a 4 or higher (College Board, 2020). It should be noted the number of test takers was a little over 300,000 for AP Calculus AB and approximately 139,000 for AP Calculus BC in 2019 (College Board, 2020). However, the percentage of students scoring 3 or above on the exams did not vary significantly. The decrease in the number of AP Calculus test takers mirrors the overall decreases in AP test takers in 2020 that are likely the result of the coronavirus pandemic (AP program participation…, 2020).

Studies have found that approximately 40% of students who received credit for the AP exam took at least two additional math courses after using AP credit in their first year. This indicates students are likely to be in a math-intensive STEM major or minor. Another 30% of those receiving credit on the AP Calculus AB exam took only one additional math course in their first year after using their AP credit and took no additional math courses afterwards (Rosenstein &

Ahluwalia, 2016). In addition, not all students who have high scores choose to use the AP credit. Studies have shown that overall 16% of students across the U.S. and more than 25% of students at research universities taking college Calculus 1 have completed an AP Calculus course in high school and passed the AP exam with a score of 3 or higher but still chose to begin their college mathematics education by taking Calculus 1 (Bressoud, 2013, Sadler & Sonnert, 2018).

As described in factors affecting college Calculus 1 success, there is disagreement among researchers regarding the benefit of AP Calculus, regardless of the AP exam score. There is also similar disagreement regarding the congruence of AP Calculus courses and college Calculus 1 courses. Those who believe that AP Calculus courses provide an equivalent or superior academic experience for students who score well on the AP exams cite information related to AP exam validations and results of several studies that show that students using AP credit are well equipped to handle Calculus 2 concepts (Bressoud, 2009, Patterson & Ewing, 2013, Hedrick & Leonard, 2016). Others believe that AP Calculus courses do not provide an equivalent conceptual framework to students as college Calculus 1 courses. Some cite concerns with the lack of adequate training for teachers of AP Calculus courses in some states. Requirements for AP instructors vary by state but no additional training is required by the state to teach an AP level class in 25 of the 50 states (Bressoud, et al., 2016, Zinth, 2016). Others point to the emphasis on use of graphing calculators in AP Calculus courses and on the AP Calculus exams which is not only unnecessary, but often prohibited in college calculus courses (Wilson, 2018, Sadler & Sonnert, 2016, Mao, et al., 2016). Finally, there is evidence that some high school teachers, rather than focusing on the mathematical conceptual understanding that is emphasized in college calculus, focus on mechanics of solving problems. This is concerning since it is imperative that students have a strong foundation in mathematical concepts in order to be successful in subsequent college calculus courses (Bressoud, 2010, Sadler & Sonnert, 2016).

A second way in which high school students can earn college credits is through Dual Enrollment. Dual Enrollment courses are often a cooperative offering between a high school and a local university, college, or community college. The format of a Dual Enrollment class can vary significantly from classes on a college or university campus with other post-secondary students to purely remote course offerings to classes taught by high school teachers in the high school environment. These courses provide credit for a college-level course and this credit is often accepted by universities if the student earns a C or higher in the class.

Again, there is no agreement regarding the quality and rigor of education from Dual Enrollment programs. Proponents of Dual Enrollment point out that students are able to take college level classes which prepare them academically and psychologically for the demands of post-secondary education while they are still in high school. In addition, students who complete Dual Enrollment classes have been shown to be more likely to enroll in and successfully graduate from post-secondary institutions (Field, 2021). Others worry Dual Enrollment courses taught by high school teachers are not as rigorous as those taught by college instructors. While high school teachers who teach Dual Enrollment courses must have a master's degree, many of the teachers across the country have master's degrees in education without an emphasis in the subject area in which they are teaching. Although new regulations are forthcoming that require high school teachers to hold a master's degree or have 18-credit hours in the subject area being taught, this discrepancy has led to some universities declining Dual Enrollment credits earned from high schools (Field, 2021).

Studies related specifically to the impact of Dual Enrollment credit for college Calculus 1 or Calculus 2 is very limited and, again, contradictory. One study raising concerns indicated that when students were tested with a modified Calculus Validation Exam, students with no credit for college Calculus who took calculus in high school scored 4.17 points out of a 16 possible points and Dual Enrollment students who had credit for a college Calculus 1 course scored 4.61 points of the 16 possible points while AP students earning at least a 4 on the AP exam scored 12.41 points from the possible 16 points (Bessoud, 2009). This would indicate a dramatic difference in understanding of calculus between the Dual Enrollment and Advanced Placement students. However, another study indicated that students who enrolled with Dual Enrollment prerequisite mathematics credits for college-level Algebra, college-level Pre-Calculus and/or college Calculus 1 had the same probability of earning a B in Calculus 1 or Calculus 2 as their counterparts who had completed prerequisite courses at the post-secondary institution (Radunzel, et al., 2014).

With the expansion of AP and Dual Enrollment programs, many students are beginning their mathematical education at post-secondary institutions in college Calculus 2 courses. It is also evident that researchers and educators are not in agreement that the entry pathways from AP Calculus and Dual Enrollment Calculus offer the same strong conceptual framework that college instructors indicate is needed to be successful in further calculus and mathematics courses.

2.7 Calculus 2

The literature indicates that as high schools have expanded AP and Dual Enrollment programs for students over the last 20 years, a larger number of students are entering 4-year universities with credit for college Calculus 1. In addition, there are a significant number of students entering 4-year universities with credit for college Calculus 1 from another post-secondary institution. And, while post-secondary enrollment in 2-year institutions, like community colleges, has declined slightly since 2010, an 3% increase in student enrollment at these institutions is projected between 2018 and 2029 (Hussar, et al., 2020). Therefore, it is also important to recognize there is a steady flow of students who have taken courses, including college Calculus 1, at a 2-year institution before transferring to a 4-year university or college and taking college Calculus 2 (Jones, 2018). While there are limited studies related specifically to student success in Calculus 2 for STEM students with credit for Calculus 1 from 2-year institutions, there is evidence that a Calculus 1 grade of B or higher at either a 2-year or 4-year institution both result in higher rates of persistence and graduation in math-intensive STEM majors at universities (Laugerman, et al., 2015).

Data from a number of large 4-year research-focused STEM universities indicate a higher number of students are now enrolling in Calculus 2 courses than Calculus 1 courses during their first year (Georgia Tech, 2018, Purdue University, 2017). Many of these students, who often have intentions of pursuing math-intensive STEM majors, are now beginning their college mathematical education at their home university in college Calculus 2. These students have had different experiences in Calculus 1 that do not necessarily encompass the same academic rigor and expectations experienced by students who have taken the Calculus 1 course at the same university. In addition, data shows that college Calculus 2 at large research-focused universities is one of the classes identified as having very high DFW rates for first-year students (Georgia Tech, 2018, Purdue University, 2019).

While it is essential that math-intensive STEM students succeed in Calculus 2 in order to persevere and graduate, there have been few studies related to Calculus 2 student success. These studies are discussed here.

Morgan & Remist, 1998

This study investigated grades from students at 21 universities in Fall 1991. A comparison of college Calculus 2 grades for students who passed college Calculus 1 at the same university versus those who earned a 3 or above on the AP Calculus exam and used the credit toward college Calculus 1 was made. Results indicated higher college Calculus 2 grades for students earning an AP exam score of 3 or higher than for those who earned college Calculus 1 credit at the university (Table 2.1). On average AP students who took the AP Calculus AB exam and/or the AP Calculus BC exam earning a 3 or higher and using the credit for college Calculus 1 outperformed other Calculus 2 students academically (Morgan & Ramist, 1998). However, this study had some limitations since it examined the average grades across all 21 universities without considering the grade variation at each university and it did not control for the pre-entry attribute variations in the student populations between those who passed the Advanced Placement courses with higher than a 3 versus the overall student population completing the college Calculus 1 course. (Bressoud, 2009).

Table 2.1: Calculus 2 Grade Comparisons for Morgan and Ramist Study (1998)

Placement by:	Average Calculus 2 grade	Placement by:	Average Calculus 2 grade
Non-AP Calculus 1 for AP Calculus AB comparison	2.52	Non-AP Calculus 1 for AP Calculus BC comparison	2.51*
AP Calculus AB – Score = 3	2.67	AP Calculus BC – Score = 3	2.88
AP Calculus AB – Score = 4	2.79	AP Calculus BC – Score = 4	3.24
AP Calculus AB – Score = 5	3.23	AP Calculus BC – Score = 5	3.66

*Note that the average Calculus 2 grade was slightly lower for the comparison related to Calculus BC Scores. This resulted from a smaller number of universities being included in this group.

Morgan & Klaric, 2007

This was a study of the grades of students taking college Calculus 2 at 22 institutions in the United States in Fall 1994. This study examined student Calculus 2 grades by comparing grades of students who earned credit for Calculus 1 at the same university and those who earned credit by scoring a 3 or higher on the AP Calculus exam. Additionally, analysis was completed both before and after adjustments were made using SAT score results to identify student populations that had similar pre-entry academic attributes. This study showed a larger impact than the Morgan & Remist (1998) study for students without matching the student populations, with AP credit students again earning higher grades in Calculus 2 than non-AP students. For the SAT-adjusted student populations the students with AP Calculus AB exam scores greater than 3 also earned Calculus 2 grades higher than students who took Calculus 1 at the same university (Table 2.2). A comparison of students scoring above a 3 on the AP Calculus BC exam with those earning credit for Calculus 1 at the same university also indicated that students who had taken AP Calculus BC academically outperformed non-AP students in Calculus 2 as seen in Table 2.3 (Morgan & Klaric, 2007).

Table 2.2: Calculus 2 Grade Comparisons for AP Calculus AB - Morgan and Klaric Study(2007)

Placement by:	Differences in Average Calculus 2 Grade Across All Students	Differences in Average Calculus 2 Grade for SAT-Adjusted Differences
Non-AP Calculus 1	2.43	2.43
AP Calculus AB – Score = 3	2.69	2.64
AP Calculus AB – Score = 4	2.90	2.78
AP Calculus AB – Score = 5	3.34	3.15

Table 2.3: Calculus 2 Grade Comparisons for AP Calculus BC - Morgan and Klaric Study (2007)

Placement by:	Differences in Average Calculus 2 Grade Across All Students	Differences in Average Calculus 2 Grade for SAT-Adjusted Differences
Non-AP Calculus 1	2.50	2.50
AP Calculus BC – Score = 3	3.00	2.92
AP Calculus BC – Score = 4	3.45	3.35
AP Calculus BC – Score = 5	3.46	3.27

Dodd, Fitzpatrick, Ayala & Jennings, 2002

This was a study of students at the University of Texas, Austin, and included student cohorts from 1996-1999. The study compared college Calculus 2 grades of AP students scoring a 3 or higher on the AP Calculus AB exam to AP Calculus AB students scoring less than a 3, non-AP students who were matched based on high school rank and total SAT scores, and students who had enrolled in a course equivalent to college Calculus 1 while still in high school. Results again indicate that students who earned a 3 or higher on the AP Calculus AB exam and used the credit received an average Calculus 2 grade of 2.98 outperforming the non-AP matched students who had taken Calculus 1 at the university with an average Calculus 2 grade of 2.55. Unfortunately, this study was unable to reach a conclusion regarding the dual/concurrent enrollment students since there was only one student in this group during the time of the study (Dodd, et al., 2002, Bressoud, 2009).

Keng & Dodd, 2008

This study compared college Calculus 2 grades of AP students scoring a 3 or higher on the AP Calculus AB exam who used the credit toward college Calculus 1 to AP students scoring a 3 or higher on the AP Calculus AB exam who chose to repeat Calculus 1 at the university, AP students scoring less than a 3 who completed Calculus 1 at the university, non-AP students with similar pre-entry academic attributes, and students who had been concurrently enrolled in a college Calculus 1 course during high school. The study was conducted at the University of Texas, Austin for students cohorts entering the university between 1998 to 2001. Again, unfortunately, there were no students in this study for the dual enrollment group during this time. The pairwise comparisons of the remaining four groups indicated that those who scored a 3 or above on the AP Calculus AB exam and who took the credit had the highest average Calculus 2 grade at 3.13 (Table 2.4). The students who scored 3 or above on the AP Calculus AB exam and chose to repeat Calculus 1 had an average Calculus 2 grade of 2.97 which was closely followed by the non-AP matched students with an average Calculus 2 grade of 2.94. All other groups outperformed the students who took AP Calculus AB and scored less than a 3 who had an average Calculus 2 grade of 2.49 (Keng & Dodd, 2008).

Table 2.4: Calculus 2 Grade Comparisons for AP Calculus AB – Keng & Dodd Study (2008)

Student Description:	Average Calculus 2 Grade
AP Calculus AB Score ≥ 3 and used credit	3.13
AP Calculus AB Score ≥ 3 and did not use credit	2.97
Non-AP Calculus student	2.94
AP Calculus AB Score < 3	2.49

Rosasco, 2013

This study compared the academic success of students with and without AP Calculus AB credit for college Calculus 1 at a university in northern California over the period from 2004 to 2010 (Rosasco, 2013). Results indicate that the students who used AP credit for Calculus 1 after taking the AP Calculus AB exam had an average Calculus 2 grade of 3.32 while the average Calculus 2 grade of all other students in the course was 2.64. In addition only 13% of students with AP Calculus AB credit earned a C- or lower in college Calculus 2 while nearly 40% of all other students earned a C- or lower. Earning a C- or lower in the Calculus 2 course required students to repeat the course. It should also be noted that no matching of pre-entry academic attributes was done for this analysis.

Further breakdown of college Calculus 2 grades based on the first college mathematics course indicated that students entering college mathematics in pre-calculus were consistently underperforming compared to other groups and typically earn grades 0.4 grade points lower in Calculus 2 than all other students. In addition, those who entered college Calculus 2 with AP Calculus AB credit academically outperformed students who entered Calculus 2 with credit for Calculus 1 with or without AP Calculus AB credit and typically earn grades 0.05 grade points higher. However, a comparison of students who began mathematics in college Calculus 2 with credit for Calculus 1 but no AP Calculus credit performed equivalently to students who entered in college Calculus 2 with credit for Calculus 1 from AP Calculus AB. No assumptions were made by the researcher regarding how these students earned credit for Calculus 1.

Finally, a regression analysis of student success in college Calculus 2 identified high school GPA, SAT Math and Verbal scores, AP Calculus AB score (at the .10 level), average composite AP exam score, Calculus 1 grade, the number of attempts at Calculus 1, and first semester university GPA as factors that were predictive of student success in college Calculus 2. The relevance of these factors varied based on the student's entry pathway into college Calculus 2 with pre-entry attributes such as high school GPA and SAT scores not being significant factors for students who started their post-secondary mathematics education in Calculus 1 or Pre-Calculus. Other factors that were investigated or controlled in this analysis were gender, ethnicity, major, time between AP Calculus AB and Calculus 2, and Pre-Calculus grade.

Precalculus to Calculus 2

In addition to the studies related to AP Calculus credit and success in college Calculus 2, the Precalculus to Calculus 2 (P2C2) program is a recent longitudinal study by the Mathematical Association of America to investigate how mathematics departments are implementing the characteristics that were deemed critical to student success in college-level calculus from the CSPCC project (Rasmussen, et al., 2019, Bressoud & Rasmussen, 2015). The first phase of the P2C2 study was a census of the mathematics departments offering graduate degrees in mathematics in the United States. The second phase, currently underway, seeks to explore the link between the seven characteristics that were identified in CSPCC and student success. The seven characteristics of successful Calculus 1 programs were identified, as noted earlier, as active learning strategies, proper placement testing, trained graduate teaching assistants, course coordination, rigorous courses, student support programs, and use of local data to evaluate programs and make improvements.

It is evident from the literature review that, unlike Calculus 1, there have not been recent studies related to the factors that impact student success in college Calculus 2. In addition, the last two decades have seen pivotal changes that have resulted in the implementation of programs, both academic and social, to increase STEM student retention and graduation. Many of these programs support students in the first-year calculus courses that are essential prerequisites for math-intensive STEM majors. As a consequence of the changes at post-secondary institutions, coupled with the extensive growth and recent updates in the Advanced Placement and Dual Enrollment programs available to many U.S. high school students and the continued enrollment of students with other post-secondary calculus experience, the demographics and experiences of Calculus 2 students have changed dramatically since 2000. Therefore, there is a compelling rationale supporting further examination of student success in Calculus 2.

2.8 Summary

The literature review has examined student success in first-year college calculus courses and STEM student persistence. Using Tinto's Model of Institutional Departure as the theoretical framework, the impact of student pre-entry attributes, goals and commitments, and institutional experiences have been investigated for STEM student retention and for college Calculus 1 success (Tinto, 1993). Factors that influenced both STEM retention and Calculus 1 success were then identified and compared. A number of similar factors were identified including high school math courses and experiences, SAT Math score, mathematical self-efficacy, career goals and commitments, when Calculus 1 was taken, Calculus 1 experience, parental background, gender, and ethnicity (Dagley, et al., 2016, Belser, et al., 2016, Ellis, et al., 2016, Geisinger & Raman, 2013, Sonnert, et al., 2020, Wade, et al., 2018).

Since the comparison revealed extensive similarities between factors associated with Calculus 1 success and STEM persistence, a discussion of post-secondary programs designed to increase retention in STEM fields and student success in calculus courses were then examined. Programs such as first-year seminars, bridge programs, math learning centers, mentoring, undergraduate research, and career exploration, and learning communities have all been found to impact STEM student retention. These programs lead to improved academic performance in STEM courses and social integration of STEM students (Tinto, 2012, Permzadian & Credé, 2016, Howard & Sharpe, 2019, Bressoud & Rasmussen, 2015, Belser, et al., Wilson, et al., 2012, Solanki, et al, 2019, Dagley, et al., 2016, Palm & Thomas, 2015).

Then, the growth and changes in AP Calculus and Dual Enrollment programs and curriculum were investigated. Both programs offer students the opportunity to earn college credit for courses, like Calculus 1, while they are still in high school and both programs have seen astronomical growth since the early 2000's (Diaz, 2019, College Board, 2020, Field, 2021, Shiyji & Wilson, 2019). While past research focused principally on student success in college Calculus 1 since most STEM students entered universities in Pre-Calculus or Calculus 1 courses, the significant increase in AP and Dual Enrollment programs in high schools coupled with continued enrollment of students with other post-secondary calculus experience has led to more students entering their first year at universities with credit for Calculus 1 (Rosenstein & Ahluwalia, 2016, Rosasco, 2013). Thus, many of these students are beginning their college mathematical education in college Calculus 2.

Though there has been extensive recent research regarding success in college Calculus 1, there has been little research related to student success in college Calculus 2 courses. The most recent research investigating Calculus 2 success was conducted with students enrolled in Calculus 2 between 2006 and 2010 and all other studies were completed with student cohorts in 2001 or earlier. Given the astronomical growth in and updates to the AP and Dual Enrollment programs and the additional programs offered by institutions to improve STEM retention rates and increase student success in mathematics, particularly in calculus, the need to re-examine student success in Calculus 2 is evident.

CHAPTER III
METHODOLOGY

The objective of educating students to meet the increasing demand for STEM professionals has resulted in extensive research to better understand post-secondary STEM retention. The importance of academic success in first-year required STEM courses, particularly in mathematics and science, has been identified as critical in many of these studies. This, coupled with the large number of students who begin their post-secondary mathematics education in college Calculus 1, has resulted in a focus on student academic success in Calculus 1. Results of previous studies indicate there is a strong parallel between factors which predict STEM student persistence and factors which predict Calculus 1 success. This is particularly true for students in math-intensive STEM majors who must take more than one full year of mathematics for their degree.

As high schools increase the number of Advanced Placement (AP) and Dual Enrollment courses offered to students and as some students choose to begin or supplement their post-secondary education at other 2-year or 4-year institutions, more students are entering their first year at universities with credit for Calculus 1. Thus, these students are beginning their mathematical education at their home post-secondary institution taking college Calculus 2. However, there is disagreement among researchers regarding the robustness of Advanced Placement and Dual Enrollment programs and little to no specific information regarding credit from other institutions. Some argue the often smaller class sizes of AP, Dual Enrollment, and other post-secondary institutions, especially community colleges, lends instructors flexibility which allows for the building of a strong conceptual framework on which to learn Calculus 2 (Bressoud, 2009, Patterson & Ewing, 2013, Hedrick & Leonard, 2016, Field, 2021). Other researchers argue that lack of adequate training, inconsistent educational requirements, and the common use of calculators in these classes does not equip students with the conceptual understanding essential for success in future math classes (Bressoud, et al., 2016, Zinth, 2016, Wilson, 2018, Sadler & Sonnert, 2016, Mao, et al., 2016, Bressoud, 2010, Field, 2021).

Since there is disagreement regarding the equivalence of various class formats that provide credit for Calculus 1 and qualify students to take college Calculus 2, it is vital that factors and experiences that impact student success in Calculus 2 be further investigated.

3.1 Setting and Participants

3.1.1 The University

Participants of the study are students attending the University of Central Florida (UCF) located in southeastern United States. The university has approximately 72,000 total students across multiple campuses with a total undergraduate population of approximately 61,400 for the 2020-2021 academic year. The geographic location of the university leads to a diverse student population with 46.3% of students identified as White, 27.5% as Hispanic/Latino, 10.3% as African American/Black, 6.4% as Asian, 3.9% as International , 4.3% as Multiracial, and the remaining 1.2% as Native Hawaiian/Pacific Islander, American Indian/Alaska Native, or Other. In addition, the student population of UCF is primarily from the state of Florida with Florida residents comprising 91% of the undergraduate student population.

The University of Central Florida is one of 131 institutions classified as an R1: Doctoral University – very high research activity by the Carnegie Classification of Institutions of Higher Education in 2018. The university also has ABET accreditation for all engineering disciplines and computer science. In 2020, UCF offered more than fifteen degrees in the math-intensive fields of engineering, science, and mathematics including aerospace, civil, computer, construction, electrical, environmental, industrial, and mechanical engineering, materials science and engineering, photonics science and engineering, computer science, forensics science, physics, chemistry, mathematics, statistics, and actuarial science. There were 11,307 students enrolled in College of Engineering and Computer Science and more than 1,760 students enrolled in math-intensive majors through the College of Sciences and the CREOL College of Optics and Photonics in the 2019-2020 academic year.

3.1.2 Math-intensive STEM Majors and Calculus

Students in engineering programs are admitted with a pending status which is removed upon the completion of several prerequisite mathematics and science courses, including college Calculus 1 (MAC 2311C), college Calculus 2 (MAC 2312), Physics 1 (PHY 2048C), and Chemistry 1 (CHS 1140, CHM 2045C, or equivalent), with a grade of “C” (2.0) or higher in each course. Students in mathematics, statistics, actuarial science, computer science, forensic science, chemistry, and physics must also complete both Calculus 1 and Calculus 2 courses and other major specific courses with a grade of “C” or higher in order to earn a bachelor’s degree. While computer science and forensic science majors require additional mathematics courses, additional calculus courses are not required for these majors. Mathematics, statistics, chemistry, physics, and engineering degree programs require a multivariate calculus course (college Calculus 3) beyond Calculus 2. In addition, mathematics, physics, and engineering programs require at least one additional mathematics course in differential equations to fulfill degree requirements.

Many students in math-intensive STEM majors begin their mathematics education at UCF in college Calculus 1 (MAC 2311C). Placement into college Calculus 1 has been primarily dependent upon the successful completion of the Math Placement Tests (MPT) including algebra, trigonometry, and pre-calculus placement exams. If a student is unable to pass any of these placement exams with a score of 70% or higher, they are placed into a course prerequisite to Calculus 1 such as college Algebra, college Trigonometry, or college Pre-Calculus. Students with AP Calculus credit or with more than 12 hours of college credit after graduating from high school may be exempted from the placement exam. So, while many students take college Calculus 1 during their first semester at UCF, there are some students who do not enroll in the course until later in their first year or even their second year depending on their incoming mathematical background and proficiency.

While some students need to improve their mathematical proficiency, others enter the university at an advanced level. As discussed in the literature review, the increased participation of high school students in AP Calculus courses and Dual Enrollment courses has led to an increase in the number of students entering universities with credit for Calculus 1 (College Board 2020, Field, 2021). Additionally, undergraduate transfer students from community colleges or other universities or colleges may enter the mathematics pipeline at UCF with credit for college Calculus 1 (Jones, 2018, Laugerman, et al., 2015). Therefore, as seen in Figure 3.1, there are multiple ‘pathways’ with varied experiences from college Calculus 1 to enter college Calculus 2 at UCF. Most commonly, students enter college Calculus 2 (MAC 2312) at UCF after completing college Calculus 1 (MAC 2311C) at the university with a grade of C or higher. However, students may also enroll in college Calculus 2 by using credit from AP Calculus with a score of 3 or higher on the AP Calculus AB exam, with credit after earning an AB sub-score of 3 or higher on the AP Calculus BC exam, or after earning credit at another institution for college Calculus 1 from a Dual Enrollment course or as transient or transfer student. It should be noted that while many students with sufficient scores on AP Calculus AB and/or AP Calculus BC exams use the credit toward college Calculus 1, some students forgo the use of the credit and choose to enroll in Calculus 1 at UCF.

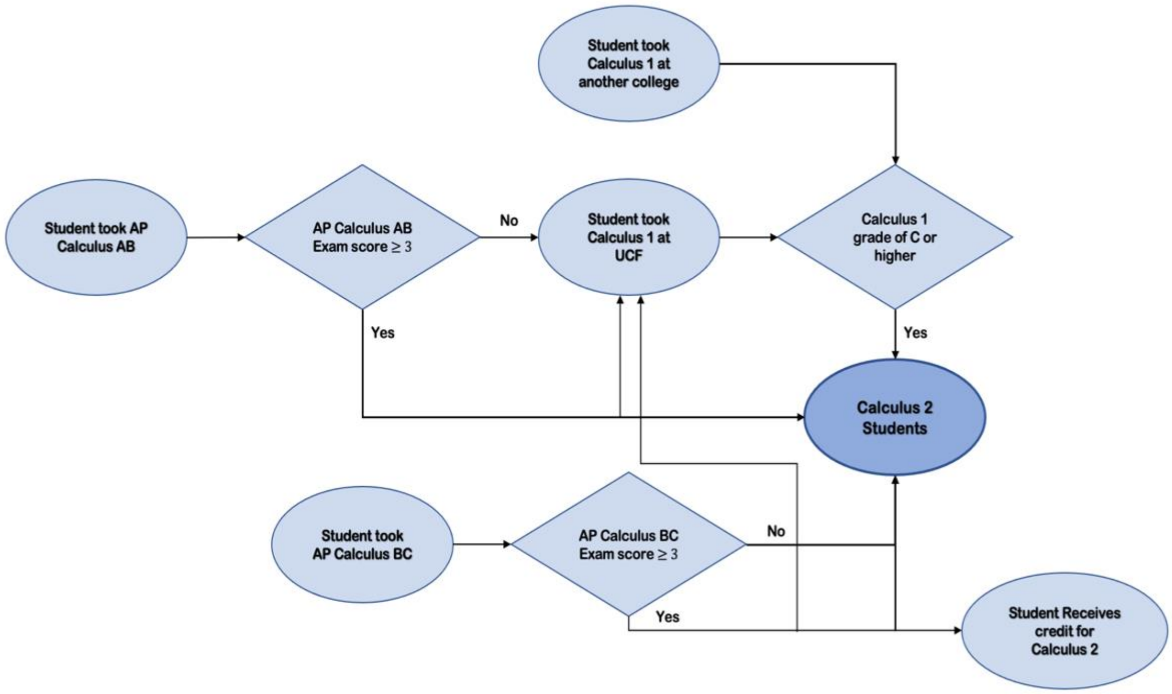


Figure 3.1: Entry Pathways to Calculus 2

3.1.3 The Population

The population of this study includes students in math-intensive STEM majors taking college Calculus 2 (MAC 2312) at the University of Central Florida between the Summer 2017 and Fall 2020 semesters. A total of 6118 students enrolled in the college Calculus 2 course at least once during the three year period from 2017 to 2020. Student information is included only for the last time a student took Calculus 2 at UCF and no information was provided regarding prior attempts in the course. The time frame for the study was chosen to minimize the variation in SAT exam scores and in AP Calculus course experiences of the students taking college Calculus 2. The SAT tests were revised to an updated exam format in March 2016 and there was an update to the AP Calculus curriculum and exam during the 2016-2017 school year (College

Board, 2020). Thus, students entering as first-year university students at UCF for the Summer 2017 academic semester or after are likely to have taken both the new format of the SAT exam and the updated AP Calculus course. This leads to increased consistency in student scores and in the material included in AP Calculus courses providing credit for Calculus 1.

Some students in math-intensive STEM majors also participate in specialized programs or learning communities at UCF that provide academic and/or social support. One of these programs is the COMPASS Learning Community, which is for students who enjoy math and science and are interested in exploring opportunities related to a STEM career, but are unsure of a specific STEM major at the start of their first year. COMPASS recruits 100 first-year students and focuses on providing students guidance regarding career opportunities, facilitating interaction with mentors, and improving student learning in math and science courses. The EXCEL Learning Community is a program for STEM students with the goal of increasing the total number of bachelor's degrees earned in STEM majors. EXCEL recruits up to 300 incoming first-year students each year and focuses on improving student learning in math and science courses and connecting students with research and industry opportunities. The University Honors Learning Community, part of the Burnett Honors College, recruits academically high-achieving first-year students and also accepts some qualified established UCF students during the spring semester of their first year. The Burnett Honors College offers smaller class sizes and more rigorous honors courses that are available only to students in the college. Finally, the LEAD Scholars Academy is a 2-year leadership development program and learning community that focuses on academic, community service, and leadership opportunities. It should be noted that COMPASS and EXCEL are available only to STEM students while University Honors and LEAD Scholars students are not composed exclusively of STEM students.

The large sample size of 6118 students for this study will result in a very high statistical power at the alpha level of 0.05. Therefore, it will be critical to examine the effect size for analysis results that are found to be statistically significant.

3.1.4 Limitations of the Study

This study is limited to a population of students from one research university in Florida and may not be generalizable to other institutions due to the high percentage of students who are residents of Florida and the unique demographic factors related to this population. In addition, only students who are in math-intensive STEM majors at the start of the semester when college Calculus 2 is taken are included in the study and requirements for STEM majors may vary from institution to institution. Thus, the study population may not be generalizable to other student populations taking Calculus 2 at other institutions. It should also be noted that variation in teaching methods and styles, grading systems, and/or exams across instructors, sections, or semesters is not included in this study. Finally, data was not complete for all students and, thus, the statistical analysis is limited by the data that could be obtained for participants.

3.2 Procedure

As noted in the literature review, a student's pre-entry attributes, goals and commitments, and institutional experiences are often used to model student retention in Tinto's Institutional Departure Model (French, et al., 2005, Tinto, 2012, Veenstra, et al., 2009). In addition, Tinto's Model is often used and modified to focus more specifically on factors affecting the retention and graduation of math-intensive STEM students (Baisley, 2019, Rosasco, 2013, Veenstra, et al., 2009, Badr, 2013). Studies of math-intensive STEM retention have identified a number of factors that influence student perseverance. Factors found to be predictive of student retention include pre-entry attributes such as the level of parental education, family financial status, and the student's high school GPA, SAT Math score, high school math and science course background, ethnicity, and gender (Chen, 2013, Baisley, 2019, Belser, et al., 2018, Ellis, et al., 2016, Rassmussen & Ellis, 2013, Griffith, 2010, Hagman, et al., 2017, French, et al., 2005, Geisinger & Raman, 2013, Veenstra, et al., 2009, Redmond-Sango, et al., 2016, Kopparla, 2019). The student's goals and commitments related to career goals and having a declared STEM major have also been identified as important factors influencing STEM student retention (Belser, et al., 2018, Geisinger & Raman, 2013, Veenstra, et al., 2009, Tinto, 2012, Tinto, 1993). Finally, institutional experiences such as the student's overall and STEM academic success, measured by GPA, the level of first-year math courses, the Calculus 1 class experience, student mathematical self-efficacy, the number of STEM courses completed, and the percentage of STEM courses with a grade of D, F, or W have been shown to be predictive of STEM student persistence (Chen, 2013, Chen, 2015, Bressoud, 2011, PCAST, 2012, Griffith, 2010, Hagman, et al., 2017, French, et al., 2005, Geisinger & Raman, 2013, Redmond-Sango, et al., 2016, Kopparla, 2019).

Since research has shown that preparation and success for college-level mathematics is an integral component in determining whether a student is retained in a math-intensive STEM major, researchers have also focused on the identification of factors that lead to mathematics success for STEM students. As such, student success in college Calculus 1, often the first college mathematical course taken, has been extensively studied and it has been determined that many of the factors impacting student success in Calculus 1 are similar to those which impact STEM persistence. Parental education level, student SAT Math score, high school math course experiences, high school mathematical teaching methods, ethnicity, and gender are all student pre-entry attributes that influence student success in college Calculus 1 (Sonnert, et al., 2020, Sadler & Sonnert, 2018, Wade, et al., 2017, Wade, et al., 2018). The student's intended career is also a predictor of college Calculus 1 success as it was an important factor related to goals and commitments predictive of STEM retention (Sadler & Sonnert, 2018, Sonnert, et al., 2020). Finally, a student's mathematical self-efficacy, the year a student takes college Calculus 1, and a student's experiences in Calculus 1 are institutional experiences found to influence student success in college Calculus 1 (Sonnert, et al., 2020, Sadler & Sonnert, 2018, Bressoud, 2013).

The identification of factors which improve mathematical success and increase STEM retention has led to the development of many programs to support students. Successful math programs have been found to have many similar characteristics including proper math placement of students, support services such as learning centers, the use of active learning strategies in classes, training for graduate teaching assistants, courses that challenge students, coordinated instruction within the mathematics department, and the periodic review of data to identify successful practices and areas needing improvement (Rasmussen, et al., 2014b, Bressoud & Rasmussen, 2015). Many programs having the objective of increasing STEM student retention include many or all of the practices found in successful math programs. STEM programs shown to be successful at increasing student retention and success include first-year seminars, bridge programs and extended orientations, math learning centers and workshops, mentoring, undergraduate research, career exploration, and learning communities (Ward, et al., 2020, Howard & Sharpe, 2019, Bressoud & Rasmussen, 2015, Subramanian, et al., 2009, Belser, et al., 2017, Wilson, et al., 2012, Hernandez, et al., 2017, Brown, et al., 2020, Solanki, et al., 2019, Tinto, 2012, Dagley, et al., 2016, Palm & Thomas, 2015).

While the number of studies related to student success in college Calculus 2 are limited and have not been recently completed, studies have shown that a student's AP Calculus AB score, AP Calculus BC score, average composite AP exam scores, Calculus 1 grade, number of attempts at Calculus 1, and first semester GPA are factors that influence student success in Calculus 2 (Morgan & Remist, 1998, Morgan & Klaric, 2007, Dodd, et al., 2002, Keng & Dodd, 2008, Rosasco, 2013, Bressoud, 2009). In addition, several studies controlled for the academic level of students with varying mathematical and academic backgrounds by controlling for the student's high school GPA, high school class rank, and/or SAT scores (Morgan & Klaric, 2007, Dodd, et al., 2002) .

An evaluation of factors impacting math-intensive STEM student retention and college Calculus 1 and Calculus 2 success along with the support programs designed to increase retention and improve academic success were evaluated by the researcher to determine which variables would be most useful in this study. In addition, considerations related to the availability of data and the protection of student privacy were used in determining which factors should be included in the study.

Data collection included the submission and approval of an IRB at Shawnee State University, the researcher's home university. A separate IRB was not required by the University of Central Florida, where data was obtained, and the IRB from Shawnee State University has been provided to UCF. Data was supplied by Institutional Knowledge Management (IKM) at UCF at the request of Dr. Melissa Dagley, Executive Director, Initiatives in STEM, on behalf of the researcher. The dataset contains no identifying student information such as student name or student identification number. The data provided by IKM includes data fields as described in Table 3.1 for students enrolled in college Calculus 2 (MAC 2312) at the University of Central Florida from the Summer 2017 through the Fall 2020 semesters.

Table 3.1: Description of Data Collected and Variables

Description of Data Variable	**Data Variable Options**	**Variable Type**	**Reason for inclusion**
Semester MAC 2312 was taken	Semester and year MAC 2312 was taken at UCF	Categorical Variable	Determination of variation between semesters
MAC 2312 Grade	A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F, W	Continuous Variable (converted to 4.0 scale)	Dependent variable
Semester MAC 2311C or equivalent was taken	Semester plus year for each student	Categorical Variable	Determination of time between taking Calculus 1 and Calculus 2
MAC 2311C Completion Type and Institution	MAC 2311C at UCF, MAC 2311C credit from another institution, MAC 2311C credit from AP exam	Categorical Variable	Prior mathematics experience is a predictor of Calculus 1 success and STEM retention
MAC 2311C Grade (if applicable)	A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F, W	Continuous Variable (converted to 4.0 scale)	Previous grades are predictors of STEM retention and Calculus 1 and Calculus 2 success
AP Calculus AB Score (if applicable)	1, 2, 3, 4, 5	Categorical Variable	AP scores are predictors of Calculus 2 success
AP Calculus BC Score (if applicable)	1, 2, 3, 4, 5	Categorical Variable	AP scores are predictors of Calculus 2 success
Student Admit Term at UCF	Semester plus Year of student admittance to UCF	Categorical Variable	Semester Calculus 1 is taken influences Calculus 1 success and STEM retention
Student's declared major at the start of the semester they take MAC 2312	Student's declared major or if undeclared	Categorical Variable	Declared major is a factor influencing Calculus 1 success and STEM retention
Total number of credit hours taken the semester of MAC 2312	Student credit load in the term MAC 2312 was taken	Continuous Variable	Course load can influence STEM retention
Math Placement Test – Algebra Sub-score (if applicable)	Score	Continuous Variable	Math placement influences mathematical success
Math Placement Test – Trigonometry Sub-score (if applicable)	Score	Continuous Variable	Math placement influences mathematical success
Math Placement Test – Pre-Calculus Subscore (if applicable)	Score	Continuous Variable	Math placement influences mathematical success
SAT Math score	Score	Continuous Variable	SAT Math score is predictive of Calculus 1 success and STEM retention
SAT Verbal score	Score	Continuous Variable	SAT verbal score is predictive of student retention
Has the student ever participated in the COMPASS program?	Yes, No	Categorical Variable	Learning Communities are predictive of academic success and STEM retention
Has the student ever participated in the EXCEL program?	Yes, No	Categorical Variable	Learning Communities are predictive of academic success and STEM retention
Has the student ever participated in the LEAD Scholars program?	Yes, No	Categorical Variable	Learning Communities are predictive of academic success and STEM retention
Has the student ever been in the Burnett Honors College?	Yes, No	Categorical Variable	Learning Communities are predictive of academic success and STEM retention
Student gender (if provided)	Gender information	Categorical Variable	Gender is predictive of Calculus 1 success and STEM retention
Student race/ethnicity (if provided)	Race/Ethnicity Information	Categorical variable	Race and ethnicity are predictive of Calculus 1 success and STEM retention

It should be noted that the Math Placement Test sub-scores were collected with the intent of including them in the analysis. However, since students not passing the Algebra or Trigonometry Placement Tests had no scores for the Trigonometry and/or Pre-calculus Placement Tests, there were many students who did not have scores for all three exams. In addition, the majority of the students with credit for Calculus 1 not from UCF did not take any of the placement tests. Therefore, students having all three scores are most likely only include students who were initially placed into Pre-calculus or Calculus 1 at UCF. Therefore, due to issues related to the lack of data for the exam scores, the Math Placement Test sub-scores are not included in this study.

3.4 Data Processing and Analysis Techniques

The following research questions will be examined to determine which factors influence and predict math-intensive STEM students' academic success in Calculus 2.

3.4.1 Calculus 2 Academic Success by Calculus 1 Credit

Research Question 1: Is there a significant relationship between the source of a student's Calculus 1 class credit, including high school AP Calculus, Calculus 1 at another post-secondary institution, and Calculus 1 at UCF, with student academic success in Calculus 2 for math-intensive STEM students?

ANOVA statistical techniques are commonly used in analysis of student success measured by grade, especially when examining groups of students with different attributes (Keselman, et al., 1998). Therefore, an ANOVA and post hoc tests will be used to assess this research question. Student success, the dependent variable, will be measured by the student's Calculus 2 grade where the grade from Calculus 2 is converted to a 4.0 GPA scale with grades of F and W recorded as 0.0 grade points. This analysis requires that the student population be divided into three groups or categories, the independent variable. The groups will be: 1) Students who received credit for Calculus 1 from any AP Calculus course, 2) Students who received credit for Calculus 1 from another college or university, and 3) students who received credit for Calculus 1 (MAC 2311C) from UCF. All students will be in math-intensive STEM majors at the start of the semester they enroll in Calculus 2. Assumptions for ANOVA analysis include independence, normality, and homogeneity of variances. Since the sample size is large, it is expected that the power will be very high at an alpha level of 0.05. Thus, the focus will be on the effect size for any statistically significant results.

3.4.2 Calculus 2 Academic Success by Calculus 1 Experiences

Research Question 2: Is there a significant relationship between a student's prior Calculus 1 background experiences and student academic success in Calculus 2 for math-intensive STEM students? Student experiences include the completion of an AP Calculus course and use of AP credit for Calculus 1, completion of and credit for a Calculus 1 course from another post-secondary institution, completion of and credit for Calculus 1 at UCF after forgoing credit from AP Calculus AB with an AP AB exam score of 3 or higher, completion of and credit for Calculus 1 at UCF after forgoing credit earned from AP Calculus BC with an AP BC exam score of 3 or higher, completion of and credit for Calculus 1 at UCF after taking AP Calculus AB or BC with an AP exam score of 1 or 2, and completion of and credit for Calculus 1 at UCF with no known AP or other post-secondary Calculus 1 experience.

ANOVA statistical techniques are commonly used in analysis of student success measured by grade when examining groups of students with different attributes (Keselman, et al., 1998).

Therefore, an ANOVA and post hoc tests will be used to assess this research question and student success, the dependent variable, will be measured by the student's Calculus 2 grade. The Calculus 2 grade will be converted to a 4.0 GPA scale with grades of F and W recorded as 0.0 grade points. The analysis requires the student population be defined by six groups or categories, the independent variable. The groups will be: 1) Students earning AP credit for Calculus 1, 2) Students earning credit for Calculus 1 from another college or university, 3) Students earning credit from Calculus 1 (MAC 2311C) at UCF after forgoing credit from AP Calculus AB with an AP AB exam score of 3 or higher, 4) Students earning credit from Calculus 1 at UCF after forgoing credit from AP Calculus BC with an AP BC exam score of 3 or higher, 5) Students earning credit from Calculus 1 at UCF after completing AP Calculus AB or BC with an AP exam score of 1 or 2, and 6) Students earning credit for Calculus 1 at UCF with no known AP or other college calculus experience. Again, all students will be in math-intensive STEM majors at the start of the semester they enroll in Calculus 2. Assumptions for ANOVA analysis include independence, normality, and homogeneity of variances. Since the sample size is large, it is expected that the power will be very high at an alpha level of 0.05. Thus, the focus will be on the effect size for any statistically significant results.

3.4.3 Calculus 2 Academic Success by Math-Intensive STEM Major

Research Question 3: Is there a significant relationship between a math-intensive STEM student's major and academic success in Calculus 2?

The statistical technique of ANOVA is commonly used in analysis of student success measured by grade, when examining groups of students with different attributes (Keselman, et al., 1998). Thus, an ANOVA and post hoc tests will be used to assess this research question and student success, the dependent variable, will be measured by Calculus 2 grade. The grade in Calculus 2 will be converted to a 4.0 GPA scale with grades of F and W recorded as 0.0 grade points. This analysis requires that the student population be defined by 18 groups or categories based on major, the independent variable. The groups will be include the math-intensive STEM majors of Mathematics, Statistics, Actuarial Science, Physics, Chemistry, Forensic Science, Computer Science, Photonics Science and Engineering, Aerospace Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Environmental Engineering, Industrial Engineering, Materials Science and Engineering, Mechanical Engineering, and Undecided Engineering/Science. Assumptions for ANOVA analysis include independence, normality, and homogeneity of variances. Since the sample size is large, it is expected that the power will be very high at an alpha level of 0.05. Thus, the focus will be on the effect size for any statistically significant results.

3.4.4 Predictors of Calculus 2 Success

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

A. math-intensive STEM students who began college mathematics at UCF in Calculus 2 with AP Credit for Calculus 1?

B. math-intensive STEM students who began college mathematics at UCF in Calculus 2 having a recorded AP Calculus AB exam score and using with AP Credit for Calculus 1?

C. math-intensive STEM students who began college mathematics at UCF in Calculus 2 after completing Calculus 1 at another post-secondary institution?

D. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus AB with an AP exam score of 3 or higher?

E. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus BC with an AP exam score of 3 or higher?

F. math-intensive STEM students who began their college mathematics education at UCF in Calculus 1 who scored a 1 or 2 on the AP Calculus exam after completing AP Calculus AB or BC in high school?

G. math-intensive STEM students who completed Calculus 1 at UCF with no known AP Calculus or other post-secondary calculus experience?

Multiple logistic regression analysis has been previously used in similar predictive studies (Ding, 2006). Thus, a multiple logistic regression analysis will be used to identify factors that predict student success in Calculus 2 for each research sub-question. Student success, the dependent variable, will be measured by the Calculus 2 grade where academic success (1) is a grade of C or higher and no academic success (0) is a grade of C- or lower or a W in Calculus 2 (MAC 2312). A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive STEM majors which are included in this study. The following predictors will be used for each sub-question:

A. SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, and number of semesters at UCF.
B. AP Calculus AB score, SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, and number of semesters at UCF.

C. Calculus 1 grade, SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, number of semesters since taking Calculus 1, the number of semesters at UCF, and whether Calculus 1 was taken before or after admission to UCF.

D. AP Calculus AB score, Calculus 1 grade, SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, number of semesters since taking Calculus 1, and number of semesters at UCF.

E. AP Calculus BC score, Calculus 1 grade, SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, number of semesters since taking Calculus 1, and number of semesters at UCF.

F. Calculus 1 grade, SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, number of semesters since taking Calculus 1, and number of semesters at UCF.

G. Calculus 1 grade, SAT Math score, SAT Verbal score, gender, ethnicity/race, intended STEM major, learning community affiliation, the standardized concurrent number of credit hours, number of semesters since taking Calculus 1, and number of semesters at UCF.

3.5 Summary

The purpose of this study is to examine how student academic success in Calculus 2 is affected by a student's pathway into the course from Calculus 1. Initially, a comparison of students earning credit for Calculus 1 using AP Calculus credit, students earning credit for Calculus 1 using credit from another college or university, and students earning credit for college Calculus 1 at UCF will be made. This will be followed with a more in depth comparison in which the groups are further broken down to examine whether students earning credit for Calculus 1 at UCF have prior AP Calculus AB or AP Calculus BC experience. Next, a comparison of student academic success in Calculus 2 will be made for math-intensive STEM students based on their major. Finally, the pre-entry attributes, goals and commitments, and institutional experiences which predict math-intensive STEM student success in Calculus 2 will be identified.

College-level Calculus 1 and Calculus 2 courses for STEM students teach essential mathematical concepts and advanced problem-solving techniques that are vital to student success in upper level mathematics, science, and engineering courses (Bressoud, 2011, Badr, 2013, Veenstra, et al., 2009). Thus, it is important that students in math-intensive STEM majors have a strong foundation in both first-year calculus courses before continuing onto more advanced core courses related to their major. To date, there has been limited research related to the success rates of STEM students in math-intensive majors entering universities in college Calculus 2 from alternative pathways or of the factors that influence student success in college Calculus 2 courses. Therefore, this study will offer critical information about factors influencing math-intensive STEM student success in this course.

The results of this study will be valuable to the STEM colleges at the University of Central Florida and can be utilized by university administers, counselors, and instructors to better understand the factors that lead to success of math-intensive STEM students enrolling in college Calculus 2 courses with varying experiences for Calculus 1. In addition, the factors that significantly impact Calculus 2 success for students in math-intensive STEM majors can be used to determine how to better support students and ensure optimal math class placement.

CHAPTER IV
DATA ANALYSIS AND RESULTS

The results of the data analysis examining factors that influence math-intensive STEM students' academic success in Calculus 2 are provided in this chapter. The purpose of this study is to investigate how varying experiences for college Calculus 1 affect math-intensive STEM student success in college Calculus 2. In addition, factors related to student pre-entry attributes, goals and intentions, and institutional experiences are analyzed to determine which factors are predictive of success in Calculus 2 courses for several groups of students.

4.1 Analysis of Participants

Data was provided by Institutional Knowledge Management (IKM) at the University of Central Florida (UCF) at the request of Dr. Melissa Dagley, Executive Director, Initiatives in STEM, on behalf of the researcher. The dataset contains no identifying student information such as student name or student identification number. A total of 6118 students enrolled in Calculus 2 (MAC 2312) at least once between the Summer 2017 and the Fall 2020 semesters are included in this study. Information was only provided for the last time a student took the Calculus 2 course and no information was provided regarding whether a student had previously enrolled in Calculus 2. A total of 5823 of the 6118 students who were in or pending full entry into a math-intensive STEM major and had completed a college Calculus 1 course prior to enrolling in Calculus 2 at UCF were retained in the dataset. Math-intensive majors for this study include Mathematics, Statistics, Actuarial Science, Physics, Chemistry, Forensic Science, Computer Science, Aerospace Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Environmental Engineering, Industrial Engineering, Materials Science & Engineering, Mechanical Engineering, Photonics Science & Engineering, and Undecided Engineering/ Science. Calculus 1 or equivalent courses included in this study are AP Calculus AB, AP Calculus BC, college Calculus 1 (MAC 2311C) at UCF, and college Calculus 1 at another institution.

Descriptive characteristics of the 5823 students included in this study can be seen in Table 4.1. The gender makeup of the STEM students enrolled in Calculus 2 is predominantly male with a total of 4430 (76.1%) male students and 1393 (23.9%) female students. The ethnicity makeup of the student population is, in general, similar to that of the university as discussed in the Methodology chapter. However, a higher percentage of STEM students are identified as Asian at 9.1% versus 6.4% in the overall university population and a lower percentage of STEM students are identified as African American/Black at 6.8% versus 10.3% in the overall university population. A total of 1465 (25.2%) students participated in at least one of the learning communities included in this study and 136 (2.3%) of students participated in 2 or more of the learning communities offering academic and/or social support to students at UCF.

Students may enter college Calculus 2 (MAC 2312) at UCF with a variety of educational experiences for college Calculus 1 (MAC 2311C or equivalent). Therefore, several subsets of the dataset, primarily based on the student's Calculus 1 experience prior to enrolling in Calculus 2 at UCF, were created to examine the research questions for this study (Figure 4.1). The majority of participants in the study have taken the college Calculus 1 course at UCF (67.8%) prior to enrolling in Calculus 2. These students also have varied backgrounds with some earning Calculus 1 credit from UCF having no known AP Calculus or other post-secondary calculus experience, some having chosen to forgo AP Calculus credit after scoring a 3 or higher on the AP Calculus AB exam, others having chosen to forgo AP Calculus credit after scoring a 3 or higher on the AP Calculus BC exam, and, finally, some students having scored a 1 or 2 on the AP exam after taking AP Calculus AB or BC. There are also students who used AP Calculus credit for Calculus 1 and began their mathematics education at UCF in college Calculus 2 (14.6%). These students also have varied backgrounds and with some having credit for AP Calculus AB with a score of 3 or higher, some having credit from AP Calculus BC with a AP AB exam sub-score of 3 or higher, and some only showing receipt of AP Calculus credit with no associated score or indication in the dataset regarding which AP course had been taken. Finally, there are students earning Calculus 1 credit from another 2- or 4-year institution (17.6%).

It should be noted that the participant sample size varies by Calculus 1 experiences (Table 4.2). In addition to Calculus 1 experience, students were also grouped by math-intensive STEM major for the analysis of the third research question and, again, the number of students in each major is not equal (Table 4.3). Finally, students enrolled in Calculus 2 in the Spring 2020 semester were impacted by the unexpected shutdown of in-person classes midway through the semester due to the Covid-19 pandemic. These students were given the option to withdraw from courses until the last week of the semester and were offered a Satisfactory/Unsatisfactory grade option. Students who chose the S/U option are not included in this study.

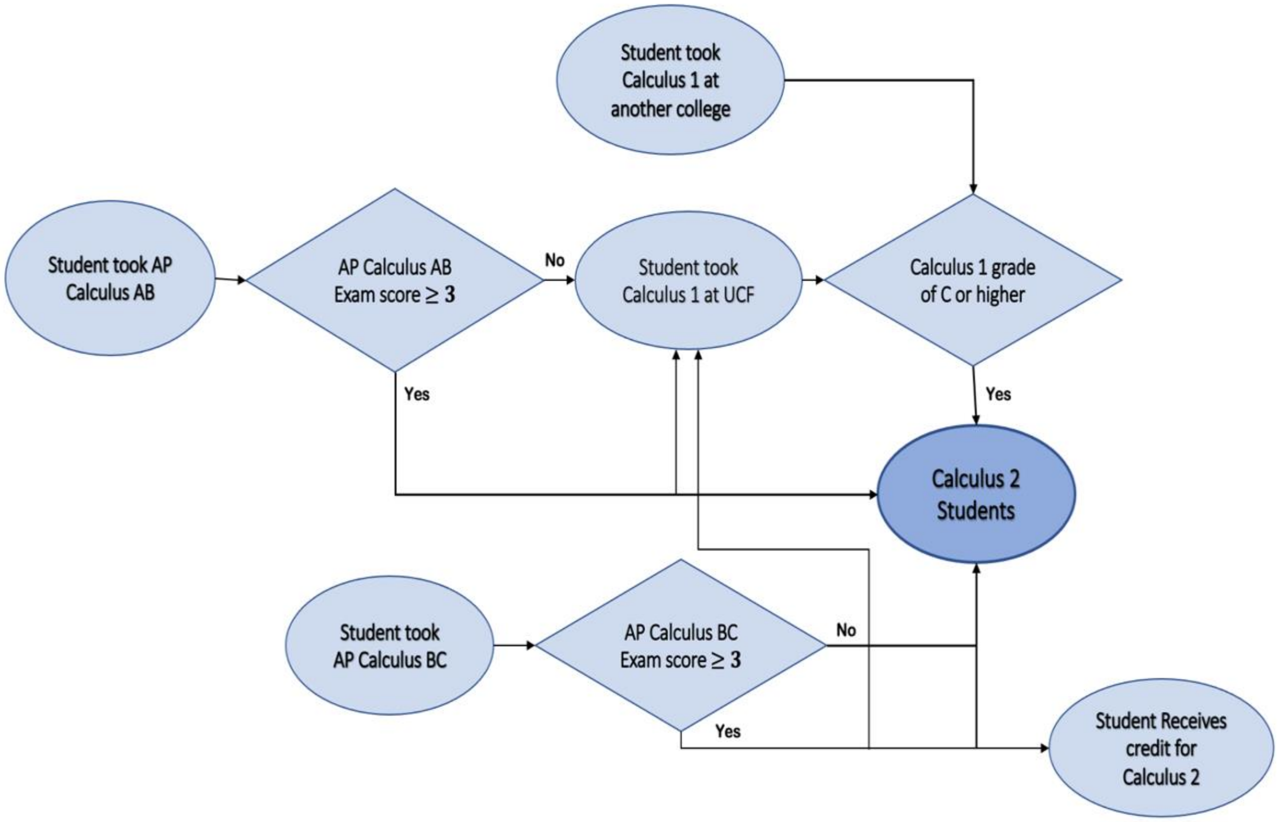


Figure 4.1: Entry Pathways to Calculus 2

Table 4.1: Student Sample Characteristics - All Math-Intensive STEM Calculus 2

	Total Number of Calculus 2 Students	Total Number of Calculus 2 Students
Total Students	5823	5823
Gender		
Male	4430	76%
Female	1393	24%
Ethnicity/Race		
Asian	530	9%
Black/African American	397	7%
Hispanic/Latino	1591	27%
Multi-racial	244	4%
White	2762	47%
International	231	4%
Other	68	1%
Learning Community*		
COMPASS	592	10%
EXCEL	430	7%
LEAD Scholars	135	2%
University Honors	584	10%
Term of MAC 2312		
Summer 2017	215	4%
Fall 2017	612	11%
Spring 2018	707	12%
Summer 2018	199	3%
Fall 2018	631	11%
Spring 2019	735	13%
Summer 2019	238	4%
Fall 2019	799	14%
Spring 2020**	532	9%
Summer 2020	305	5%
Fall 2020	850	15%

* Some students were members of more than one Learning Community

** Students were offered a Satisfactory/Unsatisfactory grade option due to the impact of the Covid-19 pandemic. Students who chose the S/U option are not included.

Table 4.2: Student Sample Size by Calculus 1 Experience

	n
Total Number of Calculus 2 Students	5823
Calculus 1 Credit from UCF	3947
Calculus 1 Credit with No Known AP Calculus Experience	3442
Calculus 1 Credit from UCF with AP Calculus AB with AP Score ≥ 3	240
Calculus 1 Credit from UCF with AP Calculus BC with AP Score ≥ 3	81
Calculus 1 Credit from UCF with AP Calculus AB/BC Exam Score ≤ 2	184
Calculus 1 Credit from AP Calculus	853
Calculus 1 Credit from AP Calculus AB with AP Score ≥ 3	143
Calculus 1 Credit from AP Calculus BC with AP AB Score ≥ 3	125
Calculus 1 Credit from AP Calculus with No Score or Class Specified	585
Calculus 1 Credit from Another Institution	1023

Table 4.3: Student Sample Size by Math-Intensive STEM Major

STEM Major	n
Mathematics	109
Statistics	64
Actuarial Science	46
Physics	128
Chemistry	204
Forensic Science	166
Computer Science	1272
Aerospace Engineering	708
Civil Engineering	394
Computer Engineering	444
Construction Engineering	29
Electrical Engineering	339
Environmental Engineering	138
Industrial Engineering	239
Materials Science & Engineering	8
Mechanical Engineering	1232
Photonic Science and Engineering	69
Undecided Engineering/Science	234
Total	5823

4.2 Calculus 2 Academic Success by Calculus 1 Credit

Research Question 1: Is there a significant relationship between the source of a student's Calculus 1 class credit, including high school AP Calculus, Calculus 1 at another post-secondary institution, and Calculus 1 at UCF, with student academic success in Calculus 2 for math-intensive STEM students?

In preparation for an ANOVA analysis of the first research question, the sample population was categorized into three groups based on the source of the student's Calculus 1 class credit. The three groups consist of 3947 students who earned credit for Calculus 1 at UCF (67.8%), 853 students who earned credit from an AP Calculus course in high school (14.6%), and 1023 students who earned credit for Calculus 1 at another post-secondary institution (17.6%). All students were in math-intensive STEM majors and enrolled in Calculus 2 at UCF at least one time between the Summer 2017 and Fall 2020 semesters (Table 4.4 and Table 4.5).

The proportion of male and female students is similar in all three groups. African American/Black students compose a higher percentage of students with Calculus 1 credit from another institution at 9.3% when compared to the overall Calculus 2 population at 6.8% and compose a lower percentage of students with AP Calculus credit at 3.3%. Additionally, Asian students make up a lower percentage of students with Calculus 1 credit from another institution at 7.3% compared to the overall Calculus 2 population of 9.1% and compose a higher percentage of students with AP Calculus credit at 12.9%. A total of 126 (12.3%) of the students with credit for Calculus 1 from another institution participated in a learning community versus participation of 770 students (19.5%) for students completing Calculus 1 at UCF, and 382 students (44.8%) for students earning AP Calculus credit for Calculus 1. Enrollment in the University Honors

Learning Community is higher for students with AP Calculus credit (26.3%) compared to those who have credit for Calculus 1 from UCF (8.6%) or those with credit from another institution (2.2%). Finally, the semester that students enroll in Calculus 2 varied by the type of Calculus 1 credit with a higher percentage of students with credit for Calculus 1 at UCF (43.3%) enrolling in Calculus 2 in the Spring semesters and a higher percentage of students with AP credit (64.8%) or credit for Calculus 1 from another institution (71.0%) enrolling in the Fall semesters.

The total enrollment for the Spring 2020 semester was markedly lower than any other Spring semester enrollment. Students enrolled in Calculus 2 during the Spring 2020 semester were impacted by the Covid-19 pandemic and the resulting unexpected suspension of in-person classes and the move to online class formats mid-semester. These students were provided the opportunity to withdraw from courses until the final week of the semester and to choose a Satisfactory (S) or Unsatisfactory (U) grade option. Students who choose the S/U option were not included in this study.

There is also an increase evident in the number of students with credit for AP Calculus in the Fall 2019 and Fall 2020 semesters when compared to earlier Fall semesters. This is likely due to a change in AP score requirements at UCF in the summer of 2019. Students enrolling in Calculus 2 prior to the Fall 2019 semester required an AP Calculus AB exam score of 5 or an AP Calculus BC AB sub-score of 5 in order to apply the AP credit toward Calculus 1 at UCF. Beginning with the Fall 2019 cohort, a score of 3 or higher on these exams was required in order to apply the AP credit to fulfill the Calculus 1 credit requirements.

Table 4.4: Student Sample Size by Calculus 1 Experience

	Total Number of Calculus 2 Students	Calculus 1 Credit from UCF	All AP Calculus Credit	Calculus 1 Credit from Another Institution
Total Students	5823	3947	853	1023
Gender				
Male	4430	3015	654	761
Female	1393	932	199	262
Ethnicity/Race				
Asian	530	345	110	75
Black/African American	397	274	28	95
Hispanic/Latino	1591	1064	234	293
Multi-racial	244	164	32	48
White	2762	1887	417	458
International	231	173	17	41
Other	68	40	15	13
Learning Community*				
COMPASS	592	446	92	54
EXCEL	430	343	43	44
LEAD Scholars	135	100	23	12
University Honors	584	338	224	22
Term of MAC 2312				
Summer 2017	215	188	3	24
Fall 2017	612	328	110	174
Spring 2018	707	606	25	76
Summer 2018	199	161	5	33
Fall 2018	631	327	125	179
Spring 2019	735	648	30	57
Summer 2019	238	204	6	28
Fall 2019	799	395	215	189
Spring 2020**	532	454	33	45
Summer 2020	305	263	8	34
Fall 2020	850	373	293	184

* Some students were members of more than one Learning Community
** Students were offered a Satisfactory/Unsatisfactory grade option due to the impact of the Covid-19 pandemic. Students who chose the S/U option are not included.

Table 4.5: Student Sample Percentages by Calculus 1 Experience

	Total Number of Calculus 2 Students	Calculus 1 Credit from UCF	All AP Calculus Credit	Calculus 1 Credit from Another Institution
Total Students	5823	3947	853	1023
		67.8%	14.6%	17.6%
Gender				
Male	76.1%	76.4%	76.7%	74.4%
Female	23.9%	23.6%	23.3%	25.6%
Ethnicity/Race				
Asian	9.1%	8.7%	12.9%	7.3%
Black/African American	6.8%	6.9%	3.3%	9.3%
Hispanic/Latino	27.3%	27.0%	27.4%	28.6%
Multi-racial	4.2%	4.2%	3.8%	4.7%
White	47.4%	47.8%	48.9%	44.8%
International	4.0%	4.4%	2.0%	4.0%
Other	1.2%	1.0%	1.8%	1.3%
Learning Community*				
COMPASS	10.2%	11.3%	10.8%	5.3%
EXCEL	7.4%	8.7%	5.0%	4.3%
LEAD Scholars	2.3%	2.5%	2.7%	1.2%
University Honors	10.0%	8.6%	26.3%	2.2%
Term of MAC 2312				
Summer 2017	3.7%	4.8%	0.4%	2.3%
Fall 2017	10.5%	8.3%	12.9%	17.0%
Spring 2018	12.1%	15.4%	2.9%	7.4%
Summer 2018	3.4%	4.1%	0.6%	3.2%
Fall 2018	10.8%	8.3%	14.7%	17.5%
Spring 2019	12.6%	16.4%	3.5%	5.6%
Summer 2019	4.1%	5.2%	0.7%	2.7%
Fall 2019	13.7%	10.0%	25.2%	18.5%
Spring 2020**	9.1%	11.5%	3.9%	4.4%
Summer 2020	5.2%	6.7%	0.9%	3.3%
Fall 2020	14.6%	9.5%	34.3%	18.0%

* Some students were members of more than one Learning Community
** Students were offered a Satisfactory/Unsatisfactory grade option due to the impact of the Covid-19 pandemic. Students who chose the S/U option are not included.

This ANOVA analysis was performed using R software for statistical analysis and student academic success was measured by the student's grade in college Calculus 2 (R Core Team, 2020). The reported student grades for Calculus 2 provided in the dataset by IKM were converted to a continuous 4.0 GPA scale with A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, C- = 1.7, D+ = 1.3, D = 1.0, F = 0.0, and W = 0.0.

The Calculus 2 grade GPA variable (Calc2_4.0) was initially investigated using histograms, boxplots, and descriptive statistics. There were not remarkable characteristics seen in this portion of the investigation for student grades. There was evidence for lack of homogeneity of variances across groups using Levene's Test of Homogeneity of Variances, $F(2, 5820) = 32.316$, $p < .001$. However, for uneven group sizes, studies have shown that when the variance ratio, defined as the ratio of the largest variance to the smallest variance for all of the groups, is less than 1.5, then the results of an ANOVA analysis are robust even when there is disparity in group sizes (Blanca, et al., 2018). The variance ratio for these three groups is $1.302 < 1.5$. Thus, it is not expected that the differences in group variances will impact the robustness of the ANOVA analysis. Due to the large sample size, the Central Limit Theorem provides support that the normality assumption is not violated. Finally, the students in this study are individuals with unique pre-entry skills, goals and commitments, and institutional experiences and, therefore, the assumption of independence is also met for the analysis.

The Calculus 2 grade has a minimum GPA value of 0.0 for the grades of F and W and a maximum GPA value of 4.0 for a grade of A. The mean Calculus 2 grade is 2.114 for all Calculus 2 students and varied based on the type of Calculus 1 credit from 1.439 for students with Calculus 1 credit from another institution to 2.141 for students with credit for Calculus 1 from UCF to a high of 2.797 for students with AP Calculus credit (see Table 4.6).

Table 4.6: Calculus 2 GPA Grade Breakdown by Calculus 1 Credit

	Calculus 2 GPA n	Calculus 2 GPA $\bar{x}$	Calculus 2 GPA s_x
Students with any source of credit for Calculus 1	5823	2.114	1.438
Students with credit for Calculus 1 from UCF	3947	2.141	1.403
Students with credit from AP Calculus for Calculus 1	853	2.797	1.250
Students with credit for Calculus 1 from another institution	1023	1.439	1.427

Results of a one-way ANOVA (Table 4.7) indicate a significant difference in mean college Calculus 2 grades (Calc2_4.0) over student Calculus 1 experience (Calc1_Credit), $F(2,5820) = 225.5$, $p < .001$, with a large effect size (ω=0.268) and a power of 100%. A Tukey HSD post hoc analysis revealed statistically significant differences in Calculus 2 mean grades between all three Calculus 1 experiences (Table 4.8). The post hoc analysis shows a statistically significant difference in mean Calculus 2 grades between students using AP credit for Calculus 1 and those with credit for Calculus 1 from another institution, $p < .001$, CI (1.207, 1.508), with a large effect size ($g = 1.01$). The post hoc testing also revealed a statistically significant difference in the mean Calculus 2 grades between students with AP credit for Calculus 1 and those with credit for Calculus 1 from UCF, $p < .001$, CI (0.534, 0.779), with a moderate effect size ($g = 0.48$), and between students with credit for Calculus 1 from UCF and those with Calculus 1 credit from another institution, $p < .001$, CI (0.587, 0.815), with a moderate effect size ($g = 0.50$).

Table 4.7: 1-Way ANOVA Table: Calculus 2 Grade Across Calculus 1 Credit

Source of Variation	df	Sum of Squares	Mean Square	F-value	p-value
Calculus 1 Credit Experience	2	866.50	433.25	225.5	< .001
Error	5820	11180.85	1.92		
Total	5822	12047.35			

Table 4.8: Tukey HSD Significant Pairwise Comparisons Across Calculus 1 Credit

Comparing Calculus 1 Credit Between		p	CI	Hedge's g
AP Credit	**Credit from Another Institution**	< .001	(0.534, 0.779)	1.01
AP Credit	**Credit from UCF**	< .001	(1.207, 1.508)	0.48
Credit from UCF	**Credit from Another Institution**	< .001	(0.587, 0.815)	0.50

4.3 Calculus 2 Academic Success by Calculus 1 Experiences

Research Question 2: Is there a significant relationship between a student's prior Calculus 1 background experiences and student academic success in Calculus 2 for math-intensive STEM students? Student experiences include the completion of an AP Calculus course and use of AP credit for Calculus 1, completion of and credit for a Calculus 1 course from another post-secondary institution, completion of and credit for Calculus 1 at UCF after forgoing credit from AP Calculus AB with an AP AB exam score of 3 or higher, completion of and credit for Calculus 1 at UCF after forgoing credit earned from AP Calculus BC with an AP BC exam score of 3 or higher, completion of and credit for Calculus 1 at UCF after taking AP Calculus AB or

BC with an AP exam score of 1 or 2, and completion of and credit for Calculus 1 at UCF with no known AP or other post-secondary Calculus 1 experience.

In preparation for an ANOVA analysis of this research question, the sample population was categorized into six groups based on the student's Calculus 1 class experience(s) and credit. The six groups consist of 3442 students who earned credit from Calculus 1 at UCF with no known AP or other post-secondary Calculus 1 experience, 240 students who earned credit from Calculus 1 at UCF after forgoing credit for AP Calculus AB with a score of 3 or higher on the AP exam, 81 students who earned credit from Calculus 1 at UCF after forgoing credit for AP Calculus BC with an AP exam score of 3 or higher, 184 students who earned credit from Calculus 1 at UCF after completing either AP Calculus AB or BC with an AP exam score of 1 or 2, 853 students who earned credit from AP Calculus in high school, and 1023 students who earned credit for Calculus 1 at another college or university. All students were in math-intensive STEM majors and enrolled in Calculus 2 at UCF at least one time between the Summer 2017 and Fall 2020 semesters (Table 4.4, Table 4.5, Table 4.9, and Table 4.10).

The proportion of male to female students ranges from 81.5% male and 18.5% female in the group with AP Calculus AB or BC experience and an AP exam score of 1 or 2 to 74.4% male and 25.6% female in the group with Calculus 1 credit from another institution. African American/Black (10.3%) and Hispanic (33.7%) students compose a higher proportion of students who did not pass the AP Calculus AB or BC exams compared to the overall group of students with credit from college Calculus 1 at UCF at 6.9% and 27.0%, respectively. White students composed a higher percentage of students forgoing credit for both AP Calculus AB (57.1%) and AP Calculus BC (50.6%) when compared to the group of all students with Calculus 1 credit from UCF (47.8%). Finally, students who chose to forgo credit for AP Calculus AB (16.3%) and those who did not pass the AP exams (22.8%) also made up larger percentages of students in the EXCEL Learning Community when compared to all students who took Calculus 1 at UCF (8.7%).

Again, the total enrollment for the Spring 2020 semester was markedly lower than any other Spring semester enrollment. Students enrolled in Calculus 2 during the Spring 2020 semester were impacted by the Covid-19 pandemic and the resulting unexpected suspension of in-person classes and the move to online class formats mid-semester. These students were provided the opportunity to withdraw from courses until the final week of the semester and to choose a Satisfactory (S) or Unsatisfactory (U) grade option. Students who choose the S/U option were not included in this study.

This ANOVA analysis was performed using R software for statistical analysis and student academic success was measured by the student grade in college Calculus 2 (R Core Team, 2020). The reported student grades for Calculus 2 were converted to a continuous 4.0 GPA scale for this analysis with A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, C- = 1.7, D+ = 1.3, D = 1.0, F = 0.0, and W = 0.0.

Table 4.9: Student Sample Size by UCF Calculus 1 Experience

	Students in Calculus 2 with Calculus 1 Credit from UCF				
	Total Students With Credit from UCF	Students Forgoing AP Calculus AB Credit	Students Forgoing AP Calculus BC Credit	Students with AP Calculus AB/BC Experience (score <3)	Students with No AP Calculus Experience
Total Students	3947	240	81	184	3442
Gender					
Male	3015	191	64	150	2610
Female	932	49	17	34	832
Ethnicity/Race					
Asian	345	15	5	17	308
Black/African American	274	12	3	19	240
Hispanic/Latino	1064	62	25	62	915
Multi-racial	164	9	5	9	141
White	1887	137	41	75	1634
International	173	4	1	1	167
Other	40	1	1	1	37
Learning Community*					
COMPASS	446	32	11	17	386
EXCEL	343	39	8	42	254
LEAD Scholars	100	3	3	8	86
University Honors	338	9	6	4	319
Term of MAC 2312					
Summer 2017	188	5	4	8	171
Fall 2017	328	22	6	18	282
Spring 2018	606	54	23	24	505
Summer 2018	161	10	1	6	144
Fall 2018	327	12	3	20	292
Spring 2019	648	51	27	23	547
Summer 2019	204	12	5	14	173
Fall 2019	395	19	3	24	349
Spring 2020**	454	51	8	13	382
Summer 2020	263	1	1	13	248
Fall 2020	373	3	0	21	349

* Some students were members of more than one Learning Community

** Students were offered a Satisfactory/Unsatisfactory grade option due to the impact of the Covid-19 pandemic. Students who chose the S/U option are not included.

Table 4.10: Student Sample Percentages by UCF Calculus 1 Experience

	Students in Calculus 2 with Calculus 1 Credit from UCF				
	Percent Students With Credit from UCF	Students Forgoing AP Calculus AB Credit (%)	Students Forgoing AP Calculus BC Credit (%)	% Students with AP Calculus AB/BC Experience (score <3)	Students with No AP Calculus Experience (%)
Total Students	3947	240	81	184	3442
Gender					
Male	76.4%	79.6%	79.0%	81.5%	75.8%
Female	23.6%	20.4%	21.0%	18.5%	24.2%
Ethnicity/Race					
Asian	8.7%	6.3%	6.2%	9.2%	8.9%
Black/African American	6.9%	5.0%	3.7%	10.3%	7.0%
Hispanic/Latino	27.0%	25.8%	30.9%	33.7%	26.6%
Multi-racial	4.2%	3.8%	6.2%	4.9%	4.1%
White	47.8%	57.1%	50.6%	40.8%	47.5%
International	4.4%	1.7%	1.2%	0.5%	4.9%
Other	1.0%	0.4%	1.2%	0.5%	1.1%
Learning Community*					
COMPASS	11.3%	13.3%	13.6%	9.2%	11.2%
EXCEL	8.7%	16.3%	9.9%	22.8%	7.4%
LEAD Scholars	2.5%	1.3%	3.7%	4.3%	2.5%
University Honors	8.6%	3.8%	7.4%	2.2%	9.3%
Term of MAC 2312					
Summer 2017	4.8%	2.1%	4.9%	4.3%	5.0%
Fall 2017	8.3%	9.2%	7.4%	9.8%	8.2%
Spring 2018	15.4%	22.5%	28.4%	13.0%	14.7%
Summer 2018	4.1%	4.2%	1.2%	3.3%	4.2%
Fall 2018	8.3%	5.0%	3.7%	10.9%	8.5%
Spring 2019	16.4%	21.3%	33.3%	12.5%	15.9%
Summer 2019	5.2%	5.0%	6.2%	7.6%	5.0%
Fall 2019	10.0%	7.9%	3.7%	13.0%	10.1%
Spring 2020**	11.5%	21.3%	9.9%	7.1%	11.1%
Summer 2020	6.7%	0.4%	1.2%	7.1%	7.2%
Fall 2020	9.5%	1.3%	0.0%	11.4%	10.1%

* Some students were members of more than one Learning Community

** Students were offered a Satisfactory/Unsatisfactory grade option due to the impact of the Covid-19 pandemic. Students who chose the S/U option are not included.

The Calculus 2 grade GPA variable (Calc2_4.0) was initially investigated using histograms, boxplots, and descriptive statistics. There were not remarkable characteristics seen in this portion of the investigation for student grades. There was evidence for lack of homogeneity of variances across groups when Levene's Test of Homogeneity of Variances was used, $F(5, 5817) = 13.808$, $p < .001$. However, for uneven group sizes, studies have shown that when the variance ratio, defined as the ratio of the largest variance to the smallest variance for all groups, is less than 1.5, then the results of an ANOVA analysis are robust even when there is disparity in group sizes (Blanca, et al., 2018). The variance ratio for these groups is 1.304 < 1.5. Thus, it is not expected that the differences in group variances will impact the robustness of this ANOVA analysis. Due to the large sample size, the Central Limit Theorem provides support that the normality assumption is not violated. Finally, the students in this study are individuals with unique pre-entry skills, goals and commitments, and institutional experiences and, therefore, the assumption of independence for ANOVA analysis is also met.

The Calculus 2 grade has a minimum GPA value of 0.0 for the grades of F and W and a maximum GPA value of 4.0 for a grade of A. The mean Calculus 2 grade is 2.114 for all Calculus 2 students and varies based on the type of Calculus 1 credit from 1.439 for students with Calculus 1 credit from another post-secondary institution to 2.797 for students with AP Calculus credit (Table 4.11).

Table 4.11: Calculus 2 GPA Grade Breakdown by Calculus 1 Student Experience

	Calculus 2 GPA n	Calculus 2 GPA $\bar{x}$	Calculus 2 GPA s_x
Students with any source of credit for Calculus 1	5823	2.114	1.438
Students with credit for Calculus 1 from UCF with no known AP experience	3442	2.136	1.408
Students with credit for Calculus 1 from UCF forgoing AP Calculus AB credit with an AP score ≥ 3	240	2.216	1.393
Students with credit for Calculus 1 from UCF forgoing AP Calculus BC credit with an AP score ≥ 3	81	2.548	1.249
Students with credit for Calculus 1 from UCF after scoring a 1 or 2 on the AP Calculus AB/BC exam	184	1.942	1.359
Students with credit from AP Calculus for Calculus 1	853	2.797	1.250
Students with credit for Calculus 1 from another institution	1023	1.439	1.427

Results of a one-way ANOVA (Table 4.12) reveal a significant difference in mean college Calculus 2 grade (Calc2_4.0) over student Calculus 1 experiences (Calc2_Exp_Detail), $F(5, 5817) = 92.65$, $p < .001$, with a large effect size (ω=0.270) and a power of 100%. A Tukey HSD post hoc analysis revealed statistically significant differences in Calculus 2 mean grades between several of the Calculus 1 experiences (Table 4.13). The post hoc analysis shows a statistically significant difference in mean Calculus 2 grades between students with AP credit for Calculus 1 and all other groups except students forgoing credit for AP Calculus BC, $p = 0.634$, CI(-0.210, 0.708). There was a statistically significant difference in student grades between the AP credit group and those with Calculus 1 from another institution, $p < .001$, CI (1.175, 1.541) with a large effect size ($g = 1.01$), students with Calculus 1 credit from UCF after scoring a 1 or 2 on the AP Calculus AB or BC exam, $p < .001$, CI(0.535, 1.176) with a moderate effect size ($g = 0.67$), students with Calculus 1 credit from UCF forgoing credit for AP Calculus AB, $p < .001$, CI(0.293, 0.870), with a moderate effect size ($g = 0.45$), and students with Calculus 1 credit with no known AP or other post-secondary calculus experience, $p < .001$, CI(0.510, 0.812), with a moderate effect size ($g = 0.48$). The post hoc testing also reveals a statistically significant difference in the student mean Calculus 2 grades between those with Calculus 1 credit from another institution and all other groups. Therefore, there was a significant difference in mean grades between students with Calculus 1 from another institution and those with credit for Calculus 1 from UCF with no AP or other post-secondary calculus experience, $p < .001$, CI (0.556, 0.838), with a moderate effect size ($g = 0.49$), students with credit from Calculus 1 from UCF forgoing credit from AP Calculus AB, $p < .001$, CI (0.494, 1.060), with a moderate effect size ($g = 0.55$), students with credit from Calculus 1 from UCF forgoing credit for AP Calculus BC, $p < .001$, CI 0.653, 1.564), with a large effect size ($g = 0.78$), and students with credit for Calculus 1 at UCF with a score of 1 or 2 on the AP Calculus AB or BC exam, $p < .001$, CI (0.186, 0.819), with a small effect size ($g = 0.35$). Finally, there was a statistically significant difference in mean Calculus 2 grades between students with Calculus 1 credit from UCF after forgoing credit for AP Calculus BC and those who scored a 1 or 2 on the AP Calculus AB or BC exam, $p < .05$, CI(0.080, 1.133), with a moderate effect size ($g = 0.46$). It should be noted that no other groups of students with Calculus 1 credit from UCF had significantly different mean grades in Calculus 2 regardless of prior AP experience.

Table 4.12: 1-Way ANOVA Table: Calculus 2 Grade Across Calculus 1 Student Experience

Source of Variation	df	Sum of Squares	Mean Square	F-value	p-value
Calculus 1 Credit Experience	5	888.66	177.73	92.65	< .001
Error	5817	11158.70	1.92		
Total	5822	12047.36			

Table 4.13: Tukey HSD Significant Pairwise Comparisons Across Calculus 1 Student Experience

Comparing Calculus 1 Expeience Between		p	CI	Hedge's g
AP Credit	**UCF with no AP Experience**	< .001	(0.510, 0.812)	0.48
AP Credit	**UCF forgoing AP Calculus AB Credit**	< .001	(0.293, 0.870)	0.45
AP Credit	**UCF with 1 or 2 on AP Calculus AB/BC Exam**	< .001	().535, 1.176)	0.67
AP Credit	**Another Institution**	< .001	(1.175, 1.541)	1.01
UCF with no AP Experience	**Another Institution**	< .001	(0.556, 0.838)	0.49
UCF forgoing AP Calculus AB Credit	**Another Institution**	< .001	(0.494, 1.060)	0.55
UCF forgoing AP Calculus BC Credit	**Another Institution**	< .001	(0.653, 1.564)	0.78
UCF with 1 or 2 on AP Calculus AB/BC Exam	**Another Institution**	< .001	(0.186, 0.819)	0.35
UCF forgoing AP Calculus BC Credit	**UCF with 1 or 2 on AP Calculus AB/BC Exam**	< .05	(0.080, 1.133)	0.46

4.4 Calculus 2 Academic Success by Math-Intensive STEM Major

Research Question 3: Is there a significant relationship between a math-intensive STEM student's major and academic success in Calculus 2?

In preparation for the ANOVA analysis of this research question, the sample population was categorized into 18 groups based on the student's major at the start of the term Calculus 2 (MAC 2312) was last taken. The groups included the math-intensive STEM majors of Mathematics, Statistics, Actuarial Science, Physics, Chemistry, Forensic Science, Computer Science, Aerospace Engineering, Civil Engineering, Computer Engineering, Construction Engineering, Electrical Engineering, Environmental Engineering, Industrial Engineering, Materials Science & Engineering, Mechanical Engineering, Photonic Science & Engineering, and Undecided Engineering/Science. Note that students classified in these majors with a 'pending' status are included in the majors since the pending status will be removed after required classes have been successfully completed with a grade of C (2.0) or higher. The group sizes for individual majors ranged from just 8 students in Materials Science & Engineering to 1272 students in Computer Science (see Table 4.14, Table 4.15, Table 4.16, and Table 4.17).

The proportion of male to female students in each major ranges from 25.3% male and 74.7% female in Forensic Science to 86.9% male and 13.1% female in Computer Engineering. Enrollment in majors also varies by ethnicity. It should be noted that students with Undecided Engineering/Science majors have a higher enrollment in the COMPASS Learning Community compared to other learning communities. This is likely due to the focus of the COMPASS Learning Community on mentoring and advising students who are unsure about which specific STEM major to choose at the beginning of their first year at UCF.

Table 4.14: Student Sample Size by Math-Intensive STEM Major

Major	Number of Students	Gender		Ethnicity/Race						
		Male	Female	Asian	Black/ African American	Hispanic/ Latino	Multi-Racial	White	International	Other
Mathematics	109	64	45	10	8	27	6	54	4	0
Statistics	64	40	24	5	8	14	2	32	2	1
Actuarial Science	46	28	18	5	4	9	2	22	2	2
Physics	128	95	33	4	2	37	6	74	2	3
Chemistry	204	90	114	15	16	60	10	93	5	5
Forensic Science	166	42	124	8	16	52	10	77	2	1
Computer Science	1272	1049	223	189	76	303	49	591	48	16
Aerospace Engineering	708	595	113	50	33	183	30	386	18	8
Civil Engineering	394	303	91	22	28	136	13	167	25	3
Computer Engineering	444	386	58	54	50	128	19	171	18	4
Construction Engineering	29	23	6	2	2	7	0	17	1	0
Electrical Engineering	339	284	55	27	25	87	14	151	30	5
Environmental Engineering	138	61	77	9	7	42	11	64	5	0
Industrial Engineering	239	141	98	13	16	96	8	78	25	3
Materials Science & Engineering	8	4	4	2	1	1	0	4	0	0
Mechanical Engineering	1232	991	241	91	90	326	52	621	40	12
Photonic Science and Engineering	69	54	15	3	6	27	3	26	2	2
Undecided Engineering/Science	234	180	54	21	9	56	9	134	2	3
Total	5823	4430	1393	530	397	1591	244	2762	231	68

Table 4.15: Student Sample Percentages by Math-Intensive STEM Major

Major	Number of Students	Gender		Ethnicity/Race						
		Male	Female	Asian	Black/ African American	Hispanic/ Latino	Multi-Racial	White	International	Other
Mathematics	109	58.7%	41.3%	9.2%	7.3%	24.8%	5.5%	49.5%	3.7%	0.0%
Statistics	64	62.5%	37.5%	7.8%	12.5%	21.9%	3.1%	50.0%	3.1%	1.6%
Actuarial Science	46	60.9%	39.1%	10.9%	8.7%	19.6%	4.3%	47.8%	4.3%	4.3%
Physics	128	74.2%	25.8%	3.1%	1.6%	28.9%	4.7%	57.8%	1.6%	2.3%
Chemistry	204	44.1%	55.9%	7.4%	7.8%	29.4%	4.9%	45.6%	2.5%	2.5%
Forensic Science	166	25.3%	74.7%	4.8%	9.6%	31.3%	6.0%	46.4%	1.2%	0.6%
Computer Science	1272	82.5%	17.5%	14.9%	6.0%	23.8%	3.9%	46.5%	3.8%	1.3%
Aerospace Engineering	708	84.0%	16.0%	7.1%	4.7%	25.8%	4.2%	54.5%	2.5%	1.1%
Civil Engineering	394	76.9%	23.1%	5.6%	7.1%	34.5%	3.3%	42.4%	6.3%	0.8%
Computer Engineering	444	86.9%	13.1%	12.2%	11.3%	28.8%	4.3%	38.5%	4.1%	0.9%
Construction Engineering	29	79.3%	20.7%	6.9%	6.9%	24.1%	0.0%	58.6%	3.4%	0.0%
Electrical Engineering	339	83.8%	16.2%	8.0%	7.4%	25.7%	4.1%	44.5%	8.8%	1.5%
Environmental Engineering	138	44.2%	55.8%	6.5%	5.1%	30.4%	8.0%	46.4%	3.6%	0.0%
Industrial Engineering	239	59.0%	41.0%	5.4%	6.7%	40.2%	3.3%	32.6%	10.5%	1.3%
Materials Science & Engineering	8	50.0%	50.0%	25.0%	12.5%	12.5%	0.0%	50.0%	0.0%	0.0%
Mechanical Engineering	1232	80.4%	19.6%	7.4%	7.3%	26.5%	4.2%	50.4%	3.2%	1.0%
Photonic Science and Engineering	69	78.3%	21.7%	4.3%	8.7%	39.1%	4.3%	37.7%	2.9%	2.9%
Undecided Engineering/Science	234	76.9%	23.1%	9.0%	3.8%	23.9%	3.8%	57.3%	0.9%	1.3%
Total	5823	76.1%	23.9%	9.1%	6.8%	27.3%	4.2%	47.4%	4.0%	1.2%

Table 4.16: Student Sample Size for Learning Communities STEM Major

Major	Learning Communities*			
	COMPASS	EXCEL	LEADS Scholars	University Honors
Mathematics	8	2	4	20
Statistics	3	3	1	8
Actuarial Science	4	2	2	6
Physics	7	8	1	19
Chemistry	18	11	5	24
Forensic Science	7	15	4	10
Computer Science	90	87	24	146
Aerospace Engineering	73	76	13	70
Civil Engineering	33	23	6	21
Computer Engineering	50	34	6	35
Construction Engineering	1	4	0	1
Electrical Engineering	37	22	8	24
Environmental Engineering	25	10	3	16
Industrial Engineering	24	13	13	15
Materials Science & Engineering	0	0	0	1
Mechanical Engineering	133	109	34	127
Photonic Science and Engineering	4	9	2	6
Undecided Engineering/Science	75	2	9	35
Total	592	430	135	584

* Some students were members of more than one Learning Community

Table 4.17: Student Sample Percentages for Learning Communities Major

Major	Learning Communities*			
	COMPASS	EXCEL	LEADS Scholars	University Honors
Mathematics	1.4%	0.5%	3.0%	3.4%
Statistics	0.5%	0.7%	0.7%	1.4%
Actuarial Science	0.7%	0.5%	1.5%	1.0%
Physics	1.2%	1.9%	0.7%	3.3%
Chemistry	3.0%	2.6%	3.7%	4.1%
Forensic Science	1.2%	3.5%	3.0%	1.7%
Computer Science	15.2%	20.2%	17.8%	25.0%
Aerospace Engineering	12.3%	17.7%	9.6%	12.0%
Civil Engineering	5.6%	5.3%	4.4%	3.6%
Computer Engineering	8.4%	7.9%	4.4%	6.0%
Construction Engineering	0.2%	0.9%	0.0%	0.2%
Electrical Engineering	6.3%	5.1%	5.9%	4.1%
Environmental Engineering	4.2%	2.3%	2.2%	2.7%
Industrial Engineering	4.1%	3.0%	9.6%	2.6%
Materials Science & Engineering	0.0%	0.0%	0.0%	0.2%
Mechanical Engineering	22.5%	25.3%	25.2%	21.7%
Photonic Science and Engineering	0.7%	2.1%	1.5%	1.0%
Undecided Engineering/Science	12.7%	0.5%	6.7%	6.0%
Total	592	430	135	584

* Some students were members of more than one Learning Community

The ANOVA analysis was performed using R software for statistical analysis and student academic success was measured by the student grade in college Calculus 2 (R Core Team, 2020). Reported student grades for Calculus 2 provided by IKM were converted to a continuous 4.0 GPA scale for this analysis with A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, C- = 1.7, D+ = 1.3, D = 1.0, F = 0.0, and W = 0.0.

The Calculus 2 grade GPA (Calc2_4.0) variable was initially investigated using histograms, boxplots, and descriptive statistics. There were not remarkable characteristics seen in this portion of the investigation for student grades. It was noted that the group of students in Materials Science & Engineering and Construction Engineering were much smaller than those in other majors. There was evidence for lack of homogeneity of variances across groups as a result of an analysis using Levene's Test of Homogeneity of Variances, $F(17, 5805) = 3.370$, $p < .001$. However, for uneven group sizes, studies have concluded that when the variance ratio, defined as the ratio of the largest variance to the smallest variance of all the groups, is between 1.5 and 2.0 there is a very limited impact on the robustness of an ANOVA analysis (Blanca, et al., 2018). Since the variance ratio for these groups is 1.90 < 2.0, it is expected that the disparity in variances will have a limited impact on the robustness of the ANOVA analysis. Due to the large sample size, the Central Limit Theorem indicates that the normality assumption is not violated. Finally, since the students in this study are individuals with unique pre-entry skills, goals and commitments, and institutional experiences, the assumption of independence for an ANOVA analysis is met.

The Calculus 2 grade has a minimum GPA value of 0.0 for the grades of F and W and a maximum GPA value of 4.0 for a grade of A. The mean Calculus 2 grade was 2.114 for all Calculus 2 students and varied based on major from 1.634 for students in Construction

Engineering to 2.700 for students in Materials Science & Engineering (Table 4.18). It should be noted that the number of students in these groups is small. For the larger groups ($n > 30$), the mean Calculus 2 grade GPA varied from 1.684 for Forensic Science majors to 2.565 for Actuarial Science majors.

Table 4.18: Calculus 2 GPA Grade Breakdown by Math-Intensive STEM Major

	n	Calculus 2 GPA $\bar{x}$	Calculus 2 GPA s_x
All Math-Intensive STEM Majors	5823	2.114	1.438
Mathematics	109	2.286	1.525
Statistics	64	2.152	1.466
Actuarial Science	46	2.565	1.507
Physics	128	2.149	1.531
Chemistry	204	2.023	1.553
Forensic Science	166	1.684	1.561
Computer Science	1272	2.145	1.485
Aerospace Engineering	708	2.186	1.371
Civil Engineering	394	2.021	1.391
Computer Engineering	444	1.978	1.412
Construction Engineering	29	1.634	1.135
Electrical Engineering	339	2.112	1.428
Environmental Engineering	138	2.264	1.392
Industrial Engineering	239	2.055	1.379
Materials Science & Engineering	8	2.700	1.334
Mechanical Engineering	1232	2.111	1.425
Photonic Science & Engineering	69	2.201	1.409
Undecided Engineering/Science	234	2.326	1.336

Results of a one-way ANOVA (Table 4.19) reveal a statistically significant difference in mean college Calculus 2 grades (Calc2_4.0) between math-intensive STEM student majors (Major), $F(17, 5805) = 2.461$, $p < .001$, with a moderate effect size (ω=0.065) and a power of 88.67%. A Tukey HSD post hoc analysis revealed statistically significant differences in Calculus 2 mean grades between Forensic Science majors and students majoring in several engineering fields, Computer Science, Actuarial Science, and Undecided Engineering and Science (Table 4.20). The difference of mean Calculus 2 grades was statistically significant between students majoring in Forensic Science and Actuarial Science, $p < .05$, CI (0.046, 1.716), with a moderate effect size ($g = 0.57$), Computer Science, $p < .05$, CI (0.047, 0.874), with a small effect size, ($g = 0.31$) Aerospace Engineering, $p < .01$, CI (0.070, 0.934), with a small effect size ($g = 0.36$), Environmental Engineering, $p < .05$, CI (0.003, 1.157), with a small to moderate effect size ($g =0.39$), Mechanical Engineering, $p < .05$, CI (0.012, 0.841), with a small effect size ($g = 0.30$), and Undecided Engineering and Science, $p < .01$, CI (0.133, 1.150), with a moderate effect size ($g = 0.45$).

Table 4.19: 1-Way ANOVA Table: Calculus 2 Grade Across Math-Intensive STEM Major

Source of Variation	df	Sum of Squares	Mean Square	F-value	p-value
Calculus 1 Credit Experience	17	86.20	5.07	2.46	< .001
Error	5805	11961.16	2.06		
Total	5822	12047.36			

Table 4.20: Tukey HSD Significant Pairwise Comparisons Across Math-Intensive STEM Major

Comparing Between		p	CI	Hedge's g
Actuarial Science	**Forensics**	< .05	(0.046, 1.716)	0.57
Computer Science	**Forensics**	< .05	(0.047, 0.874)	0.31
Aerospace Engineering	**Forensics**	< .01	0.070, 0.934)	0.36
Environmental Engineering	**Forensics**	<.05	(0.003, 1.157)	0.39
Mechanical Engineering	**Forensics**	< .05	(0.012, 0.841)	0.30
Undecided Engineering/Science	**Forensics**	< .01	(0.133, 1.150)	0.45

4.5 Predictors of Calculus 2 Success

4.5.1 Students with AP Calculus Credit for Calculus 1

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

A. math-intensive STEM students who began college mathematics at UCF in Calculus 2 with AP Credit for Calculus 1?

A logistic regression analysis was performed to predict student success in Calculus 2, where success is defined as earning a grade of C or higher in Calculus 2 and no success is defined as earning a C- or lower in the course (Pass_Fail). A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive STEM majors which are included in this study. Potential predictors of success in this logistic regression analysis include the number of semesters since the student enrolled at UCF, categorized as 1st Semester, 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the semester standardized z-score (Z_Credit_Load), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major), and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 709.55 and 666.025, respectively, for all students with AP Credit for Calculus 1. In addition, due to the limited number of students of various ethnicities/races the categories for race were combined for this logistic regression analysis to include categories of Asian, African American/Black, Hispanic/Latino, Other, and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included in this analysis. However, due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters for this dataset (Table 4.21).

A total of 853 students who used AP Calculus credit for Calculus 1 have been included in this logistic regression analysis with 724 (84.9%) of these students being classified as successful and 129 (15.1%) being classified as not successful. The logistic regression analysis was performed using R software for statistical analysis (R Core Team, 2020).

Table 4.21: Summary of Credit Hour Load by Semester for Calculus 2 Students with AP Credit for Calculus 1

Semester	n	$\bar{x}$	s_x
Fall	743	13.572	1.474
Spring	88	13.420	2.010
Summer	22	7.045	1.963

A forward stepwise logistic regression analysis minimizing the AIC for the model was performed to determine which of the eleven predictors created the best fitting model. Results of the forward stepwise logistic regression resulted in a statistically reliable model, χ^2 (12) = 295.0, $p < .001$, with six predictors: the number of semesters at UCF, the student's standardized credit hours during the semester Calculus 2 was taken, the SAT Math score, participation in the COMPASS Learning Community, participation in the University Honors Learning Community, and the student's ethnicity/race. A moderate amount of the variance related to student success was accounted for in the model with McFadden's rho = 0.110, df = 12. The prediction of success using a 0.5 threshold was very good with 726 of the 853 outcomes (85.1%) predicted correctly and with a sensitivity of 0.989 and a specificity of 0.078. A modification of the threshold to 0.845 minimized the difference in sensitivity and specificity to 0.656 and 0.666, respectively, and resulted in 562 of the 853 outcomes (65.7%) being accurately classified (Figure 4.2).

Table 4.22 shows the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. Note for the categorical predictor measuring the number of semesters a student has been at UCF when taking Calculus 2, the semester categories are compared to students who take Calculus 2 during their

1^{st} semester. The comparison group for the categorical predictor of ethnicity/race is White since the largest percentage of the students were identified as this ethnicity/race.

According to the Wald criterion, the predictors of students taking Calculus 2 in the 2^{nd} year versus 1^{st} semester at UCF, $z = 2.976$, $p < .01$, students taking Calculus 2 in their 3^{rd} + year versus 1^{st} semester at UCF, $z = 3.130$, $p < .01$, participation in the COMPASS Learning Community, $z = 2.057$, $p < .05$, participation in the University Honors Learning Community, $z = 2.022$, $p < .01$, and the ethnicity/race of Other compared to White, $z = 2.636$, $p < .01$, are statistically significant predictors of student success in college Calculus 2 for students with AP Calculus credit. The odds ratios for additional time since starting at UCF indicate a substantial decrease in the likelihood of student success with the odds ratio for taking Calculus 2 in the 2^{nd} Year compared to the 1^{st} Semester of 0.317, CI (0.148, 0.678) and for taking the course in the 3^{rd}+ year compared to the 1^{st} Semester of 0.167, CI (0.053, 0.510). Having an ethnicity/race of Other versus White also leads to a significant decrease in the likelihood of success in Calculus 2 with an odds ratio of 0.425, CI (0.227, 0.815). The learning communities of COMPASS and University Honors lead to an increased likelihood of success in Calculus 2 with odds ratios of 2.684, CI (1.150, 7.849) and 2.613, CI (1.414, 5.176), respectively. The examination of casewise effects are not concerning; although there were some residuals and standard residuals for individual cases less than - 2 in the model, all residuals and standard residuals are within +/- 3. There is also no concern related to multicollinearity with Variance Inflation Factor (VIF) values ranging from 1.010 (Race) to 1.063 (SATMATH_IMP). An examination of the interaction of the continuous predictor variables and the log of the predictors indicates that the assumption of linearity has also been met for this logistic regression analysis (Hosmer & Lemeshow, 1989).

Finally, the assumption of independence is met since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.22: Logistic Regression Analysis of Calculus 2 Students with AP Credit for Calculus 1

Predictor	β	SE β	Wald's χ^2	p-value	Odds Ratio	95% CI Lower	95% CI Upper
1st Year to 1st Semester	0.183	0.258	0.710	0.478	1.201	0.715	1.968
2nd Year to 1st Semester	-1.150	0.386	2.976	< .01	0.317	0.148	0.678
3rd + Year to 1st Semester	-1.790	0.572	3.130	< .01	0.167	0.053	0.510
Standardized Credit Load	0.164	0.099	1.662	0.097	1.179	0.973	1.434
SAT Math	0.004	0.002	1.867	0.062	1.004	1.000	1.009
COMPASS LC	0.987	0.480	2.057	< .05	2.684	1.150	7.849
University Honors LC	0.960	0.329	2.922	< .01	2.613	1.414	5.176
Asian*	0.662	0.379	1.749	0.080	1.940	0.961	4.296
Black/African American*	-0.111	0.518	0.215	0.830	0.895	0.342	2.681
Hispanic*	0.090	0.245	0.369	0.712	1.094	0.681	1.781
Other*	-0.856	0.325	2.636	< .01	0.425	0.227	0.815

* Comparison group for ethnicities/races is White

A receiver operating characteristics (ROC) graph, a valuable method of visualizing the classification performance of a logistic regression model, is included in Figure 4.3. The ROC analysis found the area under the curve (AUC) to be 0.723, indicating a fair accuracy classification using this model (Tape, 2019).

Figure 4.2: Sensitivity/Specificity Cutoff Curve – Students with AP Credit for Calculus 1

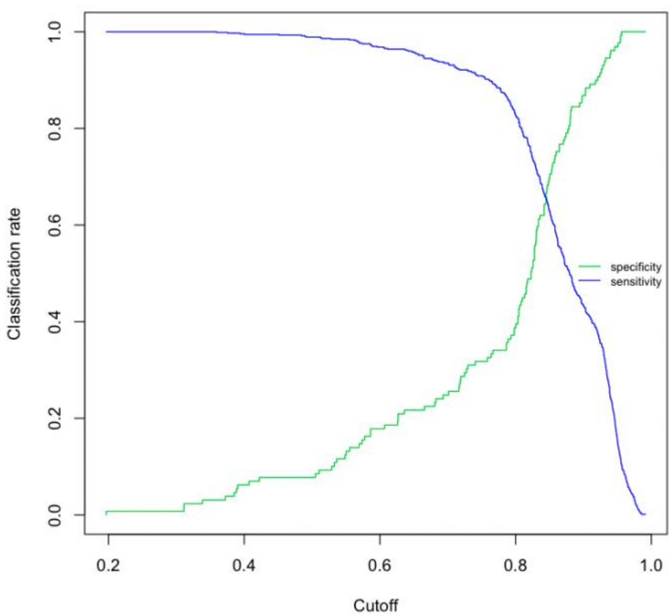
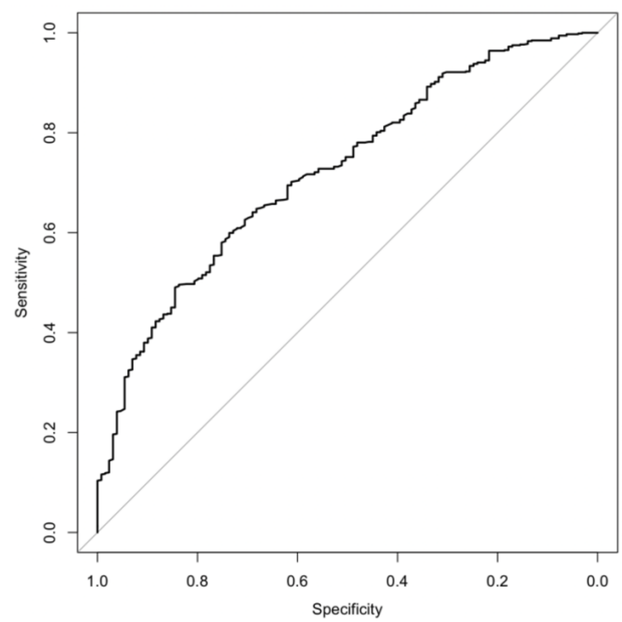


Figure 4.3: ROC Curve – Students with AP Credit for Calculus 1



4.5.2 Students with AP Calculus AB Credit for Calculus 1

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

B. math-intensive STEM students who began college mathematics at UCF in Calculus 2 having a recorded AP Calculus AB exam score and using with AP Credit for Calculus 1?

A logistic regression analysis was performed to predict student success in Calculus 2 where success is defined as earning a grade of C or higher in the Calculus 2 course and no success is defined as earning a C- or lower in the course (Pass_Fail). A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive majors included in this study. Potential predictors of success in this logistic regression analysis include the number of semesters since the student enrolled at UCF, categorized as 1st Semester, 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the semester standardized z-score (Z_Credit_Load), the student's AP Calculus AB score (APCAB_SCORE), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major), and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 694.844 and 658.516, respectively, for all students with an AP Calculus AB exam score and Calculus 1 credit for AP Calculus. The AP Calculus AB exam score was coded as a categorical variable for this analysis since the AP exam scores are ordinal values. In addition, due to the limited number of students of various ethnicities/races the categories for race were combined for this logistic regression analysis to include Asian, African American/Black, Hispanic/Latino, Other, and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included in this analysis. However, due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters for this dataset (Table 4.23).

A total of 143 students who used AP Calculus credit for Calculus 1 and had an AP Calculus AB score recorded in the dataset were included in this analysis with 112 (78.3%) of these students being classified as successful in Calculus 2 and 31 (21.7%) being classified as not successful in Calculus 2. The logistic regression analysis was performed using R software for statistical analysis(R Core Team, 2020).

Table 4.23: Summary of Credit Hour Load by Semester for Calculus 2 Students with AP Calculus AB Credit for Calculus 1

Semester	n	$\overline{x}$	s_x
Fall	113	13.487	1.548
Spring	27	12.556	2.082
Summer	3	5.000	1.732

A forward stepwise logistic regression analysis minimizing the model AIC was performed to determine which of the twelve predictors created the best fitting model. After a review of the data, the ethnicity/race predictor was removed from the stepwise analysis since all of the students identified as African American/Black passed the course. Results of the stepwise forward analysis of the remaining eleven predictors resulted in a statistically reliable model, χ^2 (4) = 41.1, $p < .001$, with two predictors: the student's standardized credit hours during the semester enrolled in Calculus 2 and the categorical variable for the AP Calculus AB exam score. A moderate amount of the variance related to student success was accounted for in this model with McFadden's rho = 0.121, df = 4. The prediction of success using a 0.5 threshold was fair with 111 of the 143 outcomes (77.6%) predicted correctly and with a sensitivity of 0.964 and a specificity of 0.097. A modification of the threshold to 0.75 minimized the difference between sensitivity and specificity to 0.688 and 0.677, respectively, and resulted in 98 of the 143 outcomes (68.5%) being accurately classified (Figure 4.4).

Table 4.24 shows the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. Note that the categorical predictor measuring the AP Calculus AB exam score uses a comparison score of 3.

According to the Wald criterion, an AP Calculus AB exam score of 5 versus a score of 3, z = 3.736, p < .001, is the only statistically significant predictor of student success in Calculus 2 for students with an AP Calculus AB exam score using AP credit for Calculus 1. Results indicate that an AP Calculus AB exam score of 5 compared to an AP exam score of 3 increases the likelihood of success in Calculus 2 with an odds ratio of 7.707, CI (2.697, 23.453). The examination of casewise effects are not concerning; although there are some residuals and standard residuals for individual cases less than - 2 in the model, all residuals and standard residuals are within +/- 3. There is not a concern related to multicollinearity related to this logistic regression analysis with Variance Inflation Factor (VIF) values ranging from 1.006 (APCAB_SCORE) to 1.012 (Z_Credit_Load). Finally, the assumption of independence is met since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.24: Logistic Regression Analysis of Calculus 2 Students with AP Calculus AB Credit for Calculus 1

Predictor	β	**SE** β	**Wald's** χ^2	**p-value**	**Odds Ratio**	**95% CI Lower**	**95% CI Upper**
Standardized Credit Load	0.291	0.208	1.398	0.162	1.337	0.899	2.053
AB Exam = 4 to AB Exam = 3	0.697	0.544	1.282	0.200	2.007	0.697	5.965
AB Exam = 5 to AB Exam = 3	2.042	0.547	3.736	< .001	7.707	2.697	23.453

The receiver operating characteristics (ROC) graph, often useful for visualizing the classification performance of logistic regression models, is included in Figure 4.5. The ROC analysis found the area under the curve (AUC) to be 0.7476, which indicates a fair accuracy classification for this model (Tape, 2019).

Figure 4.4: Sensitivity/Specificity Cutoff Curve – Students with AP Calculus AB Credit for Calculus 1

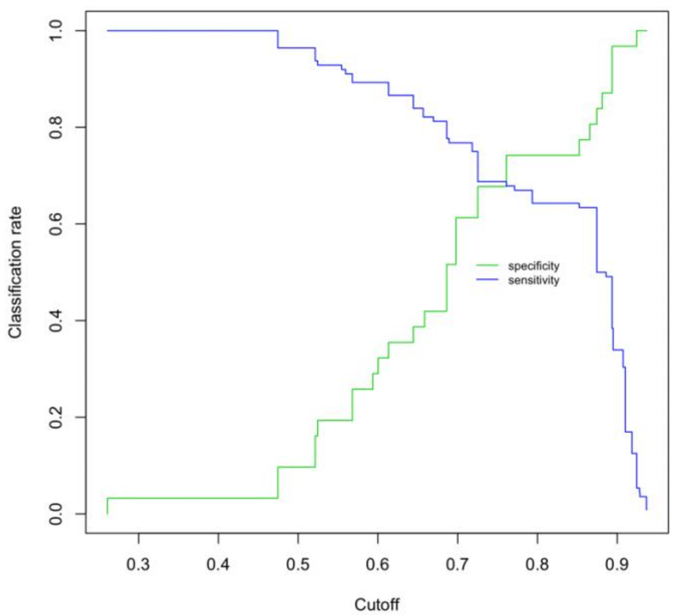
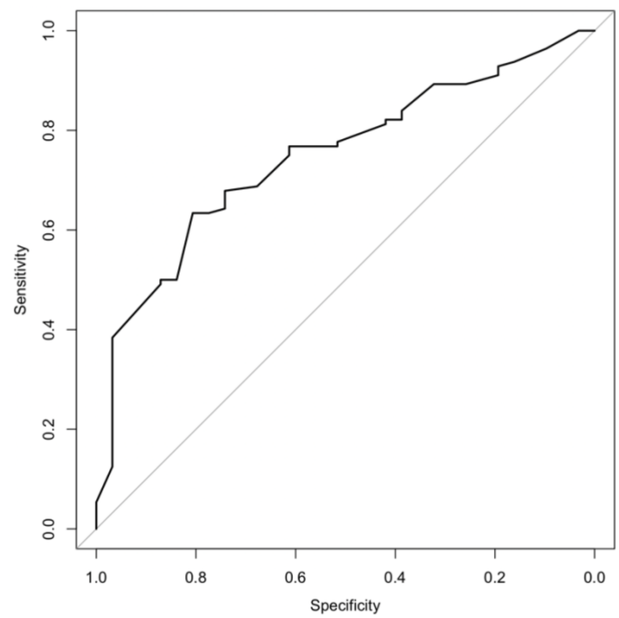


Figure 4.5: ROC Curve - Students with AP Calculus AB Credit for Calculus 1



4.5.3 Students with Credit for Calculus 1 from Another Post-Secondary Institution

<u>Research Question 4</u>: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

C. math-intensive STEM students who began college mathematics at UCF in Calculus 2 after completing Calculus 1 at another post-secondary institution?

A logistic regression analysis was performed to predict student success in college Calculus 2 with success being defined as earning a grade of C or higher in Calculus 2 and no success being defined as earning a C- or lower in the course (Pass_Fail). A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive majors included in this study. Prospective predictors of Calculus 2 success include the number of semesters since the student enrolled at UCF categorized as 1st Semester, 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2 (Semesters_Calc1_Calc2), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the semester standardized z-score (Z_Credit_Load), the student's grade in Calculus 1 (Calc1_Grade), whether the student took Calculus 1 before or after enrolling at UCF (Calc1_Before_After), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major) and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 612.066 and 602.799, respectively, for all students with Calculus 1 credit from another institution. Due to variation from institution to institution and lack of linearity for the Calculus 1 grade predictor, the Calculus 1 grade was treated as a categorical variable for this analysis with grades of A, B, and C. All ethnicity/race categories were included in this analysis including Asian, African American/Black, Hispanic/Latino, International, Multi-racial, Other and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included in this analysis. However, due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters from this dataset (Table 4.25).

A total of 1018 students who earned credit for Calculus 1 from another post-secondary institution and obtained a passing grade of C or higher as recorded in the dataset were included in this analysis with 460 (45.2%) of these students being classified as successful in Calculus 2 and 558 (54.8%) being classified as not successful in Calculus 2. This logistic regression analysis was performed using R software for statistical analysis (R Core Team, 2020).

Table 4.25: Summary of Credit Hour Load by Semester for Calculus 2 Students with Calculus 1 Credit from Another Institution

Semester	n	$\bar{x}$	s_x
Fall	723	12.057	2.719
Spring	177	11.480	3.043
Summer	118	7.169	2.615

A forward stepwise logistic regression analysis minimizing the model's AIC was performed to determine which of the fourteen predictors created the best fitting model. The results of the forward stepwise logistic regression resulted in a statistically reliable model, χ^2 (7) = 144.0, $p < .001$, with five predictors: the number of semesters between Calculus 1 and Calculus 2, the student grade in Calculus 1, the student's standardized enrollment credit hours during the semester of Calculus 2, the student's SAT Verbal score, and participation in the COMPASS

Learning Community. A moderate level of variance related to student success in Calculus 2 was accounted for in this model with McFadden's rho = 0.111, df = 7. The prediction of success using the 0.5 threshold was poor with 692 of the 1018 outcomes (68.0%) predicted correctly and with a sensitivity of 0.537 and a specificity of 0.797. A modification of the threshold to 0.40 minimized the difference in sensitivity and specificity to 0.654 and 0.659, respectively, and resulted in 669 of the 1018 outcomes (65.7%) being accurately classified (Figure 4.6).

Table 4.26 summarizes the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. Note that the categorical predictor measuring Calculus 1 grade compares a student grade of C in Calculus 1 at another post-secondary institution to student grades of A and B in Calculus 1.

According to the Wald criterion, the predictors of time between the completion of the Calculus 1 course and enrollment in the Calculus 2 course, $z = 2.245$, $p < .05$, a Calculus 1 grade of A compared to a C, $z = 10.266$, $p < .001$, a Calculus 1 grade of B compared to a C, $z = 3.458$, $p < .001$, and the student's standardized credit hours during the semester the student took Calculus 2, $z = 2.190$, $p < .05$, are statistically significant predictors of student success in Calculus 2 for students with Calculus 1 credit from another institution. The odds ratios for the time between the completion of Calculus 1 and enrollment in Calculus 2 indicate a very slight increase in the likelihood of success in Calculus 2 with the odds ratio of 1.038, CI (1.006, 1.074). Earning a Calculus 1 grade of A versus a C leads to a large increase in the likelihood of student success in the Calculus 2 course with an odds ratio of 6.399, CI (4.508, 9.162). A Calculus 1 grade of a B versus a C also leads to an increase in the likelihood of student success in Calculus 2 with an odds ratio of 1.793, CI (1.290, 2.502). Finally, the student's standardized number of credit hours during the Calculus 2 term increases the likelihood of success in Calculus 2 with an odds ratio of 1.173, CI (1.018, 1.354). The examination of casewise effects are unremarkable with no cases showing evidence of strong impact on the model. There is also no concern with multicollinearity with Variance Inflation Factors (VIF) ranging from 1.012 (COMPASS) to 1.035 (Z_Credit_Load). An examination of the interaction of the continuous predictor variables and the log of the predictors indicates that the assumption of linearity is met for this analysis (Hosmer & Lemeshow, 1989). Finally, the assumption of independence is met since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.26: Logistic Regression Analysis of Calculus 2 Students with Credit for Calculus 1 from Another Institution

Predictor	β	SE β	Wald's χ^2	p-value	Odds Ratio	95% CI Lower	95% CI Upper
Semesters between Calculus 1 and Calculus 2	0.037	0.017	2.245	< .05	1.038	1.006	1.074
Calc 1 Grade A to C	1.856	0.181	10.266	< .001	6.399	4.508	9.162
Calc 1 Grade A to B	0.584	0.169	3.458	< .001	1.793	1.290	2.502
Standardized Credit Load	0.159	0.073	2.190	< .05	1.173	1.018	1.354
SAT Verbal	0.002	0.001	1.535	0.125	1.002	0.999	1.004
COMPASS LC	0.509	0.310	1.641	0.101	1.664	0.911	3.091

A receiver operating characteristics (ROC) graph, a valuable tool to visualize the classification performance of a logistic regression model, is included in Figure 4.7. The ROC analysis found the area under the curve (AUC) to be 0.7152, indicating a fair accuracy classification for this model (Tape, 2019).

Figure 4.6: Sensitivity/Specificity Cutoff Curve – Students with Calculus 1 Credit from Another Institution

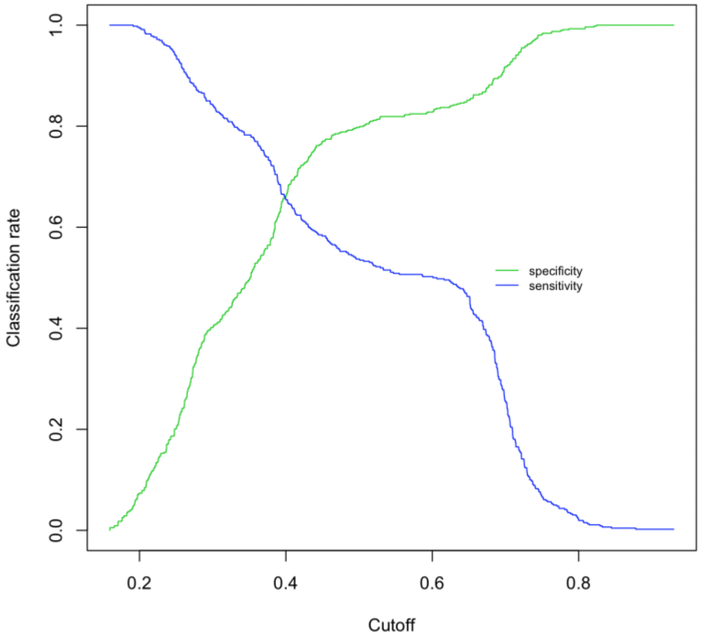
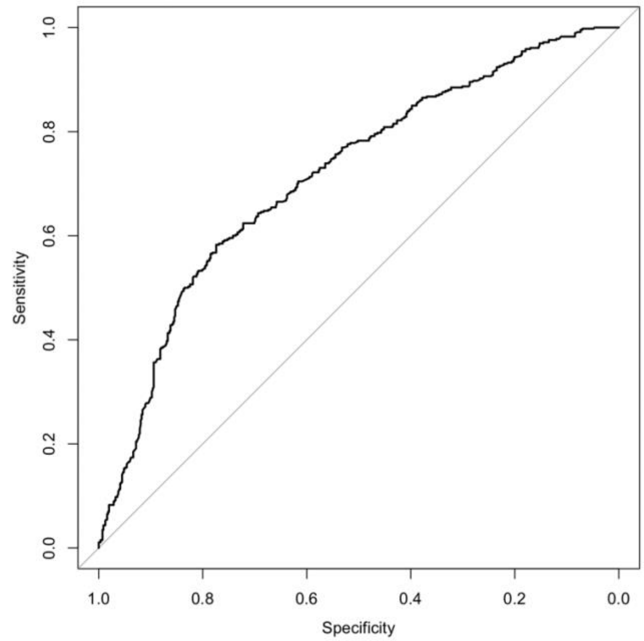


Figure 4.7: ROC Curve - Students with Calculus 1 Credit from Another Institution



4.5.4 Students with Credit for Calculus 1 from UCF Forgoing AP Calculus AB Credit

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

D. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus AB with an AP exam score of 3 or higher?

A logistic regression analysis was performed to predict student success in Calculus 2 where success is defined as earning a grade of C or higher in the Calculus 2 course and no success is defined as earning a C- or lower in the course. A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive majors included in this study. Potential predictors of success in this logistic regression analysis included the number of semesters since a student enrolled at UCF categorized as 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2 (Semesters_Calc1_Calc2), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the standardized semester z-score (Z_Credit_Load), the student's grade in Calculus 1 on a 4.0 scale (Calc1_4.0), the student's AP Calculus AB Score (APCAB_SCORE), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major) and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 666.157 and 645.740, respectively, for all students with credit from Calculus 1 at UCF after forgoing credit for AP Calculus AB. In addition, due to the limited number of students of various ethnicities/races, the categories for race were combined for this logistic regression analysis to include Asian, African American/Black, Hispanic/Latino, Other, and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included in this analysis. However, due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters from this dataset (Table 4.27).

A total of 240 students who earned credit for Calculus 1 at UCF after forgoing credit for AP Calculus AB with a AP exam score of 3 or higher have been included in this analysis with 168 (70.0%) of the students being classified as successful in Calculus 2 and 72 (30.0%) being classified as not successful in Calculus 2. The logistic regression analysis was performed using R software for statistical analysis (R Core Team, 2020).

Table 4.27: Summary of Credit Hour Load by Semester for Calculus 2 Students with Calculus 1 Credit from UCF forgoing credit for AP Calculus AB

Semester	n	$\bar{x}$	s_x
Fall	56	12.964	2.045
Spring	156	13.885	1.490
Summer	28	7.464	2.457

A forward stepwise logistic regression analysis minimizing the model's AIC was performed to determine which of the fourteen predictors created the best fitting model to predict Calculus 2 success. Results of the forward stepwise logistic regression resulted in a statistically reliable model, χ^2 (7) = 59.4, p < .001, with five predictors: the number of semesters since the student entered UCF, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, the student's grade in Calculus 1 on a 4.0 scale, the student's SAT Verbal score, and the student's participation in the EXCEL Learning Community. A moderate to high amount of the variance related to Calculus 2 success was accounted for in this model with McFadden's rho = 0.187, df = 7 The prediction of success using the 0.5 threshold was fair with 182 of the 240 outcomes (77.9%) predicted correctly and with a sensitivity of 0.899 and a specificity of 0.431. A modification of the threshold to 0.7 minimized the difference in sensitivity and specificity to

0.714 and 0.694, respectively, and resulted in 170 of the 240 outcomes (70.8%) being accurately classified (Figure 4.8).

Table 4.28 shows the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. Note that for the categorical predictors measuring the number of semesters a student has been at UCF when enrolling in Calculus 2, the other semester categories are compared to students who take Calculus 2 during their 1st Year, which is defined as their 2nd or 3rd semester, at UCF.

According to the Wald criterion, the predictors of completing Calculus 2 in the 2nd year versus the 1st Year, $z = 3.628$, $p < .001$, the student's Calculus 1 grade on a 4.0 scale, $z = 4.872$, $p < .001$, and participation in the EXCEL Learning Community, $z = 2.044$, $p < .05$, are statistically significant predictors of student success in college Calculus 2 for students forgoing AP Calculus AB credit for Calculus 1. The odds ratios for taking Calculus 2 in the 2nd year versus the 1st year indicate a substantial decrease in the likelihood of success in Calculus 2 with an odds ratio of 0.186, CI (0.073, 0.452). Earning a higher Calculus 1 grade leads to a large increase in the likelihood of student success in Calculus 2 with an odds ratio of 2.784, CI (1.878, 4.296). Finally, participation in the EXCEL Learning Community predicts a large increase in the likelihood of success in Calculus 2 with an odds ratio of 3.170, CI (1.134, 10.762). An examination of casewise effects is not concerning; although there are some residuals and standard residuals for individual cases less than - 2 in the model, all residuals and standard residuals are within +/- 3. There are also no concerns related to multicollinearity with Variance Inflation Factor (VIF) values ranging from 1.012 (SATVERB_IMP) to 1.344 (Semesters_Calc1_Calc2). An examination of the interaction of the continuous predictor variables and the log of the predictors indicates the assumption of linearity for the logistic regression has been met (Hosmer & Lemeshow, 1989). Finally, the assumption of independence is met for this analysis since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.28: Logistic Regression Analysis of Calculus 2 Students with Calculus 1 Credit from UCF forgoing AP Calculus AB Credit (Exam Score 3 or Higher)

Predictor	β	SE β	Wald's χ^2	p-value	Odds Ratio	95% CI Lower	95% CI Upper
2nd Year to 1st Year	-1.680	0.463	3.628	< .001	0.186	0.073	0.452
3rd + Year to 1st Year	-0.897	0.826	1.086	0.278	0.408	0.082	2.327
Semesters between Calculus 1 and Calculus 2	0.352	0.245	1.435	0.151	1.421	0.895	2.377
Calculus 1 Grade	1.024	0.211	4.872	< .001	2.784	1.878	4.296
SAT Verbal	-0.006	0.003	1.691	0.091	0.994	0.987	1.001
EXCEL LC	1.373	0.564	2.044	< .05	3.170	1.134	10.762

A receiver operating characteristics (ROC) graph, which is beneficial to visualize the classification performance for logistic regression models, is included in Figure 4.9. The ROC analysis found the area under the curve (AUC) to be 0.787, indicating a good accuracy classification for this model (Tape, 2019).

Figure 4.8: Sensitivity/Specificity Cutoff Curve – Students with Calculus 1 Credit from UCF forgoing AP Calculus AB Credit

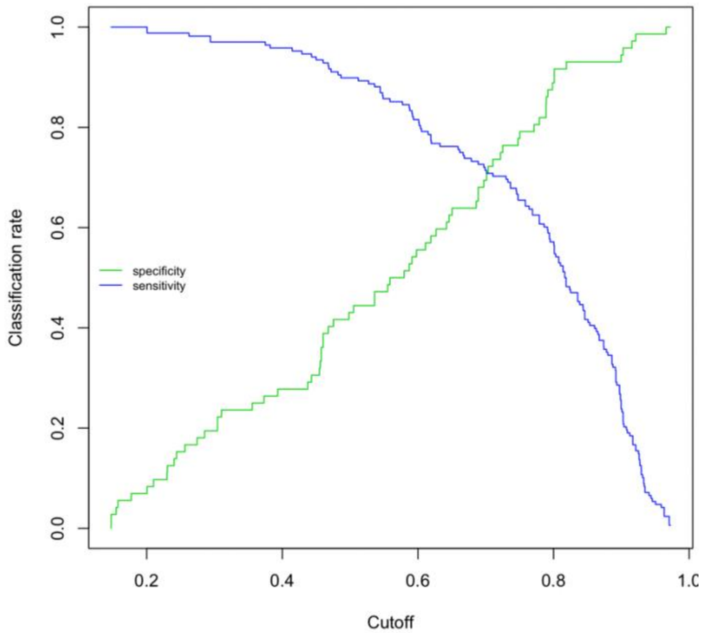
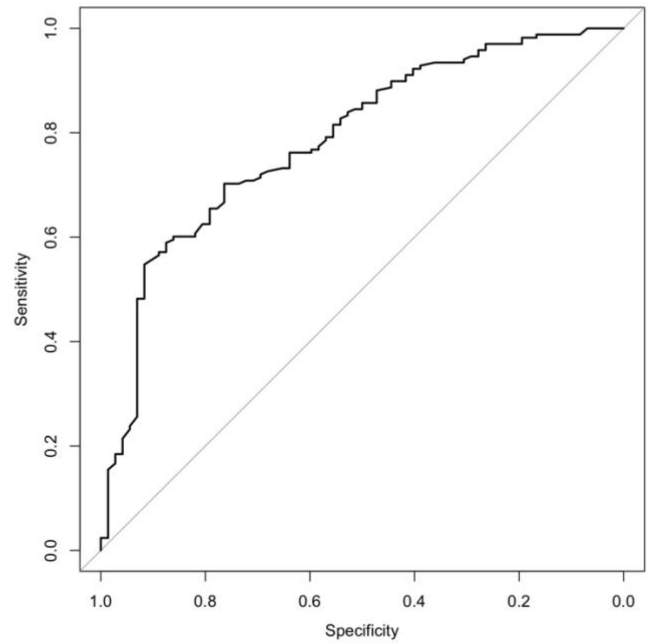


Figure 4.9: ROC Curve - Students with Calculus 1 Credit from UCF forgoing AP Calculus AB Credit



4.5.5 Students with Credit for Calculus 1 from UCF Forgoing AP Calculus BC Credit

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

E. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus BC with an AP exam score of 3 or higher?

A logistic regression analysis was performed to predict student success in Calculus 2 where success is defined as earning a grade of C or higher in the Calculus 2 course and no success is defined as earning a C- or lower in the course. A grade of C or higher was chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive majors included in this study. Potential predictors of success in this logistic regression analysis included the number of semesters since a student enrolled at UCF categorized as 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of semesters between completing Calculus 1 and enrolling in Calculus 2 (Semesters_Calc1_Calc2), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the standardized semester z-score (Z_Credit_Load), the student's grade in Calculus 1 on a 4.0 scale (Calc1_4.0), the student's AP Calculus BC exam score (APCBC_SCORE), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major) and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 679.605 and 656.184, respectively, for all students with credit from Calculus 1 at UCF after forgoing credit for AP Calculus BC. In addition, due to the limited number of students of various ethnicities/races, the categories were combined into the categories of Asian, African American/Black, Hispanic/Latino, Other, and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included in this analysis. However, due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters from this dataset (Table 4.29).

A total of 81 students who earned credit for Calculus 1 from UCF after forgoing Calculus 1 credit for AP Calculus BC with a AP exam score of 3 or higher were included in this analysis with 63 (77.8%) of these students being classified as successful in Calculus 2 and 18 (22.2%) being classified as not successful in Calculus 2. The logistic regression analysis was performed using R software for statistical analysis (R Core Team, 2020).

Table 4.29: Summary of Credit Hour Load by Semester for Calculus 2 Students with Calculus 1 Credit from UCF Forgoing Credit for AP Calculus BC

Semester	n	$\bar{x}$	s_x
Fall	12	13.667	2.146
Spring	58	14.121	1.523
Summer	11	8.000	2.720

A forward stepwise logistic regression analysis minimizing the AIC of the model was performed to determine which of the fourteen predictors created the best fitting model. The predictors had to be reduced twice due to impacts of predictors and/or cases on the results. The predictor of ethnicity/race was removed from the analysis since all students identified as Asian successfully completed the Calculus 2 course with a C or higher. Similarly, the AP Calculus BC exam score was removed as a predictor since there was only one student earning a 5 on the exam. The predictors for three of the learning communities including LEAD Scholars, EXCEL, and University Honors Learning Communities were also removed since all students in these learning communities successfully completed Calculus 2 with a C or higher. The learning community of COMPASS remained as a predictor since 1 of the 11 students participating in COMPASS was not successful in Calculus 2 for this group. Finally, after a casewise examination of predictors, the predictor of semesters at UCF before taking Calculus 2 was removed because the three students who took the course in the 3^{rd} + year heavily influenced the results. Therefore, the forward stepwise logistic regression for the group of students with credit for Calculus 1 from UCF after forgoing credit for AP Calculus BC was made with the eight remaining potential predictors. Results of the forward stepwise logistic regression resulted in a statistically reliable model, χ^2 (3) = 22.1, p < .001, with two predictors: the student's SAT Math score and the student's SAT Verbal score. The variance accounted for in this model is weak with McFadden's rho = 0.079, df = 3. The prediction of success using the 0.5 threshold was fair with 64 of the 81 outcomes (79.0%) predicted correctly and with a sensitivity of 1.000 and a specificity of 0.056. A modification of the threshold to 0.79 minimized the difference in sensitivity and specificity to 0.619 and 0.611, respectively, and resulted in 50 of the 81 outcomes (61.7%) being accurately classified (Figure 4.10).

Table 4.30 shows the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. According to the Wald criterion, the predictor of Math SAT score, z = 2.253, p < .05, is the only statistically significant predictor of student success in Calculus 2 for students with credit from Calculus 1 at UCF after forging credit for AP Calculus BC. Recall, however, that a number of predictors were removed from the forward regression due to limitations in outcomes and impacts from individual cases. The odds ratios for SAT Math score indicate a slight increase in the likelihood of success in Calculus 2 with an odds ratio of 1.015, CI (1.003,1.029). The examination of casewise effects is unremarkable; although there are residuals and standard residuals for individual cases less than - 2 in the model, all residuals and standard residuals are within +/- 3. There is not a concern with multicollinearity in this model with both Variance Inflation Factors (VIF) being 1.201

(SATMATH_IMP and SATVERB_IMP). An examination of the interaction of the continuous predictor variables and the log of the predictors indicates the assumption of linearity is met for this logistic regression analysis (Hosmer & Lemeshow, 1989). Finally, the assumption of independence is met since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.30: Logistic Regression Analysis of Calculus 2 Students with Calculus 1 Credit from UCF Forgoing AP Calculus BC Credit

Predictor	β	SE β	Wald's χ^2	p-value	Odds Ratio	95% CI Lower	95% CI Upper
SAT Math	0.015	0.007	2.253	$< .05$	1.015	1.003	1.029
SAT Verbal	-0.011	0.007	1.649	0.099	0.989	0.974	1.002

The receiver operating characteristics (ROC) graph, often useful in visualizing the classification performance for logistic regression models, is included in Figure 4.11. The ROC analysis found the area under the curve (AUC) to be 0.685, indicating a poor accuracy classification for this model (Tape, 2019).

Figure 4.10: Sensitivity/Specificity Cutoff Curve – Students with Calculus 1 Credit from UCF Forgoing AP Calculus BC Credit

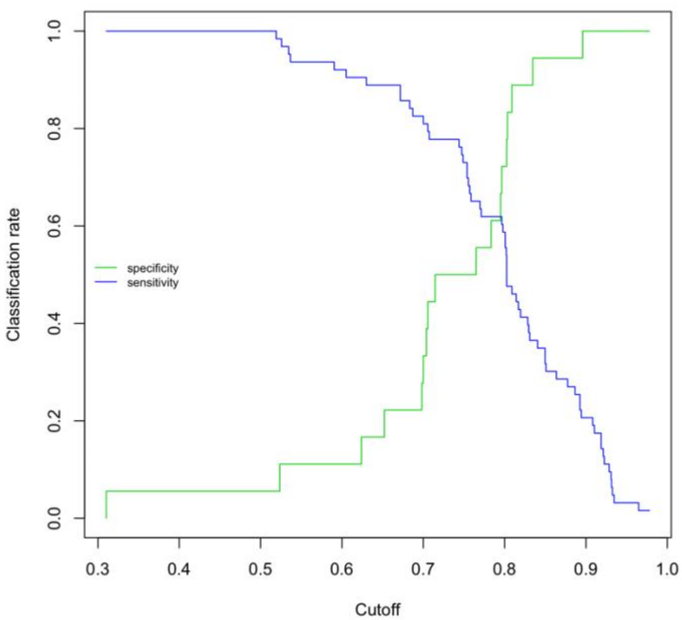
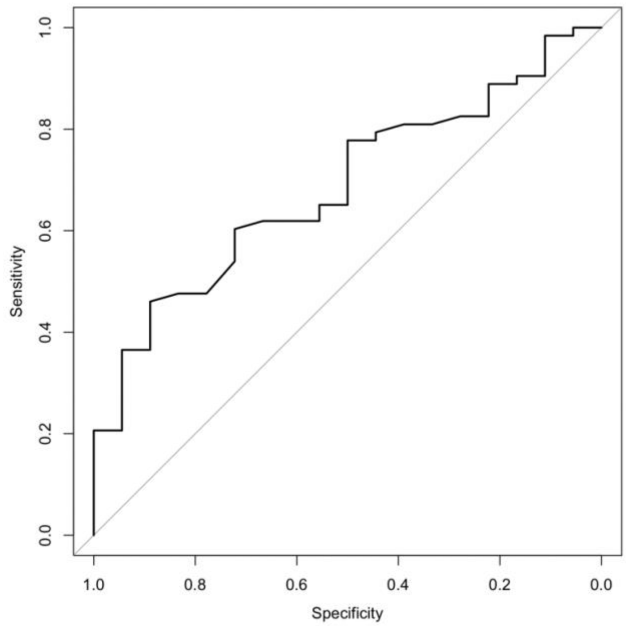


Figure 4.11: ROC Curve – Students with Calculus 1 Credit from UCF Forgoing AP Calculus BC Credit



4.5.6 Students with Calculus 1 Credit from UCF After Scoring 1 or 2 on the AP Calculus Exam

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

F. math-intensive STEM students who began their college mathematics education at UCF in Calculus 1 who scored a 1 or 2 on the AP Calculus exam after completing AP Calculus AB or BC in high school?

A logistic regression analysis was performed to predict student success in Calculus 2 where success is defined as earning a grade of C or higher in the Calculus 2 course and no success is defined as earning a C- or lower in the course. A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive majors included in this study. Potential predictors of success in this logistic regression analysis included the number of semesters since a student enrolled at UCF categorized as 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of semesters between completing Calculus 1 and enrolling in Calculus 2 (Semesters_Calc1_Calc2), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the standardized semester z-score (Z_Credit_Load), the student's grade in Calculus 1 on a 4.0 scale (Calc1_4.0), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major) and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 639.097 and 628.903, respectively, for all students with credit for Calculus 1 at UCF after earning a score of 1 or 2 on the AP Calculus AB or BC exam. In addition, due to the limited number of students of various ethnicities/races, the categories for race were combined to include those of Asian, African American/Black, Hispanic/Latino, Other, and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included in this analysis. Due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters from this dataset (Table 4.31).

A total of 184 students who earned credit for Calculus 1 from UCF after completing AP Calculus AB or BC with a AP exam score of 1 or 2 were included in this analysis with 115 (62.5%) of these students being classified as successful in Calculus 2 and 69 (37.5%) being classified as not successful in Calculus 2. The logistic regression analysis was performed using R software for statistical analysis (R Core Team, 2020).

Table 4.31: Summary of Credit Hour Load by Semester for Calculus 2 Students with Calculus 1 Credit from UCF Earning a 1 or 2 on the AP Calculus AB/BC Exam

Semester	n	$\bar{x}$	s_x
Fall	83	12.940	2.008
Spring	60	13.467	1.909
Summer	41	8.000	1.746

A forward stepwise logistic regression analysis minimizing the model's AIC was performed to determine which of the thirteen predictors created the best fitting model. Results of the forward stepwise logistic regression resulted in a statistically reliable model, χ^2 (6) = 36.2, $p < .001$, with four predictors: the number of semesters since the student entered UCF before taking Calculus 2, the Calculus 1 grade on a 4.0 scale, the student's SAT Math score, and participation in the COMPASS Learning Community. A moderate amount of the variance related to student success was accounted for in this model with McFadden's rho = 0.149, df = 6. The prediction of success using the 0.5 threshold was fair with 127 of the 184 outcomes (69.0%) predicted correctly and with a sensitivity of 0.835 and a specificity of 0.449. A modification of the threshold to 0.64 minimized the difference in sensitivity and specificity to 0.730 and 0.710, respectively, resulting in accurately classifying 133 of the 184 outcomes (72.3%) (Figure 4.12).

Table 4.32 shows the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. According to the Wald criterion, students taking Calculus 2 in the 3^{rd} + year compared to the 1^{st} year, $z = 3.988$, $p < .001$, the student's Calculus 1 grade on a 4.0 scale, $z = 3.058$, $p < .01$, the student's SAT Math score, $z = 2.099$, $p < .05$, and student participation in the COMPASS Learning Community, $z = 2.206$, $p < .05$, are statistically significant predictors of student success in Calculus 2 for students who took AP Calculus AB or BC and scored a 1 or 2 on the AP exam. Results indicate that taking Calculus 2 in the 3^{rd} + year versus the 1^{st} year leads to a decrease in the likelihood of success in Calculus 2 with an odds ratio of 0.136, CI (0.049, 3.526). In addition, an increase in the student's SAT Math score and participation in the COMPASS Learning Community both decrease the likelihood of student success in Calculus 2 with odds ratios of 0.991, CI (0.983, 0.999) and 0.282, CI (0.086, 0.849), respectively. Finally, a higher grade in Calculus 1 leads to an increased likelihood of success in Calculus 2 with an odds ratio of 2.034, CI (1.307, 3.262). An examination of casewise effects yields unremarkable results with no indication that individual students cause excessive influence in this logistic regression model. There is not a concern with multicollinearity with Variance Inflation Factors (VIF) having values ranging from 1.011 (COMPASS) to 1.092 (SATMATH_IMP). An examination of the interaction of the continuous predictor variables and the log of the predictors indicates that the assumption of linearity is met for this analysis (Hosmer & Lemeshow, 1989). Finally, the assumption of independence is met since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.32: Logistic Regression Analysis of Calculus 2 Students with Calculus 1 Credit from UCF after a 1 or 2 AP Calculus Exam Score

Predictor	β	SE β	Wald's χ^2	p-value	Odds Ratio	95% CI Lower	95% CI Upper
2nd Year to 1st Year	-0.419	0.413	1.015	0.310	0.658	0.287	1.462
3rd + Year to 1st Year	-1.995	0.500	3.988	< .001	0.136	0.049	3.526
Calculus 1 Grade	0.710	0.232	3.058	< .01	2.034	1.307	3.262
SAT Math	-0.009	0.004	2.099	< .05	0.991	0.983	0.999
COMPASS LC	-1.267	0.574	2.206	< .05	0.282	0.086	0.849

A receiver operating characteristics (ROC) graph, valuable in visualizing the classification performance for logistic regression models, is included in Figure 4.13. The ROC analysis found the area under the curve (AUC) to be 0.772 which indicates a fair accuracy classification for this model (Tape, 2019).

Figure 4.12: Sensitivity/Specificity Cutoff Curve – Students with Calculus 1 Credit from UCF with AP Calculus Exam Scores of 1 or 2

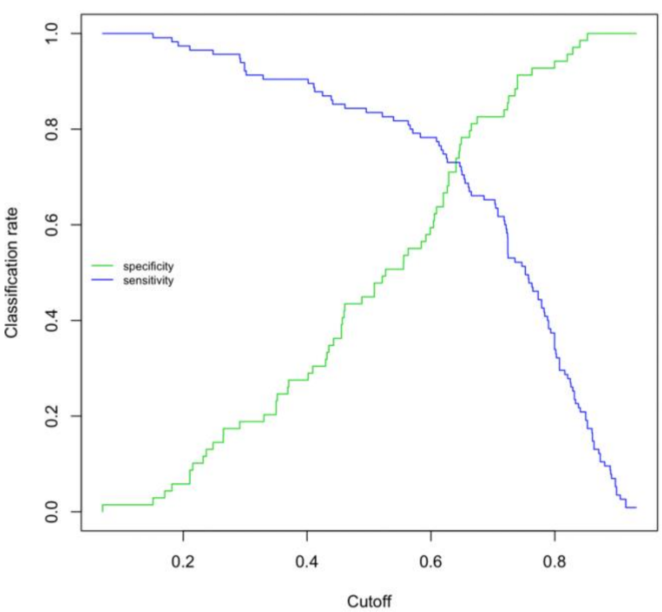
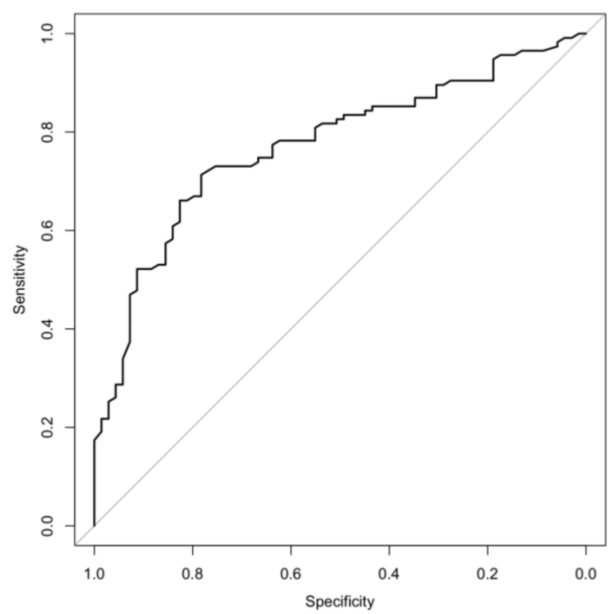


Figure 4.13: ROC Curve - Students with Calculus 1 Credit from UCF with AP Calculus Exam Scores of 1 or 2



4.5.7 Students with Credit for Calculus 1 from UCF with No Known AP Calculus or Other Post-Secondary Calculus Experience

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

G. math-intensive STEM students who completed Calculus 1 at UCF with no known AP Calculus or other post-secondary calculus experience?

A logistic regression analysis was performed to predict student success in Calculus 2 where success is defined as earning a grade of C or higher in the Calculus 2 course and not success defined as earning a C- or lower in the course. A grade of C or higher has been chosen to indicate success since students must earn a C or higher in college Calculus 2 in order to continue into their major or to earn a degree in the math-intensive majors included in this study. Prospective predictors of Calculus 2 success included the number of semesters since the student enrolled at UCF categorized as 1st Year, 2nd Year, or 3rd + Year (Semesters_At_UCF), the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2 (Semesters_Calc1_Calc2), the number of credit hours the student was taking during the semester they last enrolled in Calculus 2 using the standardized semester z-score (Z_Credit_Load), the student's grade in Calculus 1 (Calc1_Grade), the student's SAT Math score (SATMATH_IMP), the student's SAT Verbal score (SATVERB_IMP), the student's ethnicity/race (Race), the student's gender (Gender), the student's major at the start of the term for Calculus 2 (Major), and whether the student was a member of the LEAD Scholars Learning Community (LEAD_Scholar), the EXCEL Learning Community (EXCEL), the COMPASS Learning Community (COMPASS), and/or the University Honors Learning Community (University_Honors). Any missing data for the SAT Math and Verbal scores was imputed using the mean Math and Verbal SAT scores of 640.531 and 626.716, respectively, for all students with Calculus 1 credit from UCF with no known AP Calculus or other post-secondary calculus experience. All ethnicity/race categories were included in this analysis including Asian, African American/Black, Hispanic/Latino, International, Multi-racial, Other, and White. Students enrolled in Calculus 2 during Fall, Spring, and Summer semesters have all been included for this analysis. Again, due to differences in the student credit hour enrollment and the number of weeks in the Summer semester, the number of credit hours taken during the semester the student last enrolled in Calculus 2 was standardized using the z-score calculated with the mean and standard deviations across the Fall, Spring, and Summer semesters from this dataset (Table 4.33).

A total of 3442 students who earned credit for Calculus 1 from UCF with no known AP Calculus or other post-secondary calculus experience were included in this analysis with 2315 (67.3%) of these students being classified as successful in Calculus 2 and 1127 (32.7%) being classified as not successful in Calculus 2. The logistic regression analysis was performed using R software for statistical analysis (R Core Team, 2020).

Table 4.33: Summary of Credit Hour Load by Semester for Calculus 2 Students with Calculus 1 Credit from UCF with No Known AP or Other Post-Secondary Calculus 1 Experience

Semester	n	$\bar{x}$	s_x
Fall	1272	12.877	2.257
Spring	1434	13.372	1.958
Summer	735	7.654	2.041

A forward stepwise logistic regression analysis minimizing the model's AIC was performed to determine which of the thirteen predictors created the best fitting model. Results of the forward stepwise logistic regression resulted in a statistically reliable model, χ^2 (15) = 735.7, p < .001, with eight predictors: the number of semesters since the student entered UCF before taking

Calculus 2, the number of semesters between the completion of Calculus 1 and enrollment into Calculus 2, the student's Calculus 1 grade on a 4.0 scale, the student's SAT Math score, and the student's participation in the COMPASS, EXCEL, and University Honors Learning Communities, and the student's ethnicity/race. A moderate amount of variance related to student success was accounted for in this model with McFadden's rho = 0.168, df = 15. The prediction of success using the 0.5 threshold was fair with 2495 of the 3442 outcomes (72.5%) predicted correctly and with a sensitivity of 0.876 and a specificity of 0.415. A modification of the threshold to 0.65 minimized the difference in sensitivity and specificity to 0.709 and 0.699, respectively, and resulted in 2429 of the 3442 outcomes (70.6%) being accurately classified (Figure 4.14).

Table 4.34 shows the regression coefficients, standard errors, Wald statistics, p-values, odds ratios, and confidence intervals of the odds ratios for the identified predictors. According to the Wald criterion, a student taking Calculus 2 in the 2^{nd} year at UCF compared to the 1^{st} year, $z = 9.237$, $p < .001$, a student taking Calculus 2 in the 3^{rd} + year at UCF compared to the 1^{st} year, $z = 9.725$, $p < .001$, the number of semesters between the completion of Calculus 1 and enrollment in college Calculus 2, $z = 2.954$, $p < .01$, the student's Calculus 1 grade on a 4.0 scale, $z = 17.803$, $p < .001$, the student's SAT Math score, $z = 2.790$, $p < .01$, a student's participation in the COMPASS Learning Community, $z = 3.847$, $p < .001$, a student's participation in the EXCEL Learning Community, $z = 3.834$, $p < .001$, a student's participation in the University Honors Learning Community, $z = 3.294$, $p < .001$, and being an International student versus a student identified as White, $z = 3.734$, $p < .001$, are all statistically significant predictors of student success in Calculus 2 for students who have taken Calculus 1 with no known AP Calculus or other post-secondary calculus experience. Results indicate that taking

Calculus 2 in the 2nd year versus the 1st year and 3rd + year versus the 1st year lead to a decreases in the likelihood of success in Calculus 2 with odds ratios of 0.397, CI (0.326, 0.482) and 0.285, CI (0.221, 0.367), respectively. An increase in the number of semesters between taking Calculus 1 and Calculus 2 predicts an increase in the likelihood of success in Calculus 2 with an odds ratio of 1.142, CI (1.050, 1.252). An increase in a student's Calculus 1 grade also improves the likelihood of success in Calculus 2 with an odds ratio of 2.761, CI (2.471, 3.090). A higher SAT Math score slightly improves the likelihood of student success in the Calculus 2 course with an odds ratio of 1.002, CI (1.001, 1.004). International students also have an improved likelihood of success over White students with an odds ratio of 2.195, CI (1.464, 3.349). Finally, the learning communities of COMPASS, EXCEL and University Honors all increase the likelihood a student succeeding in Calculus 2 with odds ratios of 1.699, CI (1.301, 2.233), 1.910, CI (1.380, 2.676), and 1.875, CI (1.302, 2.755), respectively.

The examination of casewise effects is not of concern; although there are residuals and standard residuals for individual cases less than - 2 and greater than +2 in the model, all residuals and standard residuals are within +/- 3. There is not a concern with multicollinearity with Variance Inflation Factors (VIF) ranging from 1.008 (Race) to 1.106 (SATMATH_IMP). Examining the interaction of the continuous predictor variables and the log of the predictors indicates the assumption of linearity is met for this logistic regression analysis (Hosmer & Lemeshow, 1989). Finally, the assumption of independence is met since the students in this study are individuals with unique pre-entry attributes, goals and commitments, and institutional experiences.

Table 4.34: Logistic Regression Analysis of Calculus 2 Students with Calculus 1 Credit from UCF with No Known AP or Other Post-Secondary Calculus Experience

Predictor	β	SE β	Wald's χ^2	p-value	Odds Ratio	95% CI Lower	95% CI Upper
2nd Year to 1st Year	-0.925	0.100	9.237	< .001	0.397	0.326	0.482
3rd + Year to 1st Year	-1.254	0.129	9.725	< .001	0.285	0.221	0.367
Semesters between Calculus 1 and Calculus 2	0.133	0.045	2.954	< .01	1.142	1.050	1.252
Calculus 1 Grade	1.015	0.057	17.803	< .001	2.761	2.471	3.090
SAT Math	0.002	0.001	2.790	< .01	1.002	1.001	1.004
COMPASS LC	0.530	0.138	3.847	< .001	1.699	1.301	2.233
EXCEL LC	0.647	0.169	3.834	< .001	1.910	1.380	2.676
University Honors LC	0.628	0.191	3.294	< .001	1.875	1.302	2.755
Asian	0.215	0.153	1.409	0.159	1.240	0.922	1.679
Black/African American	-0.037	0.161	0.228	0.819	0.964	0.704	1.323
Hispanic/Latino	0.052	0.099	0.520	0.603	1.053	0.867	1.280
International	0.786	0.211	3.734	< .001	2.195	1.464	3.349
Multi-racial	-0.039	0.207	0.188	0.851	0.962	0.644	1.451
Other	-0.519	0.381	1.362	0.173	0.595	0.285	1.277

* Comparison group for ethnicities/races is White

A receiver operating characteristics (ROC) graph, valuable to visualize the of classification performance for logistic regression models, is included in Figure 4.15. The ROC analysis found the area under the curve (AUC) to be 0.774, which indicates a fair to good accuracy classification for this model (Tape, 2019).

Figure 4.14: Sensitivity/Specificity Cutoff Curve – Students with Calculus 1 Credit from UCF with No Known AP or Other Post-Secondary Calculus Experience

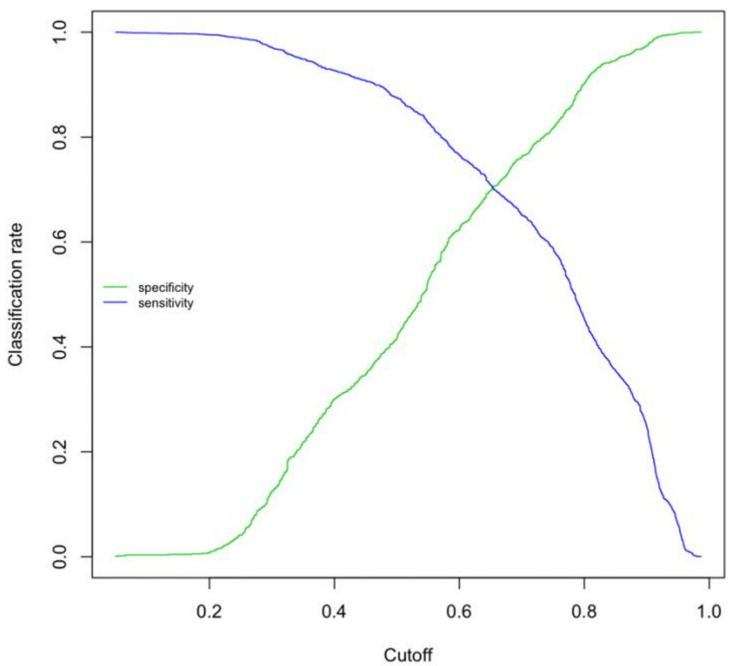
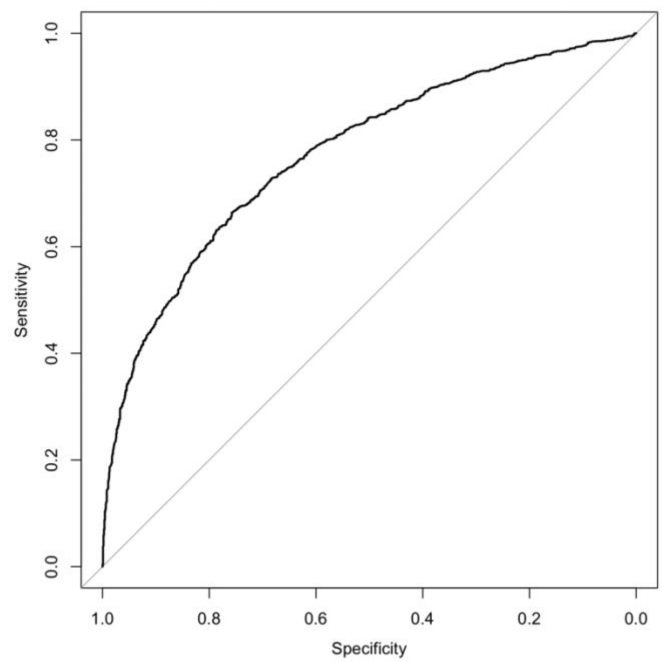


Figure 4.15: ROC Curve - Students with Calculus 1 Credit from UCF with No Known AP or Other Post-Secondary Calculus Experience



4.6 Summary

Math-intensive STEM students at universities enter college Calculus 2 courses with a wide variety of experiences including having completed Advanced Placement Calculus courses, Calculus 1 courses at other post-secondary institutions, and Calculus 1 courses at their home institution. This study sought to investigate how student experiences in college Calculus 1 affect student success in college Calculus 2. In addition, this study identified pre-entry attributes, goals and commitments, and institutional experiences of STEM students that are predictive of student success in Calculus 2.

4.6.1 Student Calculus Experiences

The initial portion of this study employed an ANOVA analysis and focused on an evaluation of Calculus 2 grades as a measurement of student success when comparing groups of students who earned credit for Calculus 1 by successfully completing AP Calculus courses, Calculus 1 at another post-secondary institution, and Calculus 1 at their home university. The results reveal a difference in mean Calculus 2 grades between the three groups, $p < .001$ and $F(2, 5820) = 225.5$. The results of a pairwise comparison concludes that students using AP Calculus credit academically outperform both other groups of students in Calculus 2 at a statistically significant level, $p < .001$ for both other groups. There is a large effect size between AP Calculus credit students and those with Calculus 1 credit from another institution, Hedge's $g = 1.01$, and a moderate effect size between AP Calculus credit students and those with Calculus 1 credit from UCF, Hedge's $g = 0.48$. Further, results of the pairwise comparisons indicate that students with Calculus 1 credit from another post-secondary institution also significantly underperform compared to the students with Calculus 1 credit from UCF with $p < .001$ and with a moderate effect size, Hedge's $g = 0.50$.

A more in depth analysis using ANOVA methods was made comparing student success based on Calculus 1 credit source and previous calculus experience(s). The results of this analysis again revealed a statistically significant difference in mean Calculus 2 grades across groups, $p < .001$ and $F(5, 5817) = 92.65$. The results of a pairwise comparison of groups concludes that students using AP credit outperform all other groups of students except those forgoing credit for AP Calculus BC at a statistically significant level with all $p < .001$. There is a large effect size for the comparison between students with AP credit and those with Calculus 1 credit from another institution, Hedge's $g = 1.01$. Moderate effect sizes exist between students with AP credit and those with Calculus 1 credit from UCF with no other known experience, Hedge's $g = 0.48$, students forgoing AP Calculus AB credit, Hedge's $g = 0.45$, and students with an AP Calculus AB/BC exam score of 1 or 2, Hedge's $g = 0.67$. In addition, pairwise comparisons indicate students with Calculus 1 credit from another post-secondary institution underperform all other groups of students at a statistically significant level, $p < .001$. The effect size between students with Calculus 1 credit from another institution and students with credit from UCF after forging credit for AP Calculus BC is large, Hedge's $g = 0.78$. Meanwhile, there are moderate effect sizes in the comparisons between students with Calculus 1 credit from another institution and those with Calculus 1 credit from UCF with no other known experience, Hedge's $g = 0.49$, and students forgoing AP Calculus AB credit, Hedge's $g = 0.55$, and a small effect size between students with Calculus 1 credit from another institution and those with Calculus 1 credit from UCF who scored a 1 or 2 on the AP Calculus AB or BC exam, Hedge's $g = 0.35$. Finally, results of the pairwise comparisons indicate a statistically significant difference in mean Calculus 2 grades for students with Calculus 1 credit from UCF after forgoing AP Calculus BC credit and those who scored a 1 or 2 on the AP Calculus AB or BC exams, $p < .05$, with a moderate effect size, Hedge's $g = 0.46$.

In summary, the results of this analysis indicate that students who have successfully completed AP Calculus courses, defined as earning an AP Calculus AB exam score or AP Calculus BC - AB exam sub-score of 3 or higher, are well-prepared for the rigorous Calculus 2 courses required for math-intensive STEM majors. On the other hand, students who have earned credit for Calculus 1 at another post-secondary institution struggle to succeed compared to their peers in college Calculus 2 courses.

4.6.2 Calculus 2 Success and Math-Intensive STEM Majors

The influence of a student's math-intensive STEM major on student success measured as grade in college Calculus 2 was also analyzed. While the results of the analysis suggest that a student's major does significantly affect student grade in Calculus 2, $p < .001$, $F(17, 5805) = 2.46$, further investigation of pairwise comparisons reveals that for the majority of math-intensive STEM students there is no significant difference in success related to the student's chosen major. However, students in Forensic Science academically underperformed in Calculus 2 at a statistically significant level when compared to students majoring in Actuarial Science, $p < .05$, Computer Science, $p < .05$, and several engineering majors, including Aerospace Engineering, $p < .01$, Environmental Engineering, $p < .05$, Mechanical Engineering, $p < .01$, and Undecided Engineering/Science, $p < .01$. There is a moderate effect size for the pairwise comparison between students in Forensic Science and students majoring in Actuarial Science, Hedge's $g = 0.57$, and Undecided Engineering/Science, Hedge's $g = 0.45$. The pairwise results indicate a small effect size for the comparison between students majoring in Forensic Science and those majoring in Computer Science, Hedge's $g = 0.31$, Aerospace Engineering, Hedge's $g = 0.36$, Environmental Engineering, Hedge's $g = 0.39$, and Mechanical Engineering, Hedge's $g = 0.45$.

Therefore, in general, a student's Calculus 2 grade is not significantly impacted by the choice of math-intensive STEM major. However, students in Forensic Science seem to struggle in Calculus 2 when compared to students majoring in Actuarial Science, Computer Science, and several engineering disciplines.

4.6.3 Calculus 2: Predictors of Success

A logistic regression analysis was used to identify of factors that predict student success in Calculus 2 for seven groups of students with various Calculus 1 backgrounds. While results varied from group to group, there were several statistically significant common predictors of student success which emerged from this analysis (Table 4.35).

<u>Learning Communities</u>

One generally positive predictor for students from a variety of Calculus 1 backgrounds are learning communities. The learning communities of COMPASS, EXCEL, and University Honors were statistically significant predictors of success in Calculus 2 for several student groups.

Participation in the COMPASS Learning Community, focusing on academically and socially supporting students interested in a STEM career but who are unsure of which STEM major to pursue at the start of their first year, increased the likelihood of success in Calculus 2 at a statistically significant level for students with AP Credit for Calculus 1, $p < .05$, odds ratio = 2.684, and students with Calculus 1 credit from UCF with no known AP Calculus or other post-secondary calculus experience, $p < .001$, odds ratio = 1.699. However, participating in COMPASS resulted in a statistically significant negative impact on the likelihood of success in Calculus 2 for students with credit for Calculus 1 from UCF after scoring a 1 or 2 on the AP Calculus AB or BC exam, $p < .05$, odds ratio = 0.282.

Participation in the EXCEL Learning Community, focusing on academic and social support of STEM students who have declared a STEM major at the start of their first year, increased the likelihood of students passing Calculus 2 at a statistically significant level for students with

Calculus 1 credit from UCF after forgoing AP Calculus AB credit, $p < .05$, odds ratio = 3.170, and for students with Calculus 1 credit from UCF with no known AP or other post-secondary calculus experience, $p < .001$, odds ratio = 1.910. It should also be noted that all students with Calculus 1 credit from UCF after forgoing AP Calculus BC credit who participated in the EXCEL Learning Community earned a C or higher in Calculus 2.

Participation in the University Honors Learning Community, a program focusing on students in any major who meet minimum academic requirements and offering challenging coursework, also significantly increased the likelihood of success in Calculus 2 for students with AP credit for Calculus 1, $p < .01$, odds ratio = 2.613, and students with Calculus 1 credit from UCF with no known AP Calculus or other post-secondary calculus experience, $p < .001$, odds ratio = 1.875. It should also be noted that all students with Calculus 1 credit from UCF after forgoing AP Calculus BC credit who participated in the University Honors Learning Community earned a C or higher in Calculus 2.

Finally, while not identified as a predictor in any individual models, all students with Calculus 1 credit from UCF after forgoing credit for AP Calculus BC who participated in the LEAD Scholars Academy also earned a C or higher in Calculus 2.

Calculus 1 Grade

Another positive predictor of student success in Calculus 2 across multiple student experiences was the student's Calculus 1 grade. The student's Calculus 1 grade was found to be predictive of success with higher grades resulting in an increased likelihood of success in Calculus 2 at a statistically significant level for students with credit for Calculus 1 from another institution, $p < .001$, odds ratio (grade A of compared to C) = 6.399, odds ratio (grade of B compared to C) = 1.793, students with Calculus 1 credit from UCF after forgoing AP Calculus

AB credit, $p < .001$, odds ratio = 2.784, students with Calculus 1 credit from UCF with a score of 1 or 2 on the AP Calculus AB or BC exam, $p < .01$, odds ratio = 2.034, and for students with Calculus 1 credit from UCF with no known AP or other post-secondary calculus experience, $p < .001$, odds ratio = 2.761.

AB Calculus AB Scores

The analysis of students with AP Calculus AB scores resulted in the identification of only one statistically significant predictor of student success. Students scoring a 5 on the AP Calculus AB exam had a substantially higher likelihood of passing Calculus 2 than students who scored a 3 on the exam, $p < .001$, odds ratio = 7.707. It should be noted that while an AP Calculus AB exam score of 4 compared to a 3 is included in the model, it was not a statistically significant predictor of student success in Calculus 2.

Time to Calculus 2

The logistic regression analysis also revealed that students who did not take Calculus 2 until their second or third year after admission at UCF were less likely to succeed compared to students taking Calculus 2 in the 1st semester or 1st year at UCF. Waiting until the second year after admission to UCF led to a statistically significant decrease in the likelihood that a student would succeed in Calculus 2 for students with AP Calculus credit, $p < .01$, odds ratio = 0.317, students completing Calculus 1 at UCF after forgoing AP Calculus AB credit, $p < .001$, odds ratio = 0.186, and for students completing Calculus 1 at UCF with no known AP or other post-secondary calculus experience, $p < .001$, odds ratio = 0.397. Similarly, waiting until the third year or later after admission to UCF led to a statistically significant decreases in the likelihood that a student would succeed in Calculus 2 for students with AP Calculus credit, $p < .01$, odds ratio = 0.167, for students completing Calculus 1 at UCF with a score of 1 or 2 on the AP Calculus AB or BC exam, $p < .001$, odds ratio = 0.136, and for students completing Calculus 1 at UCF with no known AP or other post-secondary calculus experience, $p < .001$, odds ratio = 0.285. It should be noted that this factor was not included in the stepwise regression analysis for students with Calculus 1 credit from UCF after forgoing credit for AP Calculus BC since the very small number of students waiting 3 years or more strongly influenced the results.

SAT Math Score

Finally, SAT Math scores were found to be predictive of student success in Calculus 2. A higher SAT Math score was a statistically significant predictor influencing the likelihood of success in Calculus 2 for students completing Calculus 1 at UCF after forgoing AP Calculus BC credit, $p < .05$, odds ratio = 1.015, students completing Calculus 1 at UCF with a score of 1 or 2 on the AP Calculus AB or BC exam, $p < .05$, odds ratio = 0.991, and for students completing Calculus 1 at UCF with no known AP or other post-secondary calculus experience, $p < .01$, odds ratio = 1.002. It should be noted that while Math SAT score was a statistically significant predictor for several groups, the odds ratios are close to 1 and, therefore, the results do not indicate it has a large influence on the likelihood of student success in Calculus 2.

Table 4.35: Summary of Statistically Significant Predictors of Success for Calculus 2 Students

Student Calculus 1 Experience	Calculus 1 Grade	AP Calculus AB Exam Score	SAT Math Score	Learning Community			Semesters Since Entering UCF	Semesters Between Calculus 1 and Calculus 2	Standardized Credit Hours with Calculus 2	Ethnicity/ Race
				COMPASS	EXCEL	University Honors				
AP Credit				2.684		2.613	0.317 (1)/ 0.167 (2)			0.425 (3)
AP Calculus AB Credit with a Score		7.707 (4)								
Credit from Another Institution	6.399 (5)/ 1.793 (6)							1.038	1.173	
UCF Credit Forgoing AP Calculus AB Credit	2.784 (7)				3.170		0.186 (8)			
UCF Credit Forgoing AP Calculus BC Credit			1.015		*	*	**			***
UCF Credit with AP Calculus AB/BC Score of 1 or 2	2.034 (7)		0.991	0.282			0.136 (9)			
UCF Credit with No Other Known Experience	2.761 (7)		1.002	1.699	1.910	1.875	0.397 (8)/ 0.285 (9)	1.142		2.195 (10)

(1) 2nd Year versus 1st Semester; (2) 3rd + Year versus 1st Semester; (3) Ethnicity/Race of Other versus White; (4) AP Calculus AB exam score of 5 versus score of 3; (5) Categorical Comparison of Calculus 1 grade of A versus grade of C; (6) Categorical Comparison of Calculus 1 grade of B versus grade of C; (7) Calculus 1 grade on a continuous scale; (8) 2nd Year versus 1st Year; (9) 3rd + Year versus 1st Year; (10) Ethnicity/Race of International versus White
* This factor was omitted from this regression since all students participating in the learning community passed Calculus 2 in this group
** This factor was omitted from this regression due to extreme casewise influences
*** This factor was omitted from this regressing since all students of Asian Ethnicity/Race passed Calculus 2 in this group

Other Predictors

Other statistically significant predictors of student success found within individual groups of students were those of ethnicity and race, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the standardized credit hour load of students during the semester of Calculus 2.

For students with AP credit for Calculus 1, ethnicity and race was a significant predictor reducing the likelihood of success in Calculus 2 for students indicated to be in under-represented minorities, not including African American/Blacks or Hispanic/Latinos, when compared to White students, $p < .01$, odds ratio = 0.425. Conversely, International students had a significantly higher likelihood of success in Calculus 2 compared to White students for students with Calculus 1 credit from UCF with no known AP or other post-secondary calculus experience, $p < .001$, odds ratio = 2.195. It should also be noted that the predictor of ethnicity/race was removed from the forward logistic regression analysis for the students with credit for Calculus 1 at UCF after forgoing AP Calculus BC credit since all students identified as having Asian ethnicity succeeded in Calculus 2.

The number of semesters between the completion of Calculus 1 and enrollment into Calculus 2 was a statistically significant predictor with an increased likelihood of success in Calculus 2 for students with Calculus 1 credit from another post-secondary institution, $p < .05$, odds ratio = 1.038, and those with Calculus 1 credit from UCF with no known AP or other post-secondary calculus experience, $p < .01$, odds ratio = 1.142. The odds ratios for this predictor are close to 1, indicating a minimal effect on likelihood of student success in Calculus 2.

Finally, the standardized credit load was a significant predictor of student success in college Calculus 2 for students with Calculus 1 credit from another institution. As the student's z-score credit hour load increases, the likelihood of success in Calculus 2 for these students also increases, $p < .05$, odds ratio = 1.173.

Thus, predictive factors such as learning communities, Calculus 1 grade, AP Calculus AB score, SAT Math score, and, in some cases, ethnicity and race, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the standardized credit hour load of students have emerged as predictive factors that impact the likelihood of student success in Calculus 2.

CHAPTER V
DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

Student success in the introductory mathematics and science courses which form the foundation for the more advanced mathematics, science, and engineering courses that STEM students take later in degree programs is critical to the retention and graduation of students in math-intensive STEM majors. Extensive research has focused on student success in college Calculus 1 since many prospective STEM students have traditionally begun their post-secondary mathematics education in pre-calculus or Calculus 1. However, the number of students taking college Calculus 2 as the first mathematics class at their home university has increased as Advanced Placement and Dual Enrollment programs in high schools have expanded and additional students transfer credit for Calculus 1 courses from another post-secondary institution. Therefore, this study offers insight into the factors that lead to math-intensive STEM student success in college Calculus 2.

The purpose of this chapter is to summarize and discuss the results of the quantitative study examining math-intensive STEM student success in college Calculus 2 based on the student's background experiences in Calculus 1 and the identification of factors predictive of student success in college Calculus 2 courses. The significant findings of the study will then be compared to those found in literature related to student success in Calculus 1 and Calculus 2 and to STEM student retention. Finally, this chapter concludes with a discussion of the implications of the study results and recommendations of future research.

5.1 Summary of Results

This study investigated math-intensive STEM student success in college Calculus 2 for students at the University of Central Florida (UCF). Information regarding the last time a student enrolled in college Calculus 2 (MAC 2312) between the Summer 2017 and Fall 2020 semesters was provided to the researcher by Institutional Knowledge Management (IKM) at UCF at the request of Dr. Melissa Dagley, Executive Director, Initiatives in STEM. The following Research Questions were examined in this study.

Research Question 1: Is there a significant relationship between the source of a student's Calculus 1 class credit, including high school AP Calculus, Calculus 1 at another post-secondary institution, and Calculus 1 at UCF, with student academic success in Calculus 2 for math-intensive STEM students?

Research Question 2: Is there a significant relationship between a student's prior Calculus 1 background experiences and student academic success in Calculus 2 for math-intensive STEM students?

Research Question 3: Is there a significant relationship between a math-intensive STEM student's major and academic success in Calculus 2?

Research Question 4: What pre-entry attributes, goals and commitments, and institutional experiences predict academic success in Calculus 2 for:

A. math-intensive STEM students who began college mathematics at UCF in Calculus 2 with AP Credit for Calculus 1?

B. math-intensive STEM students who began college mathematics at UCF in Calculus 2 having a recorded AP Calculus AB exam score and using with AP Credit for Calculus 1?

C. math-intensive STEM students who began college mathematics at UCF in Calculus 2 after completing Calculus 1 at another post-secondary institution?

D. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus AB with an AP exam score of 3 or higher?

E. math-intensive STEM students who began college mathematics at UCF in Calculus 1 forgoing credit from AP Calculus BC with an AP exam score of 3 or higher?

F. math-intensive STEM students who began their college mathematics education at UCF in Calculus 1 who scored a 1 or 2 on the AP Calculus exam after completing AP Calculus AB or BC in high school?

G. math-intensive STEM students who completed Calculus 1 at UCF with no known AP Calculus or other post-secondary calculus experience?

The results of the analysis for the first two research questions indicated that students who successfully completed AP Calculus courses, characterized as earning an AP Calculus AB exam score or AP Calculus BC - AB exam sub-score of 3 or higher, are well-prepared for the rigorous Calculus 2 courses required for math-intensive STEM majors and that they academically outperform students not using AP Calculus credit. Conversely, students who have earned credit for Calculus 1 at another post-secondary institution struggle to succeed and earn significantly lower grades in Calculus 2 courses compared to their peers.

The analysis related to the third research question revealed that, in general, a student's Calculus 2 grade is not significantly impacted by the student's math-intensive STEM major. However, students in Forensic Science had a lower mean grade in Calculus 2 when compared to students majoring in Actuarial Science, Computer Science, Undecided Engineering/Science, and several other engineering disciplines.

Finally, the logistic regression analysis identified several significant predictors of student success in college Calculus 2 courses. One of the common predictors of success for students from a variety of Calculus 1 background experiences was learning communities. The learning communities of COMPASS, EXCEL, and University Honors were identified as statistically significant predictors of success in Calculus 2 with students participating in these programs being more likely to succeed than students who did not participate in them. Another predictor of student success in Calculus 2 which was identified across multiple student background experiences was the student's Calculus 1 grade. As a student's grade in Calculus 1 increased the likelihood of a student succeeding in Calculus 2 also increased. Earning a AP exam score of 5 versus a score of 3 was also identified as a significant predictor of success in Calculus 2 for students earning AP Calculus AB credit. In addition, students taking Calculus 2 in the first semester or first year at UCF versus waiting until at least the second year or after were more likely succeed in the course. The logistic regression analysis also identified the SAT Math score as a significant predictor of success in Calculus 2 for students with many backgrounds, though the influence of this predictor on student success was not large. Ethnicity and race emerged as a significant predictor which indicated that for students with AP Calculus credit under-represented minority students, not including African American/Black or Hispanic students, were less likely to succeed than White students. Ethnicity and race was also a significant predictor for student's with Calculus 1 credit from UCF with no known AP Calculus or other post-secondary calculus experience with International students being more likely to succeed in Calculus 2 than White students. Finally, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2 and the standardized credit hour load of students during the semester they enrolled in Calculus 2 were identified as predictors of success for some groups of students.

5.2 Interpretation of Study Findings

The literature review in Chapter 2 included a discussion of Tinto's Institutional Departure Model and examined several factors related to student pre-entry attributes, goals and commitments, and institutional experiences which affect STEM student retention. It was also noted in the literature review that many of the factors predictive of STEM retention are similar to those predictive of student success in Calculus 1. In this section, the results from this study will be examined with respect to the results of previous research studies of STEM student retention and of student success in Calculus 1 and Calculus 2.

5.2.1 Calculus 2 Grade and Student Calculus 1 Background

A student's prior mathematical education and experiences are often identified in research studies as factors predictive of both STEM student retention and success in calculus courses (Tinto, 2012, Wade, et al., 2017, Kopparla, 2019, Hagman, et al. 2017, PCAST, 2012, Geisinger, et al., 2013, Baisley, 2019, Sadler & Sonnert, 2018, Sonnert, et al., 2020, Rosasco, 2013). Therefore, in this study, the impact of a student's source of Calculus 1 credit and background experiences were investigated for students taking college Calculus 2. More specifically, the first two research questions compared student success, measured as the student's Calculus 2 grade on a 4.0 scale, based on the source of the student's Calculus 1 credit and background experiences using an ANOVA analysis.

One source of Calculus 1 credit for students entering college Calculus 2 courses which was investigated in this study is AP Calculus. The findings of this study indicate that students with AP Calculus credit from AP Calculus AB or AP Calculus BC courses are well prepared for the concepts of college Calculus 2 and, on average, these students earn higher grades than peers with other Calculus 1 credit sources and having other Calculus 1 background experiences. In fact, the results of this study indicate students with AP Calculus credit academically outperform students with Calculus 1 credit from UCF or from another post-secondary institutions. These results support previous conclusions in literature from Calculus 2 studies which indicate students using AP Calculus credit have higher Calculus 2 grades compared to students with Calculus 1 credit from the same institution (Morgan & Remist, 1998, Morgan & Klaric, 2007, Dodd, et al., 2002, Keng & Dodd, 2008, Rosasco, 2013). Further, results of a more in depth analysis indicate that students using AP Calculus credit for Calculus 1 outperform all other peer groups in the study with different Calculus 1 background experiences except when compared to students who earned Calculus 1 credit at UCF after forgoing credit from AP Calculus BC with an AP exam score of 3 or higher. This group of AP Calculus students has not been included in any previous studies of Calculus 2 success.

The results also reveal that students with Calculus 1 credit from another post-secondary institution underperform academically in college Calculus 2 and, on average, have lower grades in Calculus 2 than students with Calculus 1 credit from UCF or AP Calculus courses. Furthermore, the results of an in depth analysis with Calculus 2 peer groups broken down by previous Calculus 1 background experiences reveals that students with Calculus 1 credit from another institution have lower mean Calculus 2 grades when compared to students with any other calculus background experiences. There are no previous studies that have examined student success measured as grade in Calculus 2 for students with Calculus 1 credit from another post-secondary institution.

Finally, this study found students with Calculus 1 credit from UCF earn grades, on average, lower than students using AP credit and higher than students with Calculus 1 credit from another institution. However, as previously noted, students with Calculus 1 credit from UCF after forgoing AP Calculus BC credit earned grades that were not significantly different than students with AP Calculus credit for Calculus 1. In addition, students in this study with Calculus 1 credit from UCF who earned less than a 3 on the AP Calculus AB or BC exam earned Calculus 2 grades that were significantly lower than students who choose to forgo credit for AP Calculus BC with an AP exam score of 3 or higher. It is important to note there was no difference in mean Calculus 2 grades identified in this study for students with any other prior Calculus 1 background experiences who had taken Calculus 1 at UCF. Although previous research studies of Calculus 2 academic performance and success have not included students forgoing credit for AP Calculus BC, the study results related to students with Calculus 1 credit from UCF contradicts the study by Keng & Dodd (2008) which found that students with Calculus 1 credit from the home university after forgoing credit for AP Calculus AB had higher grades than students with no AP experience who, in turn, had higher grades than students who earned less than 3 on the AP Calculus AB exam.

5.2.2 Calculus 2 Grade and Math-Intensive STEM Major

A student's career goals, including an interest in a STEM major and career, have been identified as predictive factors for Calculus 1 success and STEM retention in previous research (Tinto, 1993, Tinto, 2012, Geisinger & Raman, 2013, Belser, et al., 2018, Veenstra, et al., 2009, Sadler & Sonnert, 2018, Sonnert, et al., 2020). Thus, the effect of a student's math-intensive STEM major was examined for students taking Calculus 2 in this study. In particular, the third research question compared student success, measured by the student's Calculus 2 grade on a 4.0 scale, based on the student's major using an ANOVA analysis.

The study results found no difference in mean Calculus 2 grades for students in most math-intensive STEM majors as defined by the researcher for this study. However, study results indicate that students majoring in Forensic Science have a significantly lower mean Calculus 2 grade than students majoring in Actuarial Science, Computer Science, Undeclared Engineering/Science, and several engineering majors.

These results largely support previous studies of Calculus 1 student success which indicate that students in the STEM fields of engineering, computer science, and medicine have higher grades in college Calculus 1 (Sadler & Sonnert, 2018, Sonnert, et al., 2020). While the results of this study also indicate students in several other math-intensive STEM majors do not have significantly different mean Calculus 2 grades compared to students in engineering majors or Computer Science, the math-intensive STEM fields included in this study all require a minimum of two semesters of college-level calculus and at least one additional mathematics or statistics course. In fact, with the exception of Forensic Science, the mathematics requirements for students majoring in Mathematics, Statistics, Actuarial Science, Physics, Chemistry, and every engineering field all require a minimum of three semesters of college calculus in order to meet degree requirements. Therefore, the study results appear to largely support previous studies related to Calculus 1 success.

The results of this research study also indicate that students without a specific declared STEM major do not have a significantly different mean Calculus 2 grade than students with a declared STEM major. Thus, there is no indication that having a specific declared STEM major impacts student success in Calculus 2. This is contradictory to research results in literature which indicate that retention rates are higher for students who have declared a specific STEM major versus students who are undecided regarding a specific STEM major (Geisinger & Raman, 2013, Belser, et al., 2018).

5.2.3 Predictors of Calculus 2 Success

Tinto's Institutional Departure Model has been adapted to identify student pre-entry attributes, goals and commitments, and institutional experiences which are predictive of STEM student retention (Tinto, 1993, Tinto, 2012, Baisley, 2019, Roasasco, 2013). As discussed in the literature review, many of these factors have also been found to be predictive of student success in Calculus 1. Students enter Calculus 2 from a multitude of backgrounds with some having Calculus 1 credit from AP Calculus, some having Calculus 1 credit from another post-secondary institution, and still others having Calculus 1 credit from UCF. Further, students with credit for Calculus 1 from UCF have differing pre-entry backgrounds with some having no known AP or other post-secondary Calculus 1 experience, some choosing to forgo credit for AP Calculus AB after earning a 3 or higher on the AP exam, some forgoing credit for AP Calculus BC after earning a 3 or higher on the AP exam, and some after taking AP Calculus AB or BC and earning less than a 3 on the AP exam. The factors thought to influence Calculus 2 student success, defined as earning a grade of C or higher in Calculus 2, were investigated over the range of student Calculus 1 experiences using multiple logistic regression analysis in this study. The following factors were investigated in the research study.

<u>Student Calculus 1 Grade</u>

As noted in the literature review, a student's prior mathematics experience and grades are often identified as a pre-entry attributes predictive of STEM student retention and as a factors predictive of success in Calculus 1 courses. Hence, in the logistic regression analysis portion of this study the student's college Calculus 1 grade was a factor investigated for students enrolled in college Calculus 2.

The study results reveal that a student's Calculus 1 grade is a predictor of college Calculus 2 success for students with many Calculus 1 backgrounds. It was found that students earning higher grades in Calculus 1 are significantly more likely to succeed in Calculus 2 courses. These results correspond with the conclusions of previous research studies which have emphasized the importance of academic achievement in prerequisite courses for both Calculus 1 success and STEM student retention (Chen, 2015, Chen, 2013, Wade, et al., 2017, Kopparla, 2019, Hagman, et al. 2017, PCAST, 2012, Geisinger, et al., 2013, Baisley, 2019, Sadler & Sonnert, 2018, Sonnert, et al., 2020, Rosasco, 2013). In addition, these results are also consistent with the results of the study by Rosasco (2013) indicating Calculus 1 grades are predictive of student success in Calculus 2.

AP Calculus AB Scores

Again, a student's mathematical background and prior academic success are often determined to be pre-entry attributes predictive of STEM student retention and a factor predictive of success in Calculus 1. Therefore, the student's AP Calculus AB score was identified as a factor which was investigated for students enrolled in college Calculus 2 using AP Calculus credit and who had a reported AP Calculus AB score.

The study results indicate that a higher AP Calculus AB exam score leads to an increased likelihood that a student will earn a grade of C or higher in college Calculus 2. The AP exam score was a significant predictor of success in this study only for an AP Calculus exam score of 5 versus a score of 3. This result supports prior Calculus 2 research indicating that an AP Calculus AB exam score of 5 results in higher mean grades in Calculus 2. However, it should be noted that a score of 4 versus a score of 3 on the AP Calculus AB exam was not identified as a statistically significant predictor of student success in this study, contradicting prior research results found in literature (Morgan & Remist, 1998, Morgan & Klaric, 2007, Dodd, et al., 2002, Keng & Dodd, 2008, Rosasco, 2013).

SAT Math Score

Another factor commonly considered as a predictive pre-entry attribute of STEM student retention and of success in Calculus 1 is the SAT Math score. Therefore, the student's SAT Math score was included as a factor in the logistic regression analysis portion of this study.

The study results indicated that SAT Math scores are predictive of student success in college Calculus 2 with higher SAT Math scores increasing the odds that a student will pass Calculus 2 with a grade of C or higher. This is consistent with results in literature which indicate higher SAT Math scores are predictive of STEM retention and Calculus 1 and Calculus 2 success (Westrick, et al., 2019, Belser, et al., 2018, Baisley, 2019, Geisinger & Raman, 2013, French, et al., 2005, Kopparla, 2019, Sonnert, et al., 2020, Rosasco, 2013)

SAT Verbal Score

The SAT Verbal Score is also often found to be predictive of student academic success and student retention at post-secondary institutions (Tinto, 1993, Tinto 2012). Thus, the SAT Verbal score was included in this study as a potential predictor of student success in college Calculus 2.

While the results of this study did not identify the SAT Verbal score as a significant predictor of student success, it is identified as a factor which improves the overall regression model of Calculus 2 success for students with several different Calculus 1 background experiences. This result is also consistent with the past research results which did not find the SAT Verbal score to be a pre-entry attribute impacting STEM student retention or Calculus 1 success. However, it is at odds with one study of college Calculus 2 students where a higher SAT

Verbal score is identified as a significant predictor of increased student grades in Calculus 2 (Rosasco, 2013).

Ethnicity/Race

Since student ethnicity or race is often identified as a pre-entry attribute predictive of STEM student retention and a factor contributing to Calculus 1 success, it was included as a factor in the logistic regression portion of this study.

The results of this study found ethnicity and race to be predictive of Calculus 2 success in two groups of students. The first set of results indicate that students with AP Calculus credit having an ethnicity and race of Other, a group of under-represented minorities not including African American/Black or Hispanic students, have a lower likelihood of success in Calculus 2 than White students. The second of the results indicates that International students with Calculus 1 credit from UCF and no known AP or other Calculus 1 experience have higher odds of success in Calculus 2 than White students. It should also be noted that the ethnicity and race factor was not included in the analysis for students having AP Calculus AB scores and using AP credit since all African American/Black students in this group succeeded in Calculus 2; nor was it included in the analysis for students with Calculus 1 credit from UCF after forgoing AP Calculus BC credit because all Asian students in this group succeeded in Calculus 2. These results are largely inconsistent with literature results, with other studies having found that Asian students have higher retention rates and Calculus 1 grades while African American/Black students have higher attrition rates and lower Calculus 1 grades (Geisinger & Raman, 2013, Griffith, 2010, Belser, et al., 2018, Chen, 2013, Sadler & Sonnert, 2018, Sonnert, et al., 2020).

Gender

Student gender is often included as a pre-entry attribute in studies of STEM student retention and as a factor influencing Calculus 1 success. Therefore, gender was included in the logistic regression analysis portion of this study as a potential predictor of student success in Calculus 2.

These study results do not indicate gender is predictive of student success in Calculus 2 for any groups of students with various Calculus 1 background experiences. In fact, gender is also not identified as a factor which improves any of the regression models. While prior research has mixed results, there are many studies in literature with results that do not find student gender to be predictive of STEM retention or Calculus 1 success (Chen, 2013, French, et al., 2005, Sadler & Sonnert, 2018, Sonnert, et al., 2020).

Math-Intensive STEM Major

A student's major has been identified as a goal and commitment influencing student retention and as a factor predictive of student academic success. Thus, the student's math-intensive STEM major was also included as a potential predictor in the logistic regression analysis of student success in Calculus 2. Nonetheless, the factor related to the student's major did not improve the regression model for any groups of students with any Calculus 1 background experiences. This is not completely supported by previous literature results which indicate students without a specific declared STEM major are less likely to be retained in STEM fields (Geisinger & Raman, 2013, Belser, et al., 2018). However, there is no evidence from literature that students having a specific STEM major is predictive of student success in Calculus 1.

Learning Communities

Academic and social integration, both formal and informal, have been identified as predictors of student retention in Tinto's Institutional Departure Model for students at post-secondary institutions (Tinto, 1993, Tinto, 2012). In this study, student participation in a learning community is included as a factor which may influence a student's academic and/or social integration at the university. The COMPASS Learning Community, EXCEL Learning Community, University Honors Learning Community, and LEAD Scholars Academy Learning Community were included in this study.

The results of this study indicate that several learning communities at UCF are significant predictors of math-intensive STEM student success Calculus 2. This study found that students participating in the COMPASS, EXCEL, and University Honors Learning Communities at any time before or during enrollment in Calculus 2 are more likely to pass Calculus 2 than their peers who never participated in a learning community. In addition, all students participating in the LEAD Scholars Academy, the EXCEL Learning Community, and the University Honors Learning Community with Calculus 1 credit from UCF after forgoing AP Calculus BC credit earned a grade of C or higher in Calculus 2. It should be noted that the COMPASS and EXCEL Learning Communities enroll only students interested in or enrolled in STEM majors and provide supplemental academic support particularly in mathematics courses while students in the University Honors Learning Community and LEAD Scholars Academy may have any major. The study's results reinforce previous research results which indicate participation in a learning community and especially a STEM learning community often results in a higher student GPA and increased STEM student retention and graduation rates (Solanki, et al., 2019, , Carrino & Gerace, 2016, Dagley, et al., 2016, Palm & Thomas, 2015).

Finally, it should be noted that for students with Calculus 1 credit from UCF who earned less than a 3 on the AP Calculus AB or BC exam, the COMPASS Learning Community decreased the odds of student success in Calculus 2. Since students in the COMPASS Learning Community are initially not committed to a specific STEM major, this may be a result of students deciding to pursue a major which does not require Calculus 2.

Time to Calculus 2

The time between a student's admission to UCF and when Calculus 2 is taken is included as a factor related to the student's institutional experiences. Longer time intervals between university admission and enrollment in Calculus 2 often indicate the student enrolled in pre-requisite courses such as Algebra, Trigonometry, or Pre-Calculus at the university prior to enrolling in Calculus 1 or that the student may have repeated the Calculus 1 and/or Calculus 2 courses.

The results of this study suggest that students taking Calculus 2 in their first year at UCF are most likely to succeed in the class and students waiting until the second year or later have increasingly lower likelihoods of success. This corresponds with previous results from literature which indicate that taking Calculus 1 or other advanced mathematics in the first year increases STEM retention rates and that students taking Calculus 1 in the first year at a university have higher grades than students taking the class after the first year (Chen, 2013, Kopperla, 2019, Sadler & Sonnert, 2018, Sonnert, et al., 2020).

Credit Hour Load

Another factor examined in the logistic regression portion of this study was the student's standardized credit hour load during the semester they enrolled in Calculus 2. Students in math-intensive STEM majors often take Calculus 2 concurrently with other challenging STEM classes such as physics, chemistry, biology, and/or programming courses. Therefore, the impact of credit loads were investigated to determine whether they were predictive of students earning a grade of C or higher in Calculus 2.

Results indicate that the standardized credit load is important in the regression model for several groups of students. However, it was only a statistically significant predictor of Calculus 2 success for students with Calculus 1 credit from another institution. For this group of students, an increase in the credit load when taking Calculus 2 increases the odds of student success in Calculus 2. There are no similar research results in literature related to the number of credit hours a student is enrolled in during a given semester with Calculus 1 or Calculus 2 success or related to STEM student retention.

Time Between Calculus 1 and Calculus 2

The time between the completion of Calculus 1 and enrollment in Calculus 2 was also included in this study to assess whether it was predictive of Calculus 2 success. The study results for this factor indicate that the number of semesters between the two courses is predictive of student success in Calculus 2 for several groups of students with differing Calculus 1 background experiences. Study results found that as the number of semesters between the two courses increases, the odds of student success in Calculus 2 increases slightly. There are no previous research results in literature which are comparable to this factor.

Timing of Calculus 1 Compared to Admission at the University

A factor indicating whether Calculus 1 was taken before or after admission to UCF specifically for students with Calculus 1 credit from another post-secondary institution was included in the logistic regression analysis of this study. The study results for this factor indicate that it is not predictive of student success in Calculus 2 for this group of students. There are no previous research results in literature which have investigated this factor.

5.3 Implications of Study Findings

The literature review in Chapter 2 included a discussion of Tinto's Institutional Departure Model and examined several factors related to pre-entry attributes, goals and commitments, and institutional experiences which affect STEM student retention. It was also noted that many of these factors are similar to factors predictive of student success in Calculus 1 and Calculus 2. In this section, the implications of this study's results related to student success in Calculus 2 will be examined.

5.3.1 Calculus 2 Grade and Student Calculus 1 Background

The results of this study reinforce previous research and validation studies examining the success of AP Calculus students which indicate students using AP Calculus credit for Calculus 1 are well-prepared for college Calculus 2 courses. In fact, 84.9% of all students with AP Calculus credit at UCF and 78.3% of students with reported AP Calculus AB scores in this study passed Calculus 2 with a grade of C or higher. It should be noted that the AP score required to receive credit for Calculus 1 at UCF was changed starting with the Fall 2019 cohort of students from requiring an AP Calculus AB exam score or sub-score of 5 to requiring an AP Calculus AB exam score or sub-score of 3 or higher. Thus, students using AP credit for Calculus 1 prior to the Fall 2019 semester earned a 5 on the AP exam unless an exception was granted by the university. Finally, it should be noted that no matching of student pre-entry attributes, such as SAT scores, was made in this study.

Study results indicate students earning Calculus 1 credit from UCF after forgoing credit for AP Calculus did not earn significantly higher Calculus 2 grades compared to other students with Calculus 1 credit from UCF with no previous AP Calculus experience. In addition, while not a statistically significant result, the results of this study suggest students who were not successful in AP Calculus courses may be academically struggling more in Calculus 2 compared to their peers with Calculus 1 credit from the home university. Students with credit from UCF passed Calculus 2 with a grade of C or higher at an overall rate of 67.4% with success rates varying from 62.5% for students having earned less than a 3 on the AP Calculus AB or BC exam to 77.8% for students choosing to forgo credit for AP Calculus BC.

Finally, the results of this study expand upon the very limited research into students with Calculus 1 credit from another institution. The results of this study clearly reveal that students with Calculus 1 credit from another post-secondary institution are academically struggling in Calculus 2 at UCF compared to students with all other Calculus 1 backgrounds. In fact, only 45.2% of students with Calculus 1 credit from another institution passed Calculus 2 at UCF with a grade of C or higher during the time of this study. This implies that these students are either not sufficiently prepared academically for Calculus 2 at the university or that other outside factors are negatively influencing the odds of student success in Calculus 2 for this group of students.

5.3.2 Calculus 2 Grade and Math-Intensive STEM Major

The results of this study suggest that for the majority of math-intensive majors there is not a significant difference in success related to a student's chosen major. Further, students having declared a specific math-intensive STEM major achieve grades that are not significantly different from those who have not yet chosen a specific STEM major. These results imply that math-intensive STEM students have similar goals and commitments regardless of whether they have declared a specific major or not.

The results also revealed students in Forensic Science underperformed academically in Calculus 2 compared to students in several other STEM majors in this study. It should be noted that unlike all other math-intensive STEM majors included in this study except Computer Science, students in Forensic Science are not required to complete any additional calculus courses in order to earn a degree. In addition, while students in Forensic Science are required to complete a statistics course and many other science courses to complete a degree, they are not required to take discrete mathematics courses which are required for students majoring in Computer Science. This may explain the difference in mean Calculus 2 grades between students in the Forensic Science major and students in several other math-intensive STEM majors.

5.3.3 Predictors of Calculus 2 Success

While results varied from group to group, several common predictors of student success emerged from this study. Factors such as participation in learning communities, Calculus 1 grade, AP Calculus AB score, SAT Math score, ethnicity and race, the number of semesters between admission until enrolling in Calculus 2, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the standardized credit hour load of students emerged as factors impacting the likelihood of student success in Calculus 2 for students with various Calculus 1 background experiences. These results can be used by advisors and faculty to identify students at risk of needing additional support and those most likely to succeed in Calculus 2. However, some of these factors have more specific implications.

Participation in a learning community emerged as a significant predictor of student success in college Calculus 2 for students with many different Calculus 1 backgrounds. These results reinforce ideas related to Tinto’s Model suggesting both academic and social integration are vital for students to succeed and be retained at an institution (Tinto, 1993, Tinto, 2012). In addition, these results reveal that participation in the STEM learning communities of COMPASS and EXCEL lead to improved odds of success in Calculus 2 similar to those of students in the academically selective University Honors Learning Community. This emphasizes the impact which academic and social support can provide to STEM students from many backgrounds and with varying pre-entry attributes. Finally, the COMPASS Learning Community was included in the model for students with Calculus 1 credit from another institution and though not statistically significant it suggests there is potential for this predictor to affect the likelihood of success in Calculus 2 for these students. It should be noted that participation in learning communities for this group of students was much lower than for any students with other Calculus 1 background experiences. At most 54 of 1023 students (5.3%) with Calculus 1 credit from another institution participated in any one learning community compared to participation rates of up to 11.3% for students with Calculus 1 credit from UCF and up to 26.3% for students with AP Calculus credit.

Therefore, the study results strongly support the benefit of student participation in learning communities. Students in math-intensive STEM majors should be encouraged to participate in a learning community regardless of their academic background. In particular, learning communities should be expanded where possible for students who plan to study a math-intensive STEM major and who are transferring Calculus 1 credit from another post-secondary institution.

Students taking Calculus 2 more than one year after admission at UCF are much less likely to succeed in Calculus 2 than students taking the course in the first year. Students who wait to take Calculus 2 beyond the first year may either have repeated Calculus 1 and/or Calculus 2 or needed to take pre-requisite mathematics courses prior to taking Calculus 1. In the first situation, students may need additional support from faculty or additional outside tutoring to succeed in Calculus 2. In the second case, students needing to take several pre-requisite courses before Calculus 1 have been shown to struggle more in advanced mathematics courses than students beginning in Calculus 1 or higher (Rosasco, 2013). Again, programs which provide academic support to students completing courses prior to Calculus 1 could be expanded or participation in existing programs could be encouraged by advisors and faculty.

Not surprisingly, a student’s Calculus 1 grade was also identified as a predictor of Calculus 2 success regardless of whether the student took Calculus 1 at UCF or at another institution. This suggests that students earning higher grades in Calculus 1 have a better understanding of the calculus concepts necessary to succeed in Calculus 2 courses.

In addition, the student’s AP Calculus AB score was identified as predictive of Calculus 2 student success for students using AP Calculus credit. While it is tempting to say that a higher AP Calculus exam score is likely to indicate that a student better understands the concepts needed to succeed in Calculus 2, it was not found that an AP exam score of 4 versus a score of 3 was a significant predictor increasing the likelihood of Calculus 2 success. This result is not expected and is further discussed in the recommendations section of this chapter.

The student’s SAT Math score was also found to be predictive of Calculus 2 success for students with several Calculus 1 background experiences. However, it has been noted that the impact of a change in a student’s SAT Math score on the likelihood of Calculus 2 success is small. This is not surprising since the time between taking the SAT exam and taking college Calculus 2 is often at least one year or more. So, while the SAT Math score may indicate a student’s level of mathematical preparation in the year before they graduate from high school, students have often taken several additional math courses before enrolling in Calculus 2 at a university.

A student's ethnicity and race was predictive of student success in Calculus 2 for only two groups of students. For students with AP Calculus credit, under-represented minorities not including African American/Black or Hispanic students were less likely to earn a C or higher in Calculus 2 than White students. On the other hand, International students were more likely to succeed in Calculus 2 than White students after earning Calculus 1 credit at UCF with no known AP or other post-secondary calculus experience. While under-represented minority students are sometimes identified as needing additional support in calculus courses, the performance of International students has not been documented in previous studies. In addition, this result is interesting because student ethnicity, especially for students of African American and Hispanic ethnicities, is often identified as a negative predictor of student success in mathematics courses. The results of this study do not find any such negative correlation related to student success in Calculus 2 at UCF for these two student ethnicities. This is also further discussed in the recommendation section of this chapter.

The number of semesters between the completion of Calculus 1 and enrollment in Calculus 2 was also predictive of student success in Calculus 2. As the number of semesters between the two courses increases, the likelihood of success increases slightly. This result may be due to the fact that the calculated number of semesters between classes includes the summer semester. Therefore, students completing Calculus 1 in the Spring semester may be more likely to take Calculus 2 in the subsequent Fall semester and will have one semester between the two courses.

In addition, the standardized credit hour load of students during the semester they enrolled in Calculus 2 was predictive of student success for students with Calculus 1 credit from another institution. As the student's standardized credit load increased, so did the likelihood that a student would earn a C or higher in Calculus 2. This result may be due to the difference between students enrolled full time at the university versus part time student enrollment. It can be seen in the results in Chapter 4 that the mean credit load for this group of students is very close to 12 credit hours during the Fall and Spring semesters which is the number of hours that determine whether a student has full or part time status at UCF. It is likely that a student's outside commitments vary significantly between full time and part time students.

Finally, given the focus on supporting women in STEM fields and in mathematics courses, it is interesting to note that gender was not found to be predictive of student success in Calculus 2 in this study. Many recent studies have suggested that women often earn slightly higher grades in many mathematics courses but have lower mathematical self-efficacy leading to STEM attrition (Hagman, et al., 2017, Geisinger & Raman, 2013, Veenstra, et al., 2009). Therefore, it is possible that female students with low levels of mathematical self-efficacy have already left the math-intensive STEM pipeline before taking Calculus 2 courses or that these students have increased their level of mathematical self-efficacy prior to taking Calculus 2.

5.4 Recommendations for Future Research

There are several recommendations for future research that would be beneficial based on the results of this study.

First, the results of this study highlight the need for additional research of Calculus 2 academic success for students with Calculus 1 experience from a post-secondary institution other than the home university. In further examinations of this group of students it would be beneficial to separate students who have credit from Dual Enrollment programs in high school, community college transfer students, and transitory students who take individual courses at another institution during the Summer or another semester. In addition, while some factors have been identified that may influence the success of these students, the results are limited to one university and one group of students. The researcher suspects that there are additional unidentified factors which influence success for these students in Calculus 2. These factors may include academic and social integration at the home institution and other student obligations.

Second, the study results suggest additional research related to the effect of the AP Calculus AB exam score on student success in Calculus 2. While previous research results have indicated significant differences between AP exam scores of 3, 4, and 5, the results of this study suggest a large difference calculus mastery between an AP exam score of 3 or 4 and an AP Calculus exam score of 5. Since all previous research was completed prior to the most recent AP Calculus course and exam updates, an in-depth analysis of success rates versus AP Calculus exam scores would be beneficial to better understand the influence of the student's AP Calculus exam score related to the student's understanding of calculus concepts and student success in more advanced calculus courses.

Another recommendation would be to complete additional research into student success in Calculus 2 across ethnicity and race. The results of this study were contradictory to existing research results with respect to the effect of ethnicity and race on student success in post-secondary mathematics. The identification of a factor that is predictive of higher success rates for under-represented minority students, specifically African American/Black and Hispanic students, could be beneficial at many post-secondary institutions.

Several additional potential predictive factors are recommended for future studies of student success in Calculus 2 when using regression analysis. These factors include a measure of course load difficulty during the semester a student is enrolled in Calculus 2, a factor indicating whether a student has repeated Calculus 1 and/or Calculus 2, a factor indicating whether students with Calculus 1 credit from another institution earned credit through Dual Enrollment during high school, earned credit at a community college after graduating from high school, earned credit as a transitory student during a summer or other semester, or earned credit from another 4-year institution.

Finally, additional research is recommended to investigate whether STEM learning communities for students transferring credit for Calculus 1 or other mathematics courses increases student success in Calculus 2 and thereby leads to increases in STEM retention rates for these students. It is recommended that the learning communities not only offer academic support in mathematics, but also support students in the academic and social transition from one institution to another institution.

5.5 Conclusions

As more students are entering universities with credit for Calculus 1 courses from AP Calculus, Dual Enrollment Calculus, or Calculus 1 from another post-secondary institution, the number of students beginning their mathematical education at their home university in Calculus 2 is increasing. Statistics from large, research-focused universities indicate that more students are now taking Calculus 2 classes than are taking Calculus 1 classes and that a high number of students are not succeeding in Calculus 2. Since students who do not succeed in first-year introductory science and mathematics courses are unable to continue into math-intensive

STEM majors, it is important that student success in courses like Calculus 2 are well understood to improve the retention and graduation of qualified STEM professionals in the United States.

Previous studies related to student success in Calculus 2 courses are very limited and examined student cohorts from the 1990's or early 2000's. Thus, since many changes have occurred in mathematics education at both the secondary and post-secondary levels in the last 20 years, this research study first sought to examine the impact of a student's Calculus 1 entry pathway to Calculus 2 on academic success in college Calculus 2 for students in math-intensive STEM majors. The results of this study indicate that students with AP Calculus credit for Calculus 1 are well equipped to succeed in college Calculus 2 courses. Conversely, students with Calculus 1 credit from another post-secondary institution are less likely to be prepared for the academically rigorous Calculus 2 courses at universities.

In addition, since various math-intensive STEM majors have differing mathematics requirements, an examination of student success in Calculus 2 across math-intensive STEM majors was included in this study. The results reveal that with the exception of students majoring in Forensic Science, there is no evidence that student success in Calculus 2 varies across any STEM majors or, indeed, with having a specific math-intensive STEM major declared when beginning a Calculus 2 course.

Finally, an investigation of factors predictive of student success in Calculus 2 was made to identify pre-entry attributes, goals and commitments, and institutional experiences which impact student success. Factors found to be predictive of Calculus 2 academic success included the student's participation in a learning community, the student's Calculus 1 grade, the student's AP Calculus AB score, the student's SAT Math score, and, in some cases, the student's ethnicity, the number of semesters between student admittance to the university and when they enrolled in

Calculus 2, the number of semesters between the completion of Calculus 1 and enrollment in Calculus 2, and the standardized credit hour load of the student when enrolled in Calculus 2.

While many results supported existing research from literature, there were several findings that had not been previously investigated or that were contradictory to the existing results. An examination of these new and contradictory results culminated in the development of potential explanations and suggestions for future research to better understand the factors affecting student success in Calculus 2. Recommendations included encouraging student participation in learning communities with a focus on the expansion of STEM learning communities especially for students transferring credit for Calculus 1, providing additional academic support to students needing to take several math courses prior to enrolling in Calculus 1, students having repeated Calculus 1, or students repeating Calculus 2, a closer examination of factors impacting student success in Calculus 2 for students with Calculus 1 credit from another institution, and further investigation of a student's AP Calculus AB score on a student's understanding of calculus concepts and student success in Calculus 2.

Given the similarity in factors predictive of Calculus 1 success and STEM student retention, it is expected that factors which predict success in Calculus 2 are also predictive of STEM student retention. Therefore, this study provides not only insight into student success in Calculus 2 courses, but also into STEM student retention. Thus, as researchers gain an understanding of the factors critical to student success in 'gateway' courses, like Calculus 2, universities are better equipped to educate, retain, and graduate STEM students to fuel the giant leaps in science, technology, engineering, and mathematics that will improve the way we live, work, and communicate in the future.

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APPENDIX A

Letter of Approval from Shawnee State University's Institutional Review Board (IRB)

Re: Exempt IRB Submission

IRB <irb@shawnee.edu>
Sun 11/8/2020 10:41 PM

To: Kathleen McCormack <mccormackk@mymail.shawnee.edu>
Cc: Douglas Darbro <ddarbro@shawnee.edu>

Good evening, Kathleen & Doug,

I've reviewed your application, and I agree that it does fall under the Exempt category. You're ready to go!

Sincerely,
Dr. Hamilton

From: IRB <irb@shawnee.edu>
Sent: Tuesday, November 3, 2020 9:36 PM
To: Kathleen McCormack <mccormackk@mymail.shawnee.edu>
Cc: Douglas Darbro <ddarbro@shawnee.edu>
Subject: Re: Exempt IRB Submission

Good evening, Kathleen,

I've received your application, and I will review it and give you a reply soon, later this week.

Sincerely,
Tim Hamilton
Chairman, IRB

From: Kathleen McCormack <mccormackk@mymail.shawnee.edu>
Sent: Sunday, October 25, 2020 2:38 PM
To: IRB <irb@shawnee.edu>
Cc: Douglas Darbro <ddarbro@shawnee.edu>
Subject: Exempt IRB Submission

Hello Dr. Hamilton,

I am a student working on my master's thesis with Dr. Darbro and am submitting the IRB application and associated documents in attached pdf file. Please let me know if you have any questions or concerns.

Thank you,

Katie McCormack

BIBLIOGRAPHY

KATHLEEN MARIE MCCORMACK

Candidate for the Degree of

Master of Science Mathematics

Thesis: FACTORS CORRELATED TO THE SUCCESS OF STEM STUDENTS IN CALCULUS 2

Major Field: Mathematics

Background: Enthusiastic instructor with more than 15 years of experience. Mentored team of 60 mathematics and science tutors, developed and delivered lectures, tutored students in person and online, conceived and coordinated interactive student activities and hands-on labs, and coached and mentored students in STEM competitions. Additional experience as a manufacturing engineer and engineering manager for medical devices and as a research and development engineer in nuclear reactor physics design.

Education: Bachelor of Science Nuclear Engineer, Purdue University, 1991

Completed the requirements for the Master of Science in Mathematics, Portsmouth, Ohio in August 2021.

ADVISOR'S APPROVAL: Dr. Douglas Darbro, PhD