INFLUENCE OF HIGH SCHOOL BIOLOGY AND MATHEMATIC COURSES ON THE INTRODUCTORY COLLEGE BIOLOGY COURSE SUCCESS AT ANGELO STATE UNIVERSITY, TX

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DEDICATION PAGE

Dedicated to my mother, the woman that supported me through every decision and challenge that I faced and encouraged me to pursue my dreams regardless of where they took me.

ABSTRACT

For students to be adequately informed and prepared to succeed in Science, Technology, Engineering, and Mathematics (STEM) fields, it is important to understand the influence of the number of science and mathematics courses taken in high school on success in introductory biology courses. This study examined the significance between the number of mathematics and science courses taken by high school students and success in the Principles of Biology (Bio 1480) introductory college biology course offered at Angelo State University (ASU) in San Angelo, TX. This study utilized questionnaires and multiple binomial general linear regressions to determine the likelihood of success that existed between the number of high school science and mathematics courses taken and success in the Bio 1480 course sections in the Fall 2012 and Spring 2013 semesters. It was determined that, overall, the number of mathematics and science courses taken by a student in high school does affect success in Bio 1480; however, the extent of the effect varied between the fall and spring terms. In the fall term, it was determined that an increased number of mathematics and science courses taken always decreased a student's likelihood of being unsuccessful. In the spring, the results varied in which the number of mathematics and biology courses did have an effect while the number of science courses did not. The differences in a significant effect between the semesters were also present when examining the number of all science courses with lab time taken in high school. The number of biology courses with lab time taken in high school had a significant effect in both the fall and spring semester. This trend was also evident when the number of Advanced Placement (AP) courses taken in high school was examined. Having taken AP Calculus had a significant effect on success in the introductory college biology course as well as having taken AP Biology, but when examining the total number of AP science courses taken in high school a significant effect was evident in the fall but not in the spring semester.

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INTRODUCTION

Academic success in a student's first year of college, especially in science course work, is important for future achievement. Many factors influence achievement in introductory biology courses. Research suggests that students should take at least three years of both mathematics and science courses (ACT, 2008a; Teitelbaum, 2003); however, which science and mathematics courses the student takes is often based on what is offered at the school, what is required by the individual schools to graduate, and what the student's peers are taking. The report produced by The Education Trust (2003) states that general patterns emerge between different states "college – prep" curriculum. This "college – prep" curriculum includes the afore mentioned 3 years of mathematics and science, but it goes on to mention that of those 3 mathematics courses, students should be taking Algebra 1, Geometry, Algebra 2, and 1 more year of mathematics beyond Algebra 2 along with 3 years of natural science that include lab sciences such as biology, chemistry, and physics (The Education Trust, 2003).

Many parents and students feel that just because they have met a university's admission requirements, that they are "college-ready", but this is not always the case (The Education Trust, 2003). Somerville and Yi (2002) found that there is actually very little consensus between the K – 12 and higher education, that many the institutions of higher education have not come to agreement on the number of topics for many high school coursework requirements, and that even within the high school graduation requirements in the United States there is too much variation (The Education Trust, 2003). In mathematics,

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10 states had K – 12 and higher education agreements on the number of mathematics courses that students should take in high school (The Education Trust, 2003). This study hopes to inform parents, college advisors, and high school teachers of the best mathematics and science route that their students should complete to be "college ready" for introductory biology.

Several studies have considered the influence of courses taken in high school and the relationship this influence has on a student's first year college success (Boon and Reid, 2011; Gifford and Harpole, 1968; Hart and Cottle, 1993; Sadler and Tai, 2000). These studies examined success in introductory computer science, mathematics, chemistry, and physics courses. Even though previous authors have examined the influence of classes taken in those 4 subject areas and have also determined that the laboratory experience is a key factor, other authors have not been satisfied with the predictive power of high school STEM courses (including advanced placement courses) for success in corresponding introductory college level STEM courses determined within these same studies (Sadler and Tai, 2000). Very few studies have examined factors influencing success in introductory college biology courses, and of those, even fewer have determined the role high school mathematics and science, particularly biology, courses play in students' success. Understanding the influence that the number of science and mathematics courses taken in high school can have on success in introductory biology courses can be extremely useful in adequately informing STEM students and preparing them to succeed in those and similar introductory courses. Understanding this influence can also be helpful in aiding high school science teachers by allowing them to reflect upon the courses they teach in preparation of college-bound students.

The current study was designed to determine what, if any, effect previous mathematics and science courses have on student success in those introductory college biology courses required for STEM majors. The insight gained from this study benefits not only the students involved, but also high school teachers and college professors. Both high school teachers and college instructors can use this study to advise their students as to the mathematics and sciences course load that is necessary when preparing for college. To provide this insight, this study examined the influence of the number of science courses taken in high school on success in introductory college biology courses by correlating the number and grade earned in high school mathematics and science courses, particularly biology, to success in their introductory biology course (Principles of Biology (Bio 1480) in the Fall 2012 and Spring 2013 semesters at Angelo State University (ASU).

Research Questions:

This study was designed to answer the following research questions and sub-questions.

- *Question #1:* Does the number of mathematics and science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #1.1:* Does an increased number of mathematics courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #1.2:* Does the number of science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #1.3:* Does the number of biology courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

- *Question #2:* Does the number of science courses with a lab taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #2.1:* Does the total number of science courses with lab time taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

- *Sub-Question #2.2:* Does the number of biology courses with lab time taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

- *Question #3:* Does the number of Advanced/ college placement mathematics and science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #3.1:* Does taking Advanced/ college placement mathematics courses in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #3.2:* Does taking any Advanced/ college placement science courses in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?
    - *Sub-Question #3.3:* Does taking Advanced/ college placement Biology courses in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

Table 1: Definition of Terms

Area	Term	Definition
Student Category	**Successful**	Since there is no agreed upon measure of college success, academic achievement is most frequently used (Camara and Echternacht, 2000). In this study, academic success in the introductory biology courses is considered a final grade of 70% or higher which is equivalent to a 'C'. A grade of 70% or higher is required to take General Zoology which is required continue into upper-level biology courses.
	Unsuccessful	Unsuccessful students in the introductory biology courses are considered having a final grade of 69.99% or lower. This is equivalent to a 'D' or lower in the course.
	Withdrawn	Withdrawn students are those that began the course and completed a questionnaire, but those students withdrew from the course before the end of the semester. The withdrawal can be for any reason.
	Respondents	Those students that completed the questionnaire in its entirety. This term does not refer those students that did not sign the IRB consent form or students that did not initially include student ID numbers on the questionnaire.
Introductory College Biology	**Principles of Biology**	(Bio 1480) This is an introductory college biology course offered at ASU. This course is required by students pursuing a degree in Biology at ASU and many other STEM courses. "An introduction to the unifying principles of biology, including the chemistry of life, cell structure and function, energy, inheritance, development, evolution, and ecology. Laboratory is designed to develop and improve critical thinking and problem solving skills related to the topics discussed in lectures. Intended for the biology major or minor." (ASU, 2011)

Table 1 List and Definition of terms for reference.

Limitations:

This study was conducted only at ASU. The Principle Investigator (PI) did not have access to data from other Texas regional universities. This study was also limited to the two introductory biology courses generally taken by freshmen during their first and second semesters at ASU (Principles of Biology). The PI did not have access to other courses and, therefore, did not analyze other courses.

Study Time Frame

The study took place according to the following time frame.

- August 9, 2012 – IRB consent given to start study
- First Week of Class – August 27 -31, 2011 – permission to use student data from registrar
- August 26, 2012 – Permission to use class time to distribute questionnaires granted by faculty members
- August 27 - 31, 2012 – First week of class, questionnaires distributed in introductory biology course (the Principles of Biology sections)
- December 10 - 14, 2012 – Last week of class, questionnaires distributed in introductory biology courses to self-report predicted course grade
- December 17 -19, 2012 – After finals, faculty provided student grades
- December 20, 2012 – Data analysis began for Fall 2012 students
- January 14 - 18, 2013 – First week of class, questionnaires distributed in introductory biology course (the Principles of Biology sections)
- April 29 – May 3, 2013 – Week before final exams in courses, questionnaires were distributed in introductory biology courses to self-report predicted course grade
- May 13, 2013 – After finals, faculty provided final grades
- May 13, 2013 – Data analysis began for Spring 2013 students and compilation data for both semesters

LITERATURE REVIEW

College readiness is highly related to college success, and research suggests that students should take at least three years of both mathematics and science (ACT, 2008a; Teitelbaum, 2003). Because of the importance of mathematics and science to future success, it is recommended that students take higher–level mathematics and sciences courses in high school, and these higher – level mathematics and science courses will, in turn, help students gain more knowledge and become more proficient in mathematics and science (ACT, 2008a; Robinson and Ochs, 2008; Teitelbaum, 2003). Studies have concluded that the increased number of mathematics and science courses is positively associated with student achievement (Teitelbaum, 2003). According to Teitelbaum (2003), enrollment in mathematics and science courses is a powerful determinant of math and science proficiency. According to Robinson and Ochs (2008), students would be better prepared for college science courses that lead to science, technology, engineering, and mathematics (STEM) careers if they were to achieve a better grounding in mathematics and science.

There exists tremendous support for the strong influence of mathematics and science courses on student success. In 2008, 23 states required 2 years of science and 23 states required 3 years of science. This requirement standard was selected based on national trends and research and also selected to ensure that high school graduates were prepared for opportunities after graduation, whether it be education or employment (Robinson and Ochs, 2008). However, benchmarks associated with success for these mathematics and science course requirements are not always met. In a case where benchmarks for mathematics and science were not met, such as in the study by Hoffer et al. (1996), high school teachers still reported that preparation for further educational study is a major emphasis for the way they teach. In a survey performed by the Peter D. Hart Research Associates and Public Opinion Strategies, 40 percent of high school graduates stated that they were not adequately prepared for employment or post-secondary education (Achieve, 2005). These students also stated that if they could repeat high school, they would work harder, especially in math, science, and English (Achieve, 2005). Many students feel that they should avoid rigorous mathematics and science courses in high school because they believe that earning lower grades in these courses will decrease their chance of being admitted into the college of their choice (Sadler and Tai, 2000); however, Barth states that quality courses completed in high school are a greater predictor of college success than test scores, class rank, and grade point average (Barth, 2003).

In literature on high school to college transitions, a variable found to account for some of the differences in performance is prior coursework taken by the students (Kaufman, 1990). This study stated that the types of courses that students took in high school corresponded to the types of courses the students took in college, and this relationship was stronger in math and science courses than in other courses (Kaufman, 1990). The study by Kaufman (1990) also stated that the high school mathematics and science courses that students take act as a "critical filter" that sifts out students in college who lack that prerequisite high school coursework. These advanced science courses generally consisted of advanced biology, advanced chemistry, and physics while the advanced mathematics courses consisted of advanced algebra, trigonometry, and calculus (Kaufman, 1990). Mastery of mathematics and science is seen as a series of building blocks that provides a foundation for the next courses, and students that lacked these building blocks, especially in the subject areas that required solid math and science skills such as engineering, health science, and natural sciences, were less likely to overcome this lack of preparation (Kaufman, 1990).

According to college professors and employers, to be successful beyond high school, graduates should have mastered content taught in the four-year rigorous mathematics sequence of Algebra I, Geometry, Algebra II, as well as analysis and statistics (Achieve, 2004). A study performed by Lewerke et al. (2004) found that academic preparation, measured through the ACT mathematics score, predicted persistence in majors of entering engineering students. Gifford and Harpole (1968) found that higher high school math grades were also associated with high grades in college physics. Hart and Cottle (1993) found that high performing students in college physics at Florida State University had performed well in high school math. Sadler and Tai (2000) found that taking a calculus course in high school was highly correlated with doing well in college physics. This study also determined that students with strong math preparation could equal and even outperform students that had only taken physics in high school.

Academic success in first-year college science coursework can strongly influence the future career paths of students (Breckler et al., 2011). Introductory biology courses provide the essential foundation and act as scientific 'gateways' for students hoping to enter science and health professional careers, and failure in these courses narrows career options and pushes students toward non-science fields (Wood, 2009; Sadler and Tai, 2000; Labov, 2004). Those students who plan to pursue college sciences in general are encouraged to prepare with high school courses in biology, chemistry, and physics (Sadler and Tai, 2000) because dropout and failure rates are extremely high in these “gate-keeping” college courses (Gainen, 1995).

The study by Gifford and Harpole (1986) found that taking high school physics courses and high amounts of laboratory time in high school were associated with high performance in college physics. The study by Hart and Cottle (1993) found that high performing students in college physics at Florida State University had also taken high school physics. This relates to the study by Sadler and Tai (2000) which determined that taking high school physics was related to better performance in introductory physics at the college level. Additionally, students in more rigorous high school physic courses performed, on average, better in introductory college physics (Sadler and Tai, 2000).

Given that prior academic achievement has been found to have a large influence on the performance and success of students in the freshman year of college, the relationship between high school biology and mathematics courses and college biology courses is a very important issue to study (Evans and Farley, 1998). One would think, as Boon and Reid (2011), that completion of biology at the senior high school level would be an important predictor of achievement level in introductory biology classes. In the study by Boon and Reid (2011), students performed best when they had completed biology in conjunction with chemistry in the senior year. Boon and Reid (2011) suggested that students needed a sound knowledge in fundamental chemistry to fully understand the concepts presented in biology courses and that students that had only taken biology in their senior year may have a lower scientific literacy than those that had taken biology along with chemistry and other sciences. However, in the study by Boon and Reid (2011), there was no mention of the influence of biology and mathematics high school courses on college biology success. This relationship between prior coursework and success was even noted as early as 1969 in the study by Tamir (1969). In the study by Tamir (1969), it was demonstrated that students who had no biology in high school were at a distinct disadvantage in college compared to those students that took biology and chemistry in high school (Tamir, 1969). Like Boon and Reid (2011), that study determined that there existed a clear relationship between biology and chemistry achievement in high school and success in college biology, and these courses appear to be very valuable (Tamir, 1969).

This study also examines the influence of Advanced Placement (AP) high school coursework on student success in the Principles of Biology introductory college biology course at ASU. To truly understand the influence of AP coursework, one must understand the general procedure behind the AP process. When a student takes an AP examination in high school, he or she hopes to receive credit for (and the ability to bypass) a particular introductory college level course in which the exam tests (Sadler and Tai, 2007; College Board, 2004). The university then uses the scores on this exam to determine whether or not the student will receive AP or college credit at that university (College Board, 2004). How much credit or AP that is awarded is left up to the discretion of the university (Sadler and Tai, 2007, College Board, 2004). The AP course-taking process generally appeals to highly motivated students that wish to earn college credit while in high school (Sadler and Tai, 2004). In a previous study, Champagne and Klopfer (1982) analyzed 110 physics students using multiple regressions which revealed that high school math and physics courses (even AP Physics (AP Physics)) were not a significant factor in predicting student performance in the University of Pittsburgh physics class (Sadler and Tai, 2000; Champagne and Klopfer, 1982).

METHOD

IRB

This study was conducted in accordance with guidelines set forth by the Institutional Research Board (IRB) of ASU (Appendix A). The process and questionnaire instruments were approved by the IRB at the university. Participation was voluntary and responses were anonymous. Students were asked to sign a consent form in order to allow the PI to gain access and use of data routinely collected upon admission to the university (Appendix A). This data included college GPA, number of transfer courses previously taken, number of previous college courses taken at ASU, AP college credit, and number of dual credit courses taken while in high school.

Research Design

This study utilized questionnaires (Appendix B) to help quantify the relationship between high school mathematics and science courses and introductory college biology by determining the number of science and mathematics courses taken in high school by each student respondent in the Principles of Biology (Fall 2012 and Spring 2013) course at ASU. Answers to this questionnaire were compared to the success of students in each course.

Questionnaires

The PI obtained permission from the instructors of the Principles of Biology course (during the Fall 2012 and the Spring 2013 semesters) to use class time to administer the questionnaires designed for this study (Appendix B). To determine the high school course background and general background information of the respondents, a 36-question questionnaire that contained specific questions relating to the number of science and mathematics courses taken in high school, the grade received, perceptions about teacher and methods, and lab experience in high school were used (Appendix B).

The questionnaires were distributed in all sections of the Principles of Biology courses at ASU (Bio 1480) during the Fall 2012 and Spring 2013 semesters. The questionnaires were completed in a normal class setting in which the PI discussed the purpose behind the questionnaires and the general manner for completing the questionnaires before distributing them. The students had as much time as desired to complete the questionnaires. Only the PI retrieved the questionnaires. The PI received the data concerning grades after finals for the fall and spring semester (2012 and 2013). These self-report questionnaires are reasonably reliable, and when encoded in an organized fashion, they can be reliably accurate (Oetting and Beauvais, 1990; Sadler and Tai, 2000; Bradburn 2000). It was understood that questionnaires are dependent on the respondents' accurate recall of past experiences. This type of survey, where students recall the frequencies of events, are preferred over strictly subjective surveys and increases the accuracy of self-reports by "deceasing cognitive effort required" (Sadler and Tai, 2000; Menon and Yorkston, 2000).

The completed forms were not seen by the instructor in order to maintain the anonymity of the students. Student questionnaires were initially matched by student ID numbers. These questionnaires were handled entirely by the PI. Once matched data from questionnaires had been converted to electronic spreadsheets, a randomized ID number was assigned to the data and the student ID numbers were deleted. The PI maintained a copy of the list containing the student ID number matched to the randomized number. This list was compiled in order to match and compare the final grades. However, once the randomized number was attached to the student and the student ID number was removed, there was no way to associate the data with the individual student from questionnaires except through the PI. Once original questionnaires were checked for accuracy and data entry was completed, the original hard copies of records were stored in a locked filing cabinet and only accessed by the PI. Upon completion of the study and after the mandatory 5 year period, all original questionnaires will be shredded. The randomized ID number was the only identifying feature used in the analysis.

Respondents

Descriptive statistics for the respondents were calculated for all variables (Appendix C). All variables were coded using a dummy variable in order to allow the linear regressions as the primary analysis tool. All respondents enrolled in the ASU course sections of Principles of Biology in the Fall 2012 and Spring 2013 semesters were invited to participate in the study. Outcomes for the study were based on 272 (N=272) respondents. That included 187 Bio 1480 students in the fall and 85 Bio 1480 students in the spring (Appendix C). The questionnaire subjects ranged in time since they had high school biology and mathematics from less than one year to twenty years. Since educational experiments rarely have full control over variables or the ability to randomly choose or assign subjects, the methodology for this study is considered epidemiological rather than experimental (Sadler and Tai, 2000). For this reason, I relied on the natural variation in the experiences, backgrounds and decisions of this sample of college students rather than explicit comparison of control groups (Sadler and Tai, 2000). For example, the students sample varied greatly in the kind, intensity, and structure of high school biology course taken along with a varied demographic background. For this reason, this study cannot claim any causal connection. For this reason, the results of this study must be reviewed carefully to prevent any misunderstandings.

Those students that were enrolled in the Fall 2012 semester, completed the questionnaire, were unsuccessful during that original fall attempt, re-enrolled for the course in the spring semester, and completed the questionnaire and course in the Spring 2013 semester were analyzed separately to ensure that those individuals were not analyzed twice. Those results were compared to the group data. Students that withdrew by the end of either the fall or spring semester were removed due to the variation present within that student group. There was no way to determine if these students withdrew due to class pressures or due to personal reasons (financial, family, etc.). Those students that completed the questionnaire at the beginning of the Fall 2012 term and withdrew before the end of the fall semester but re-enrolled for the Principles of Biology course and completed the questionnaire and the course in the Spring 2013 semester were only analyzed as part of the spring students. That group of students was not analyzed twice.

Courses

The total coursework number does not include courses taken as dual high school and college credit nor does it include courses taken at another college and considered transfer credit due to the fact that these course types are given college credit at ASU. For the purpose of this study, those two course types were accounted for in the statistical comparison of students' backgrounds.

While the actual AP courses were counted toward the total number of subject area science or mathematics courses taken in high school, to answer question 3, concerning AP courses, only the students that received AP college credit (3 + hours) for taking AP high school coursework and passing the AP exam were provided a 1 and analyzed as such. This is because not all high schools require students enrolled in an AP course to take the AP exam. Even in a curriculum labeled as "advanced," the curriculum requirements for graduation may fall short of what students actually need to succeed in a college class (The Education Trust, 2003). A large number of students taking an introductory science course that have done well in AP science courses while in high school, may not "place out" in college (Sadler and Tai, 2007). This method ensured that the analysis for question 3 of students that had actually taken an AP course and the appropriate exam were accurate.

The list of students that received college credit for taking the AP exams was provided by ASU. At ASU, those students that do well enough to earn college credit for biology after taking and passing the AP exam only earn college credit for the non-majors biology course and lab at ASU, not the majors course; however, one would believe as Sadler and Tai (2007), that students that pass the AP examination would earn substantially higher grades, on average, when taking the majors course at the college level. There is a great deal of interest in the value of the AP courses in the sciences and mathematics (Sadler and Tai, 2007). For this reason, this study will exam the influence that AP calculus, AP science courses in general, and AP biology have on success in the Principles of Biology course at ASU.

High school mathematics courses analyzed, titled, and considered as "Math" for the purpose of this study were the following: pre-Algebra, Algebra, Algebra 2, Geometry, Trigonometry (Trig), Pre-Calculus (Pre-Cal), Calculus, Calculus 2, Advanced Placement Calculus (AP Calculus), and Other Mathematics courses (including but not limited to statistics, etc.). This was based on students' self-reported course titles. The total number of mathematics classes taken by a student would be calculated as '1' per each of the mathematics courses taken while in high school from the list above. If a student reported that he took Algebra, Trigonometry, and Geometry, that student would have a total number of mathematics courses equal to 3.

High school biology courses analyzed, titled, and considered as "Biology" for the purpose of this study were the following: Biology 1, Biology 2, Biology 3, Pre-Advanced Placement Biology (Pre-AP Biology), Advanced Placement Biology (AP Biology), Anatomy, Physiology, Anatomy and Physiology (combination course), and Other Biology (including but not limited to Microbiology, Marine Biology, etc.). This was based on students' self-reported course titles. The total number of biology classes taken by a student would be calculated as '1' per each of the biology courses taken while in high school from the list above.

High school chemistry courses analyzed, titled, and considered as "Chemistry" for the purpose of this study were the following: Chemistry 1, Chemistry 2, Pre-Advanced Placement Chemistry (Pre-AP Chemistry), Advanced Placement Chemistry (AP Chemistry), and Other Chemistry. This was based on students' self-reported course titles. The total number of chemistry classes taken by a student would be calculated as '1' per each of the chemistry courses taken while in high school from the list above. High school physics courses analyzed, titled, and considered as "Physics" for the purpose of this study were the following: Physics 1, Physics 2, Pre-Advanced Placement Physics (Pre-AP Physics), Advanced Placement Physics (AP Physics), and Other Physics. This was based on students' self-reported course titles. The total number of physics classes taken by a student would be calculated as '1' per each of the physics courses taken while in high school from the list above.

Other high school science courses analyzed, titled, and considered as "Other Science" for the purpose of this study were the following: Physical Science, Environmental Science, Introduction to Physics and Chemistry (IPC), and any other sciences that were not previously categorized as Biology, Chemistry, or Physics and were not categorized under "Other Science" as Physical Science, Environmental Science, or IPC. This was based on students' self-reported course titles. The total number of other science classes taken by a student would be calculated as '1' per each of the chemistry courses taken while in high school from the list above.

Data Collection Method

Since there is no agreed upon measure of college success, academic achievement is most frequently used (Camara and Echternacht, 2000). Academic grades were chosen as the measure of students success because, during the course, it is the professor that provides feedback in the form of grades to his or her students (Sadler and Tai, 2000), and this is the teacher's measure of a student's level of understanding of biology taught and whether he/ she feels that the students should pursue further study. Academic grades in introductory college courses are not the only measure of student achievement; however, they are the most accessible form and a universal measure (Sadler and Tai, 2000). Course grades also represent the completion by students of teacher –assigned objectives that are generally made clear from the beginning of the semester (Tai et al., 2005). Both instructors for the Principles of Biology course at ASU operate from the same syllabus, and therefore, all objectives are clear and stated from the beginning of not just one section but all sections. Courses grades also serve as a summative assessment of student performance (Tai et al., 2005).

Personnel and Facilities Needed

This study took place at ASU, located in San Angelo, Texas, USA. The study required cooperation between the students and professors of the Principles of Biology course. This included two lecture instructors that taught both Fall 2012 and Spring 2013 semesters of Principles of Biology.

Semester Statistical Similarities Analysis

To determine if combining the semesters' data was appropriate, t-tests and Kruskal-Wallis (or the non-parametric equivalent) were performed over student background compilation data. Kruskal-Wallis test was only performed when comparing the three group divisions that included successful, unsuccessful, and withdrawn students. Summary statistics were determined from overall group data for both the Fall 2012 and Spring 2013 Principles of Biology course (Appendix C).The summary statistics on student background data were used to determine if a significant difference existed between the two semesters and the three groups. The background variables compared were the age of the students, the high school type attended, the community size, sex ratios, number of courses taken at ASU prior to the current semester, classification composition, ethnicity, high school graduating class size, and the number of years since senior year in high school.

Data Analysis

Regression techniques are routinely used in this field to reveal underlying relationships that may otherwise be hidden by covariates (Sadler and Tai, 2000; Lee, 1983; Reynolds and Walberg, 1992). For this reason responses to the questionnaires were analyzed using binomial generalized linear regressions, multinomial linear regressions, and student t-tests. The comparisons between the successful versus unsuccessful students in the terms were made using a Wilcoxon Two-Sample t-test. This test was chosen because it is the non-parametric analog to the two-sample t-test. Due to the design of the study, most of the data followed a binomial distribution, and they were, therefore, non-normal. The Wilcoxon Two-Sample t-test is based on ranks. Attitude measures were not included as predictive variables because attitude is too closely tied to performance as an outcome variable (Sadler and Tai, 2000). There is previous research on demographic information, in which the following variables account for some differences in performance (Sadler and Tai, 2000): gender (Kahle, 1992; Maple, 1991; Linn and Hyde, 1989; Sadler and Tai, 2001), race (Maple, 1991), parents' education (National Center for Educational Statistics, 1992, 1995), school size, whether it is public or private, school affluence (National Center for Educational Statistics, 1995; Neuschatz & McFarling, 1999), school course offerings (Neuschatz & McFarling, 1999), and prior coursework taken by students (Kaufman, 1990). To address these variables, background information was included in the questionnaires.

Missing responses for this type of questionnaire are very common because data is collected from many sources (Tai et al., 2005). Missing responses were treated as missing. If a student did not select an answer on the background portion of the questionnaire, it was considered missing. However, if a student did not list a science course under one of the science questions, that student was provided a value of '0'. For example, if a student did not list any chemistry courses under the Chemistry question, this student received a value of '0' for the Total number of Chemistry Courses taken. This was not determined to be a missing value because of the way the questionnaire was set up. The student was presumed to have completed zero chemistry classes while in high school and therefore left that section blank. However, if a student skipped the remainder of the questionnaire after that question, that data was deemed missing instead of receiving a value of '0'. All data was analyzed using the free R-project statistical software (R-Project, 2012). All data and tables were organized and compiled using the Microsoft Office Excel program (2010).

To answer *Question 1*, this study compared the number of high school mathematics, biology, chemistry, physics, and other science courses taken by successful students, as defined above as a grade earned of a C average or better, to those of unsuccessful students to determine if a correlation exists (Table 1). A more specific comparison was made between the number, and therefore increased level, of high school biology courses taken by successful students and those taken by unsuccessful students. To answer *Question 2*, a comparison was made between the numbers of science courses with lab time taken by successful students to the number taken by unsuccessful students. A more specific comparison was made between the number of high school biology courses with lab time taken by successful students and those taken by unsuccessful students. To answer *Question 3*, a comparison was made between the number of Advanced Placement mathematics and science courses taken by successful students to the number taken by unsuccessful students. A more specific comparison between the numbers of Advance Placement biology courses taken by successful students to the number taken by unsuccessful students was also made.

For each of the individual comparisons made, a separate analysis was made using individual groups of those students that were successful, unsuccessful, and withdrawn (Table 1 and Appendix C). Those students that withdrew from the introductory biology courses required for STEM majors before the end of the semester were analyzed as a separate group during this second set of comparisons to determine if a correlation existed between that student group and the number of mathematics and science courses those withdrawal students have taken; however, due to the large amount of student variation within this group in the data, these students were removed. Because the reason for student withdrawal could not be determined for each of the students, the PI felt confident that this removal was acceptable and would not hinder the study. This removal of the withdrawal student group decreased the total sample size from 272 to 229 (N = 229; Fall = 160; Spring = 69).

It was originally proposed that the data analysis for the spring semester was to only be based on grade averages calculated from the first two exams. Due to the lack of a strong correlation between the Fall 2012 student averages after the first two exams and the final average of the students after the end of the Fall semester, only students' final grades could be used. Statistical similarities of the two semesters of Biology 1480 were determined in order to see if student composition was comparable.

Specific Data Analysis Procedures

To answer *Question 1*: *Does the number of mathematics and science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?,* generalized linear regressions and t-tests (or the non-parametric equivalent) were performed to answer the three sub-questions and conclusions were drawn. To answer *Sub-Question 1.1: Does the number of mathematics courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?,* a generalized linear regression including the number of mathematics courses and the number of science courses as variables was performed to determine if the total number of mathematics courses taken by a student high school was a significant predictor of success. The generalized regression included the number of mathematics courses, the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses taken in high school as variables. To determine if the total number of mathematics courses were significant predictors of success for comparing successful to unsuccessful students, the regression was run two ways: one including a mathematics course number interaction terms and one not including interaction terms. This form of regression was also run including all non-background questions as variables to determine if the total number of mathematics courses were significant predictors of success. Because the data was non-parametric, a Two-Sample Wilcoxon test was performed to determine if there was a significant difference between the number of mathematics courses taken by successful versus unsuccessful students.

To answer *Sub-Question #1.2: Does the number of science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?* A binomial generalized regression was run including the number of mathematics courses and the number of science courses as variables to determine if the total number of science courses taken is a significant predictor of success for comparing successful versus unsuccessful students. The regressions were also run including all non-background questions as variables to determine if the total number of science courses taken were significant predictors of success. Because the data was non-parametric, a Two-Sample Wilcoxon test was run to determine if there was a significant difference between the number of science courses taken by successful versus unsuccessful students.

To answer *Sub-Question #1.3: Does the number of biology courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?,* a binomial generalized linear regression was performed to include the number of mathematics courses and the number of biology courses taken as variables to determine if the total number of biology courses were significant predictors of success. The regression included the number of mathematics courses, the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses as variables to determine if the total number of biology courses were significant predictors of success. This regression type was run two ways: including math interaction term and not including a math interaction term. Also, a regression including the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses as variables was run to determine if the total number of biology courses were significant predictors of success. A Two-Sample Wilcoxon test was also run to determine if there was a significant difference between the number of biology courses taken by successful versus unsuccessful students.

To answer *Question #2: Does the number of science courses with a lab taken by a student in high school increase the likelihood of being successful in the introductory college* *biology course required for STEM majors offered at ASU?,* Two-Sample Wilcoxon tests were run to answer the two sub-questions. These tests were run on the sub-questions to aid in supporting a conclusion concerning the effect that the number of science courses with a lab taken by a student in high school has on success in introductory biology courses required for STEM majors offered at ASU. In order to answer *Sub-Question #2.1: Does the total number of science courses with lab time taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?,* a Two-Sample Wilcoxon test was run to determine if there was a significant difference between the number of science courses with lab time taken by successful versus unsuccessful students. To answer *Sub-Question #2.2: Does the number of biology courses with lab time taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?,* a two-sample Wilcoxon test was run to determine if there was a significant difference between the number of biology courses with lab time taken by successful versus unsuccessful students.

To answer *Question #3: Does the number of Advanced/ college placement mathematics and science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?,* binomial generalized regressions were run along with a Two sample Wilcoxon test to answer the three sub-questions. These tests were run on the sub-questions to aid in supporting a conclusion concerning the effect that the number Advanced/ college placement mathematics and science courses taken by a student in high school has on success in introductory biology courses required for STEM majors offered at ASU. To answer *Sub-Question #3.1: Does taking Advanced/ college placement mathematics courses in high school* *increase success in the introductory biology courses required for STEM majors offered at ASU?,* a binomial generalized regression was run including the number of pre-Algebra, Algebra, Algebra 2, Geometry, Trigonometry (Trig), Pre-Calculus (Pre-Cal), Calculus, Calculus 2, Advanced Placement Calculus (AP Calculus), and Other Mathematics courses as variables to determine if the total number of AP mathematics courses were significant predictors of success. A generalized linear regression was also run including all non-background questions as variables to determine if the total number of Advanced/ college placement mathematics courses taken were significant predictors of success. Also, a two-sample Wilcoxon test was run to determine if there was a significant difference between the number of AP mathematics courses taken by successful versus unsuccessful students. This Two-Sample Wilcoxon test run on one sets of data variables including the number of AP mathematics courses.

To answer *Sub-Question #3.2: Does taking any Advanced/ college placement science courses in high school increase success in the introductory biology courses required for STEM majors offered at ASU*?, a binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of Advanced/ college placement science courses taken were significant predictors of success. A Two-Sample Wilcoxon test was run to determine if there was a significant difference between the number of AP science courses taken by successful versus unsuccessful students. This test was also run on just one set of data variables including just the number of AP science courses.

To answer *Sub-Question #3.3: Does taking Advanced/ college placement Biology courses in high school increase success in the introductory biology courses required for STEM majors offered at ASU?,* a binomial generalized linear regression was run including the number of Biology 1, Biology 2, Biology 3, Pre-Advanced Placement Biology (Pre-AP Biology), Advanced Placement Biology (AP Biology), Anatomy, Physiology, Anatomy and Physiology (combination course), and Other Biology courses as variables to determine if the total number of AP biology courses were significant predictors of success. The generalized linear regressions were also run including all non-background questions as variables to determine if the total number of Advanced/ college placement biology courses taken were significant predictors of success. This was followed by running the Two-Sample Wilcoxon test to determine if there was a significant difference between the number of AP biology courses taken by successful versus unsuccessful students.

For each of the generalized linear regression models run for the compilation data that included both the fall and spring student group, a separate analysis was run to determine if taking the course in different semester terms had a significant effect. Even though there may not exist a significant difference within the individual background and student composition variables (see the *Semester Statistical Similarities Analysis* of the Results section) there may be slight student composition differences between the semesters that may account for some of the variation within the regression. To account for this variation and to determine if within some regression models there are differences, the semester term variable was included. Although the PI would have preferred to run a mixed effects model to account for this variation, this was not possible due to sample size and students' coursework backgrounds.

RESULTS

Student Demographics

The students come from a wide variety of backgrounds (Appendix C). Students in the Principles of Biology course at ASU are primarily freshmen from public schools with the largest majority of students being Caucasian (Appendix C). However, over one-quarter of the students were Hispanic in each semester (Appendix C). The male to female ratio varied between semesters with students from the fall semester being approximately 40 % male and 60 % female and students from the spring semester being approximately half male and half female (Appendix C). The largest percentage of students in each semester were from a small town. The parental education level of the students varied. Over three-fourths of the students in each semester completed 4 mathematics classes (Appendix C). Around 50% of the students had only taken 1 biology class while in high school(Appendix C). Over 80% of the students in each semester took at least one chemistry class while having taking a physics class while in high school varied between the semesters (fall = 72%; spring= 58%)(Appendix C). Around 20% of students in each semester had taken 4 science classes with a lab time. Less than 10% of students in both semesters had taken 2 biology classes with lab time (Appendix C). Less than 15% of students in both semesters had taken AP biology while in high school (Appendix C).

Statistical Similarities Analysis

The following table provides the statistical results from the two –sample comparison tests between each semester of the background variables. The parametric test run was the student's t-test. The non-parametric test was the Wilcoxon Signed Rank Test.

Background Variable	
Age	(t-test) t = 1.1004, df = 6, p-value = 0.3133
High School Type	(Wilcoxon Signed Rank) V = 3, p-value = 0.3711
Sex	V = 3, p-value = 0.3711
ASU Past STEM Courses	V = 0, p-value = 0.5
Classification	t = 0.9326, df = 5, p-value = 0.3938
Community Type	t = 2.0338, df = 5, p-value = 0.09763
Ethnicity	V = 12, p-value = 0.2785
High School Graduating Class Size	t = 2.0338, df = 5, p-value = 0.09763
Years Since Graduating High School	V = 27.5, p-value = 0.592

Table 2 Statistical results from the two –sample comparison tests between background variables of students within the two semesters

To determine if the two semesters' data could be combined, the background variables including the age of the students, the high school type attended, the community size, the sex ratios, the number of courses taken at ASU prior to the current semester, the students' classification, ethnicity, the students' high school graduating class size, and the number of years since senior year in high school were compared using t-tests. Based on the analyzed background of all of these variables, it was determined that the two groups could be combined. Therefore, separate analyses (including multinomial linear regression) were conducted on the fall Principles of Biology course and spring Principles of Biology courses. However, when all generalized linear regressions were run including the semester term (fall versus spring) as a variable (to determine if the semester term variable has a significant effect), the variable had a significant effect in each regression model. The semester term variable remained in every generalized linear regression throughout the model simplification process. For this reason, the two Biology 1480 groups were analyzed separately and major conclusions drawn.

Specific Data Analysis Results

An example process for determining the probability of success is presented in the table below. This table provides the original natural log of the odds results and follows the process through to the determination of the probability of success.

Example Process

	Process	Example		
		Intercept	# of Biology Classes	# of Mathematics Classes
Natural Log of Odd Ratio	Variable coefficient = x	-0.02258	0.13245	0.11902
Odds Ratio	OR = exp (x)	0.9777	1.1437	1.1264
Probability	OR / (1+ OR)	0.4944	0.5335	0.5297

Table 3 Step-by-Step break-down for Processing Results

The comparison for the binomial generalized linear regression was made against the unsuccessful students. Therefore, the regression conclusions can only be made in comparison to the unsuccessful students. For instance in Table 3, if the probability of student success was 52.97% for the mathematics courses taken in high school, this can only be interpreted that a student is 52.97% less likely to be unsuccessful for each additional mathematics course taken when all other variables are held constant. The initial probability of success after increasing the number of mathematics courses taken in high school by 1 mathematics course is originally based on the number of courses taken under each variable category in high school. In order to calculate the probability of success, it is based on the number of courses a student takes. One must use the original natural log of the odds equation from the original model simplification. After plugging in the value for the number of mathematics and science courses taken in high school, follow the general process break-down laid down in Table 3.

Due to the development and model simplification process of the binomial generalized linear regression and the fact that the unsuccessful students were the base comparison group, the results must be stated representing that relationship. For example, "a student is 52.97% less likely to be unsuccessful for each additional mathematics course taken when all other variables are held constant" is the most accurate way to state the binomial generalized linear regression relationship between the variables. However, due to the difficulty in interpreting the double negative, all subsequent results are worded in the positive for clarity. For example, "a student is 52.97% more likely to be successful for each additional mathematics course taken when all other variables are held constant".

Question 1: Does the number of mathematics and science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU? (Process break-down is available in Table 3, Appendix D, and Appendix E)

Sub-Question 1.1: "Does the number of mathematics courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?"

A.) A binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of mathematics, general science courses, or biology courses taken were significant predictors of success. However, due to the variation in the student course background and the fact that students could take a wide range of courses, the sample size obtained was not large enough to complete the model simplification process. For this reason, there is not a complete simplified model that included all non-background variables to determine which out of ALL variables have a significant effect. This is why individual generalized linear regression models were created and analyzed. The following models represent this process.

B.) Success = Total # of Mathematics class * Total # of Science classes taken

The results of the generalized linear regression run that included just the total number of mathematics and total number of science courses taken as variables are presented in the table below. The identification number 1.1.B mentioned in Appendices D and E also corresponds to data presented here.

Probability for Success			
Semester Term	Intercept	Total # of Mathematics Courses	Total # of Science Courses
Fall	0.1521	0	0.6462
Spring	1	0	0

Table 4 Probability for success results for the generalized linear regression including just the total number of mathematics and total number of science courses taken as variables.

To answer the question as to whether or not the total number of mathematics courses taken in high school has a significant effect on success, with the binomial generalized linear regression presented here, it was determined that, in the fall semester, a student was not any more likely to be successful for each additional math class taken and a student was 64.6 % more likely to be successful for each additional science class taken. In the spring, a student was not any more likely to be successful for each additional math or science class. (Table 4)

C.) Success = Total # of Mathematics class * Total # of Biology classes taken

The results of the generalized linear regression run that included just the total number of mathematics and total number of biology courses taken as variables are presented in the table below. The identification number 1.1.C mentioned earlier in Appendix D and Appendix E also corresponds to the write-up portion presented here.

Probability for Success			
Semester Term	Intercept	Total # of Mathematics Courses	Total # of Biology Courses
Fall	0.0821	0.6284	0.6591
Spring	0.9768	0.3706	0.3754

Table 5 Probability for success results for the generalized linear regression including just the total number of mathematics and total number of biology courses taken as variables.

To answer the question as to whether or not the total number of mathematics courses taken in high school has a significant effect on success, it was determined that, a student was 62.8 % more likely to be successful student for each additional math class taken and a student was 65.9 % more likely to be successful for each additional biology class taken. In the spring, a student was 37.1 % more likely to be successful student for each additional math class taken and a student was 37.5% more likely to be successful for each additional biology class taken (Table 5). Overall, this table provides data for the importance of high school mathematics courses in influencing the success of students in the introductory Principles of Biology course at ASU.

D.) Success = Total # of Mathematics class+ Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken

The results of the generalized linear regression run that included the number of mathematics courses, the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses as variables are presented in the table below. The identification number 1.1.D mentioned earlier in Appendices D and E also corresponds to the write-up portion presented here.

Probability for Success						
Semester Term	Intercept	Total # of Math Courses	Total # of Biology Courses	Total # of Chemistry Courses	Total # of Physics Courses	Total # of Other Science Courses
Fall	0.4944	0.5297	0.5335	0	0	0
Spring	0.6691	0.5471	0.468	0	0	0

Table 6 Probability for success results for the generalized linear regression including just the number of mathematics and total numbers of each science course taken as variables.

To answer the question as to whether or not the total number of mathematics courses taken in high school has significant effect on success, it was determined that, in the fall semester, a student was 52.9 % more likely to be successful for each additional math class taken, a student was 53.4 % more likely to be successful for each additional biology class taken, a student was not any more likely to be unsuccessful for each additional chemistry, physics, and other science class taken. In the spring, a student was 54.7 % more likely to be successful student for each additional math class taken, a student was 46.8% more likely to be successful for each additional biology class taken, and a student was not any more likely to be successful for each additional chemistry, physics, and other science class taken (Table 6). This is another table that provides support for the importance of high school mathematics courses in influencing the success of students in the introductory Principles of Biology course at ASU by presenting that the number of mathematics courses taken has a significant effect on success.

E.) Success = Total # of Mathematics class+ Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken+ Mathematics course # *(Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken)

The results of the generalized linear regression run that included the number of mathematics courses, the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses as variables are presented in the table below. The identification number 1.1.E mentioned earlier in Appendices D and E also correspond to the write-up portion presented here.

Probability for Success						
Semester Term	Intercept	Total # of Math Courses	Total # of Biology Courses	Total # of Chemistry Courses	Total # of Physics Courses	Total # of Other Science Courses
Fall	0.4944	0.5297	0.5335	0	0	0
Spring	0.6691	0	0.4683	0.5469	0	0

Table 7 Probability for success results for the generalized linear regression including just the number of mathematics and total numbers of each science course taken plus a mathematics course number interaction term per each science course as variables.

To answer the question as to whether or not the total number of mathematics courses taken in high school have a significant effect on success, it was determined that, in the fall semester, a student was 52.9 % more likely to be successful for each additional math class taken, a student was 53.4 % more likely to be successful for each additional biology class taken, a student was not any more likely to be unsuccessful for each additional chemistry, physics, and other science class taken. In the spring, a student was 46.8% more likely to be successful for each additional biology class taken, a student was 54.7% more likely to be successful for each additional chemistry class taken, and a student was not any more likely to be successful for each additional mathematics, physics, and other science class taken (Table 7). Although not as evident in the Spring 2013 term, this table provides support for the importance of high school mathematics courses in influencing the success of students in the Fall 2012 semester.

F.) Wilcoxon Signed Rank Test for the Number of Mathematics Courses Taken

Because the data was non-parametric (Fall: $p= <0.00001$ ($W=0.5733$); Spring: $p= <0.00001$ ($W=0.6307$)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of mathematics courses taken by successful versus unsuccessful students. The results are presented in the table below.

Number of Mathematics Courses		
Average Number of Courses	Fall	Spring
Successful	3.834651	3.563636
Unsuccessful	3.561404	3.85
Wilcoxon Value with P-value	0.02066 (W=3418)	0.1914 (W=461.5)

Table 8 Wilcoxon Signed Rank Test results from a comparison between the number of mathematics courses taken by successful and unsuccessful students.

In the fall, there did exist a significant difference between the mean number of mathematics courses taken by successful students versus the mean number of mathematics courses taken by unsuccessful students with the higher mean number of mathematics courses falling to the successful students (p=0.02; W= 3418). However, in the spring there did not exist a significant difference between the number of mathematics courses taken by successful students versus the number of mathematics courses taken by unsuccessful students (p=0.19; W= 461.5). (Table 8)

G.) Bar Graph of Percentages of Students Taking A Specific Number of Mathematics Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of mathematics courses taken. For example, out of the entire Fall Unsuccessful student group, 0% had taken 5 or more mathematics courses while in high school and 70% had taken 4 mathematics courses while in high school.

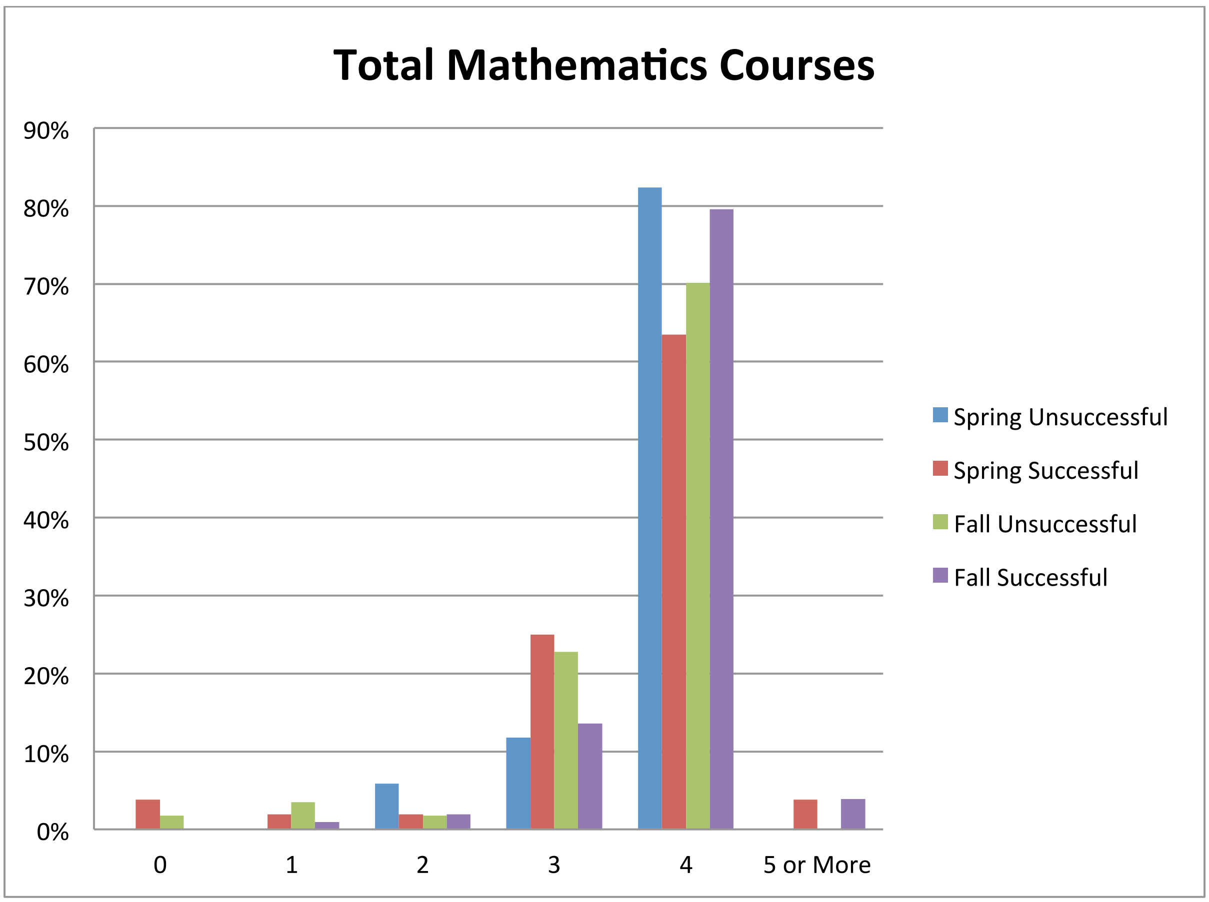

Figure 1 Bar graph of percentages of students taking a specific number of mathematics courses

This graph appropriately demonstrates the trend observed in the binomial generalized linear regressions. 100% of the unsuccessful Fall 2012 and Spring 2013 students had only taken 4 or fewer mathematics courses in high school whereas 67% of the Spring 2013 successful students and 84% of the Fall 2012 successful students had taken 4 or more mathematics courses in high school.

H.) Bar Graph Representing a Specific Number of Mathematics Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of mathematics courses and the group and semester in which they belong. For example, out of all the students that participated in this study that took 5 or More mathematics courses while in high school, 100% were successful (67% in the Fall; 33% in the Spring).

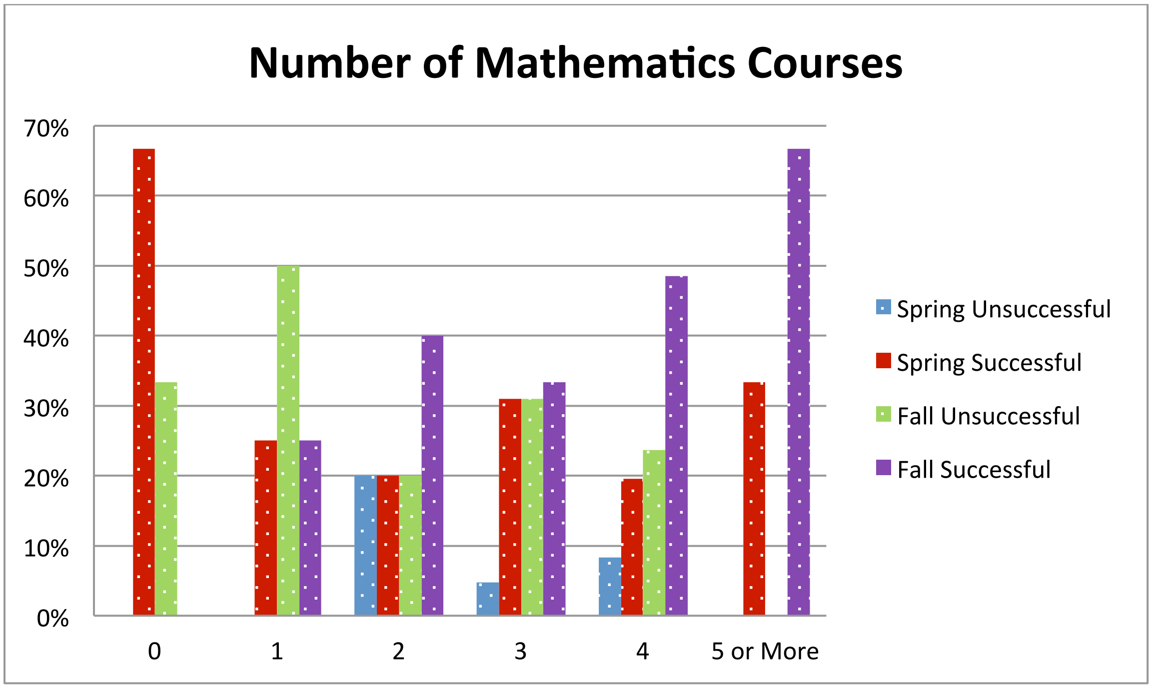

Figure 2 Bar graph representing the specific number of mathematics courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

This graph also demonstrates the trend of an increased number of mathematics courses taken in high school decreasing the likelihood of being unsuccessful. Figure 2 also adds support to this conclusion, in that 69% of the students that had taken 4 mathematics courses were successful.

I.) Bar Graph Representing a Specific Number of Mathematics Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of mathematics courses and the group in which they belong. For example, out of all the students that participated in this study that took 5 or More mathematics courses while in high school, 100% were successful.

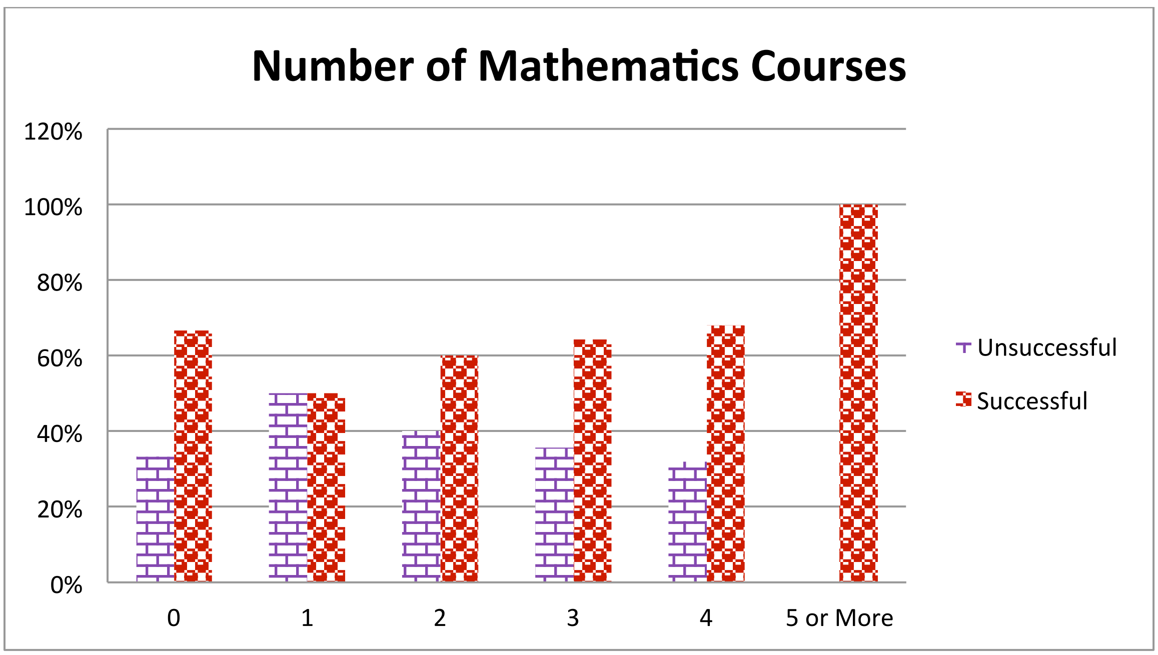

Figure 3 Bar graph representing a specific number of mathematics courses taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

This graph also demonstrates the trend of an increased number of mathematics courses taken in high school decreasing the likelihood of being unsuccessful. Figure 3 also supports this in that 100% of the students that had taken 5 or more mathematics courses were successful.

Sub-Question #1.2: Does the number of science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

A.) A binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of mathematics, general science courses, or biology courses taken were significant predictors of success. (See 1.1.A earlier in the Results section)

B.) Success = Total # of Mathematics class * Total # of Science classes taken

A binomial generalized linear regression was run to include the number of mathematics courses and the total number of science courses as variables in order to determine if the number of science courses taken by a student in high school decreases the likelihood of being unsuccessful in the introductory college biology course required for STEM majors. (See 1.1.B previously in the Results section). Overall, table 4 provides support for the importance of high school science courses in influencing the success of students in the introductory Principles of Biology course at ASU. In the fall, the number of science courses taken in high school was a significant predictor of success.

C.) Wilcoxon Signed Rank Test for the Number of Science Courses Taken

Because the data was non-parametric (Fall: p= <0.00001 (W=0.87); Spring: p= <0.00001 (W=0.8819)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of science courses taken by successful versus unsuccessful students. The results are presented in the Table 9.

Number of Science Courses		
Average Number of Courses	Fall	Spring
Successful	4.136	3.6727
Unsuccessful	3.5486	3.75
Wilcoxon Value with P-value	0.0005 (W=3818.5)	0.9286 (W=543)

Table 9 Wilcoxon Signed Rank Test results from a comparison between the number of science courses taken by successful and unsuccessful students.

In the fall, there did exist a significant difference between the number of science courses taken by successful students versus the number of science courses taken by unsuccessful students with the higher mean number of science courses falling to the successful students (p=0.0005; W= 3818.5). However, in the spring there did not exist a significant difference between the number of science courses taken by successful students versus the number of science courses taken by unsuccessful students ($p=0.9286$; $W= 543$). Also, between the fall and spring, there was not a statistical difference in the number of science courses taken by all students ($p= 0.1666$; $W=6108.5$).

D.) Bar Graph of Percentages of Students Taking A Specific Number of Science Courses

The bar graph below demonstrates the percentage of students for each semester grouped by the number of science courses taken. For example, out of the entire Fall Unsuccessful student group, 9% had taken 5 or more science courses while in high school and 51% had taken 4 science courses while in high school.

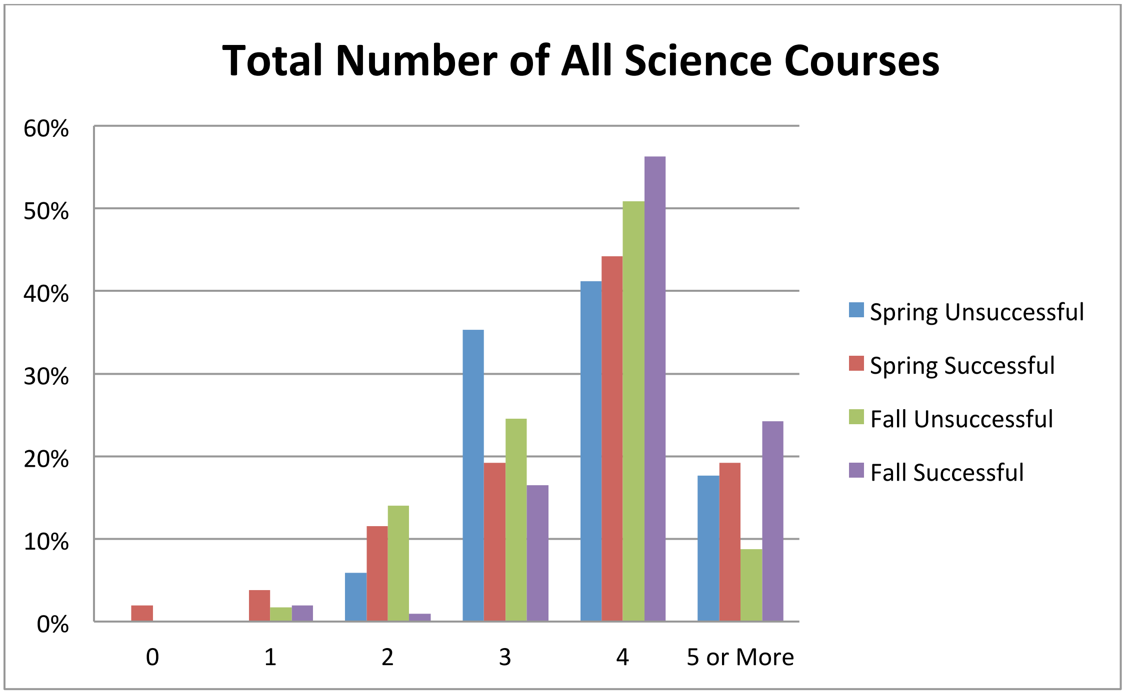

Figure 4 Bar graph of percentages of students taking a specific number of science courses

This graph also demonstrates the trend, supported by the previously mentioned binomial generalized linear regression, in that an increased number of science courses taken in high school decreasing the likelihood of being unsuccessful. Figure 4 also adds support to this conclusion, in that 97% of the Fall 2012 success students had taken 3 or more science course whereas only 85% of the Fall 2012 unsuccessful students had taken 3 or more science courses. However, the presence of about 19% of the spring unsuccessful students having taken 5 or more science courses helps explain some of the discrepancies in the Wilcoxon Signed Rank test.

E.) Bar Graph Representing a Specific Number of Science Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Science courses and the group and semester in which they belong. For example, out of all the students that participated in this study that took 5 or More Science courses while in high school, 81% were successful (58% in the Fall; 23% in the Spring).

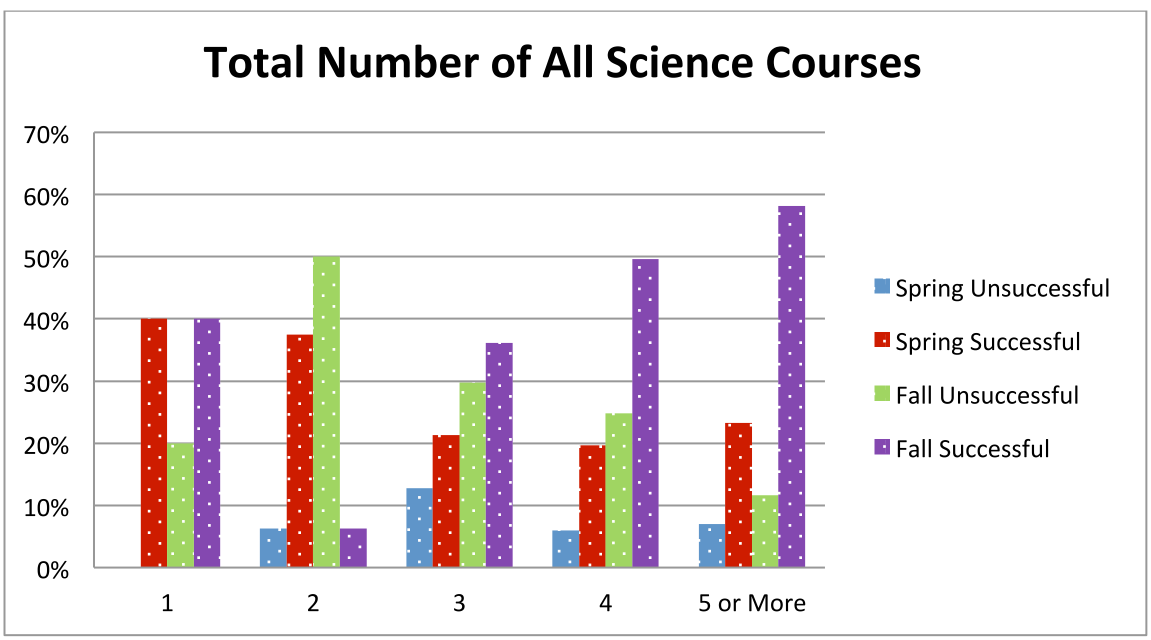

Figure 5 Bar graph representing a specific number of all science courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

This graph, along with the previously mentioned linear regressions, also supports the trend that an increased number of science courses taken in high school decreasing the likelihood of being unsuccessful. However, it can also be seen from this figure that there is a percentage of student that have taken 1 biology course and are successful. This overall observation seems to contradict the general trend observed with the rest of the data but may provide some support to the discrepancies within the Wilcoxon Signed Rank test.

F.) Bar Graph Representing a Specific Number of All Science Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total science courses and the group in which they belong. For example, out of all the students that participated in this study that took a total 5 or more science courses while in high school, 81% were successful.

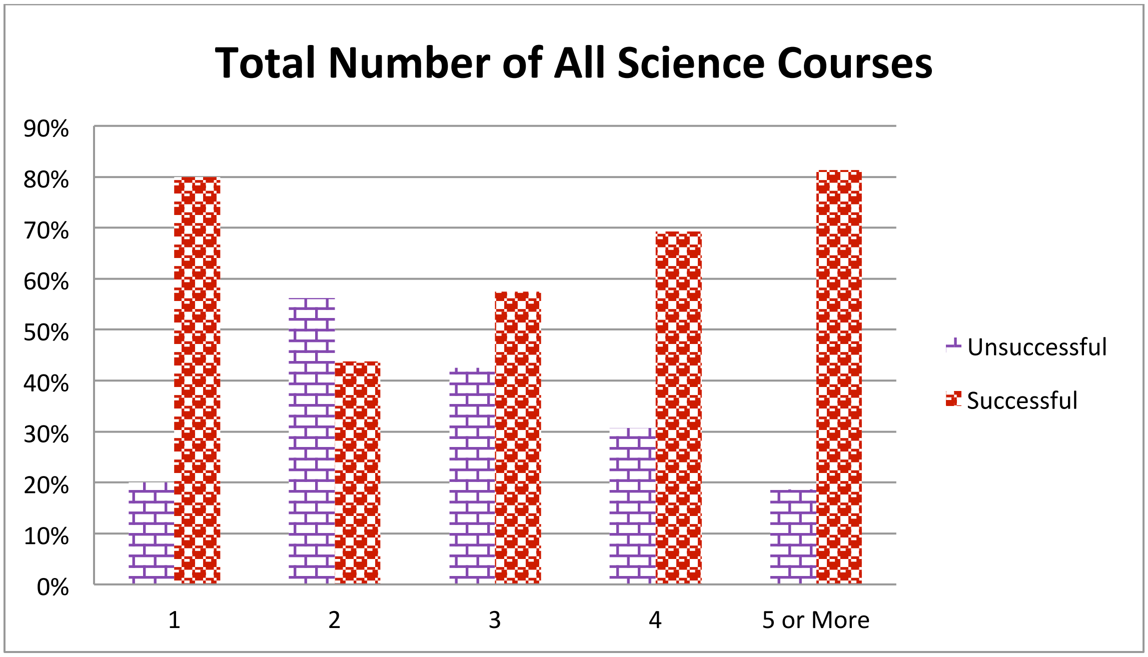

Figure 6 Bar graph representing a specific number of all science courses taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

This graph provides support to the overall conclusion. Figure 6 adds support to this conclusion, in that over 80% of the students that had taken 5 or more science courses were successful. However, it also ads support to the differences between the semesters in which the number of biology courses taken in high school had a significant effect in the fall semester but not the spring semester. Overall, one can see that a large percentage of the students that took 1 biology course, were also successful. This trend is also observed in Figure 5.

Sub-Question #1.3: Does the number of biology courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

A.) A binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of mathematics, general science courses, or biology courses taken were significant predictors of success. (See 1.1.A earlier in the Results section)

B.) Success = Total # of Mathematics class * Total # of Biology classes taken

A binomial generalized linear regression was run to include the number of mathematics courses and the total number of biology courses as variables in order to determine if the number of biology courses taken by a student in high school decreased the likelihood of being unsuccessful in the introductory college biology course required for STEM majors offered at ASU (See 1.1.C earlier in the Results section). Overall, Table 5 provides support for the importance of high school biology courses in being a significant predictor of success in both the Fall 2012 and Spring 2013 semesters.

C.) Success = Total # of Mathematics class+ Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken

A binomial generalized linear regression including the number of mathematics courses, the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses without math interaction terms as variables was also run to determine if the total number of biology courses were significant predictors of success (See 1.1.D earlier the Results section for the results). Table 6 provides support for the importance of high school biology courses in being a significant predictor of success in both the Fall 2012 and Spring 2013 semesters.

D.) Success = Total # of Mathematics class+ Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken+ Mathematics course # *(Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken)

A binomial generalized linear regression including the number of mathematics courses, the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses with math interaction terms as variables was run to determine if the total number of biology courses were significant predictors of success (See 1.1.E in Appendix D). Table 7 provides support for the importance of high school biology courses in being a significant predictor of success in both the Fall 2012 and Spring 2013 semesters.

E.) Success = Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken+ Mathematics course #

The results of the generalized linear regression run that included the number of biology courses, the number of chemistry courses, the number of physics courses, and the number of other science courses as variables are presented in the table below. The identification number

1.3.E mentioned earlier in Appendices D and E also correspond to the write-up portion presented here.

Probability for Success					
Semester Term	Intercept	Total # of Biology Courses	Total # of Chemistry Courses	Total # of Physics Courses	Total # of Other Science Courses
Fall	0.2515	0.6581	0.6504	0	0
Spring	0.6635	0.3267	0.7907	0	0

Table 10 Probability for success results for the generalized linear regression including just the total numbers of each science course taken as variables.

To answer the question as to whether or not the number of biology courses taken by a student in high school would increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU it was determined, in the fall semester, that a student was 65.8 % more likely to be successful for each additional biology class taken, a student was 65.0 % more likely to be successful for each additional chemistry class taken, a student was not any more likely to be unsuccessful for each additional physics or other science class taken. In the spring, a student was 32.7% more likely to be successful for each additional biology class taken, a student was 79.1% more likely to be successful for each additional chemistry class taken, and a student was not any more likely to be successful for each additional physics or other science class taken (Table 10). This table also provides support for the fact that the number of biology courses taken in high school does influence success in the introductory college biology course at ASU in that the number of biology courses taken in high school had a significant effect on success.

F.) Wilcoxon Signed Rank Test for the Number of Biology Courses Taken

Because the data was non-parametric (Fall: p= <0.00001 (W=0.8085); Spring: p= <0.00001 (W=0.807)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of biology courses taken by successful versus unsuccessful students. The results are presented in the table below.

Number of Biology Courses		
Average Number of Courses	Fall	Spring
Successful	1.7669	1.32727
Unsuccessful	1.4385	1.65
Wilcoxon Value with P-value	0.003 (W=3675)	0.0624 (W=409)

Table 11 Wilcoxon Signed Rank Test results from a comparison between the number of biology courses taken by successful and unsuccessful students.

To answer the question as to whether or not the number of biology courses taken by a student in high school would increase the likelihood of being successful, it was also determined, in the fall, that there did exist a significant difference between the number of biology courses taken by successful students versus the number of biology courses taken by unsuccessful students with the higher mean number of biology courses falling to the successful students ($p=0.003$; $W= 3675$) with the higher mean falling for those students that were successful. However, in the spring there did not exist a significant difference between the number of biology courses taken by successful students versus the number of biology courses taken by unsuccessful students ($p= 0.0624$; $W=409$); yet, the higher mean number of biology courses taken did lie with those students that were successful. Also, between the fall and spring, there was not a statistical difference in the number of biology courses taken by all students ($p= 0.1927$; $W=1927$).

G.) Bar Graph of Percentages of Students Taking A Specific Number of Biology Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of biology courses taken. For example, out of the entire Fall Unsuccessful student group, 39% had taken 2 biology courses while in high school and 2% had taken 3 biology courses while in high school.

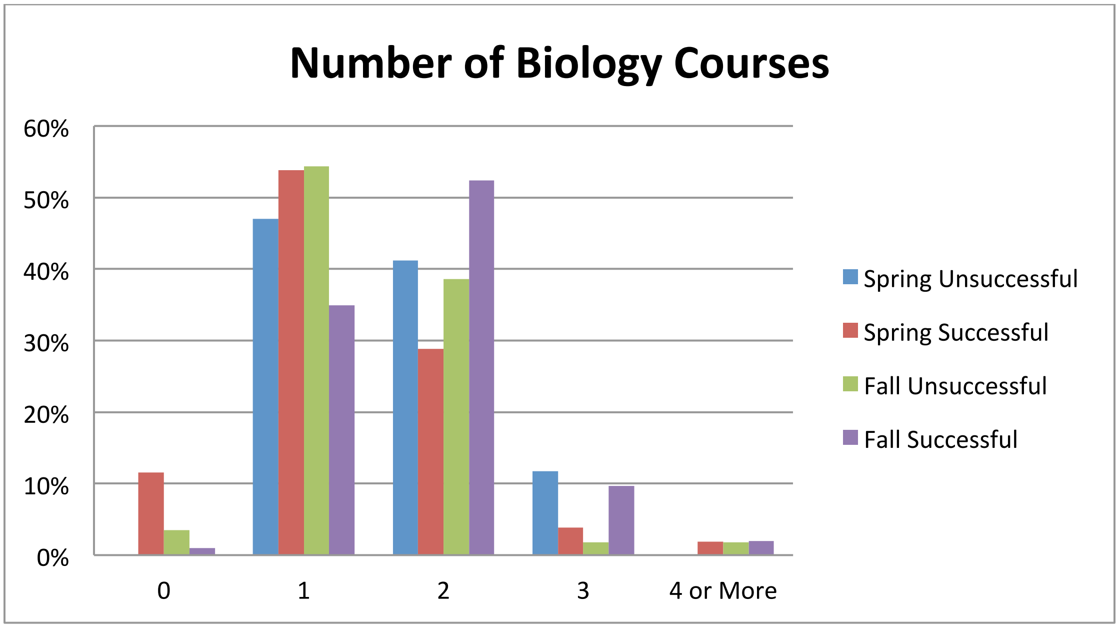

Figure 7 Bar graph of percentages of students taking a specific number of biology courses

This graph also demonstrates the trend, supported by the previously mentioned binomial generalized linear regression, in that an increased number of biology courses taken in high school decreases the likelihood of being unsuccessful. Figure 7 adds support to this conclusion, in that 64% of the Fall 2012 successful students had taken 2 or more biology course whereas only 43% of the Fall 2012 unsuccessful students had taken 2 or more science courses.

H.) Bar Graph Representing a Specific Number of Biology Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Biology courses and the group and semester in which they belong. For example, out of all the students that participated in this study that took 3 Biology courses while in high school, 80% were successful (67% in the Fall; 13% in the Spring).

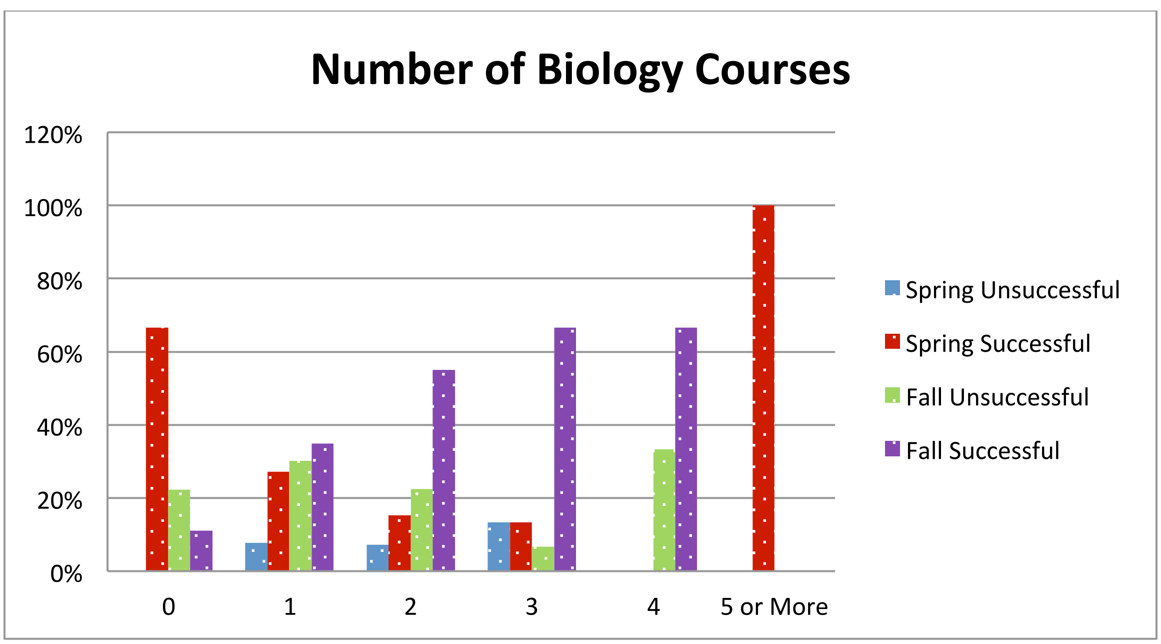

Figure 8 Bar graph representing a specific number of all biology courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

This graph also supports the trend, also supported by the previously mentioned binomial generalized linear regression, of an increased number of biology courses taken in high school effects success in the introductory college biology course at ASU. It is supported by the table in that 100% of the students that had taken 5 or more biology courses in high school were successful.

I.) Bar Graph Representing a Specific Number of All Biology Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total biology courses and the group in which they belong. For example, out of all the students that participated in this study that took a total 3 biology courses while in high school, 80% were successful.

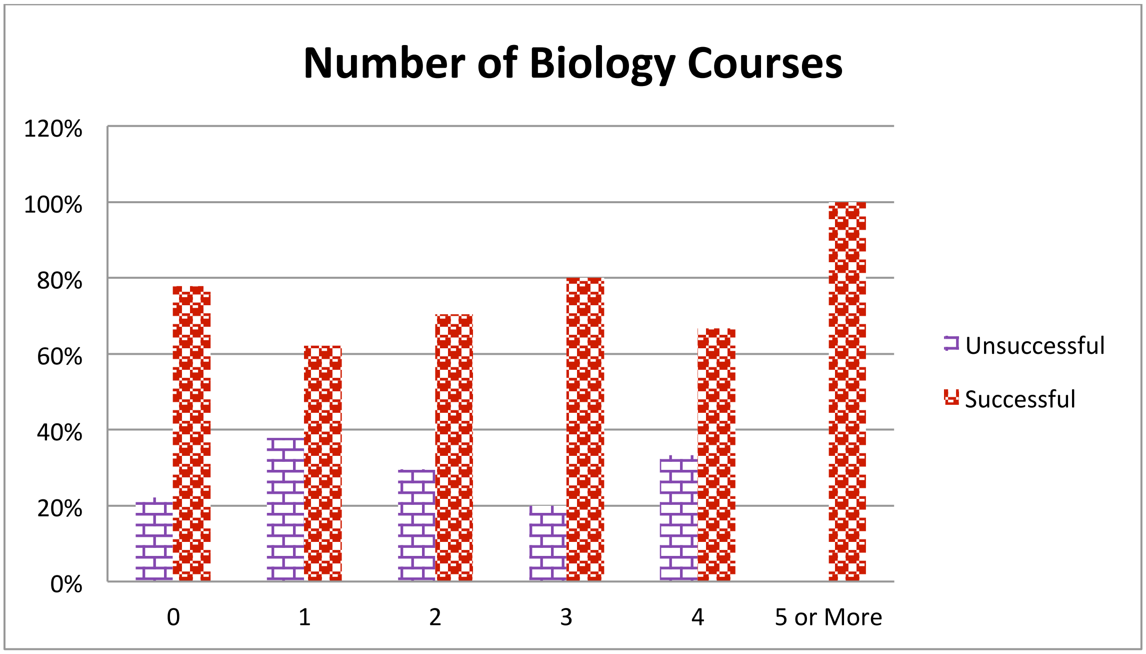

Figure 9 Bar graph representing a specific number of all biology courses taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

Just as with Figure 9, this graph supports the trend of an increased number of biology courses taken in high school effecting success in the introductory college biology course at ASU. It is supported by the table in that 100% of the students that had taken 5 or more biology courses in high school were successful.

Question #2: Does the number of science courses with a lab taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

Sub-Question #2.1: Does the total number of science courses with lab time taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

A.) Wilcoxon Signed Rank Test for the Number of Science Courses with Lab Time Taken

Because the data was non-parametric (Fall: p= <0.00001 (W=0.9007); Spring: p= <0.00001 (W=0.8813)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of science courses with lab time taken by successful versus unsuccessful students.

Number of Science Courses with Lab Time		
Average Number of Courses	Fall	Spring
Successful	2.9417	1.6727
Unsuccessful	2.3684	2.4
Wilcoxon Value with P-value	0.026 (W=3545.5)	0.07135 (W=403)

Table 12 Wilcoxon Signed Rank Test results from a comparison between the number of science courses with lab time taken by successful and unsuccessful students.

To answer the question as to whether or not the number of science courses with lab time taken by a student in high school would increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU, it was determined that, in the fall, there did exist a significant difference between the number of science courses with lab time taken by successful students versus the number of science courses with lab time taken by unsuccessful students with the higher mean number of science courses with lab time falling to the successful students ($p=0.026$; $W= 3545.5$). However, in the spring there did not exist a significant difference between the number of science courses with lab time taken by successful students versus the number of science courses with lab time taken by unsuccessful students ($p=0.07135$; $W= 403$). Also, between the fall and spring, there did exist a statistical difference in the number of science courses with lab time taken by all students with the higher mean of students with science courses with lab time being in the fall ($p= 0.000127$; $W=7245$).

B.) Bar Graph of Percentages of Students Taking A Specific Number of Science Courses with lab time Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of science courses with lab time taken. For example, out of the entire Fall Unsuccessful student group, 9% had taken 5 or more science courses with lab time while in high school and 5% had taken 5 or more science courses with lab time while in high school.

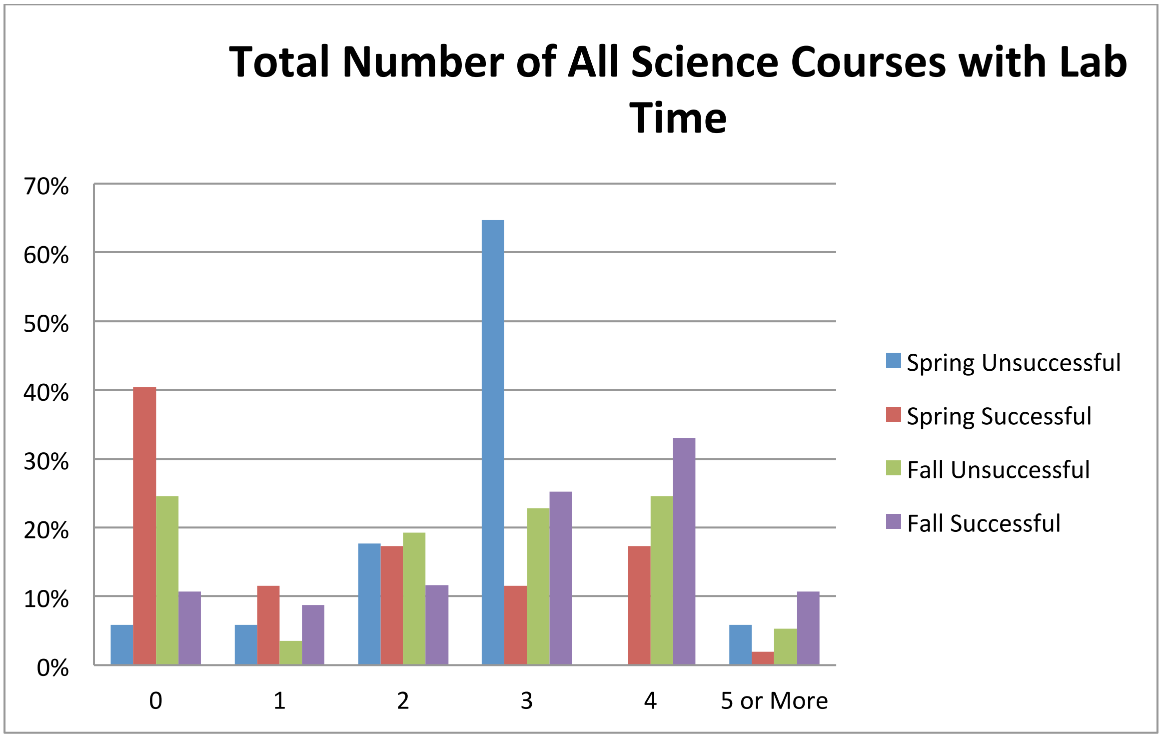

Figure 10 Bar graph of percentages of students taking a specific number of science courses with lab time

This bar graph provides support to the binomial generalized linear regression in that it appears from Figure 10 that there exists a steady increase in the number of successful students in the fall semester that have taken increased number of science courses with lab and an opposite effect for those Fall 2012 unsuccessful students. However, just like the regression, there does not appear to be a trend with the spring data. That data appears to be more sporadic than linear.

C.) Bar Graph Representing a Specific Number of Science Courses with lab time Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Science Courses with lab time and the group and semester in which they belong. For example, out of all the students that participated in this study that took 5 or More Science Courses with lab time while in high school, 75% were successful (69% in the Fall; 6% in the Spring).

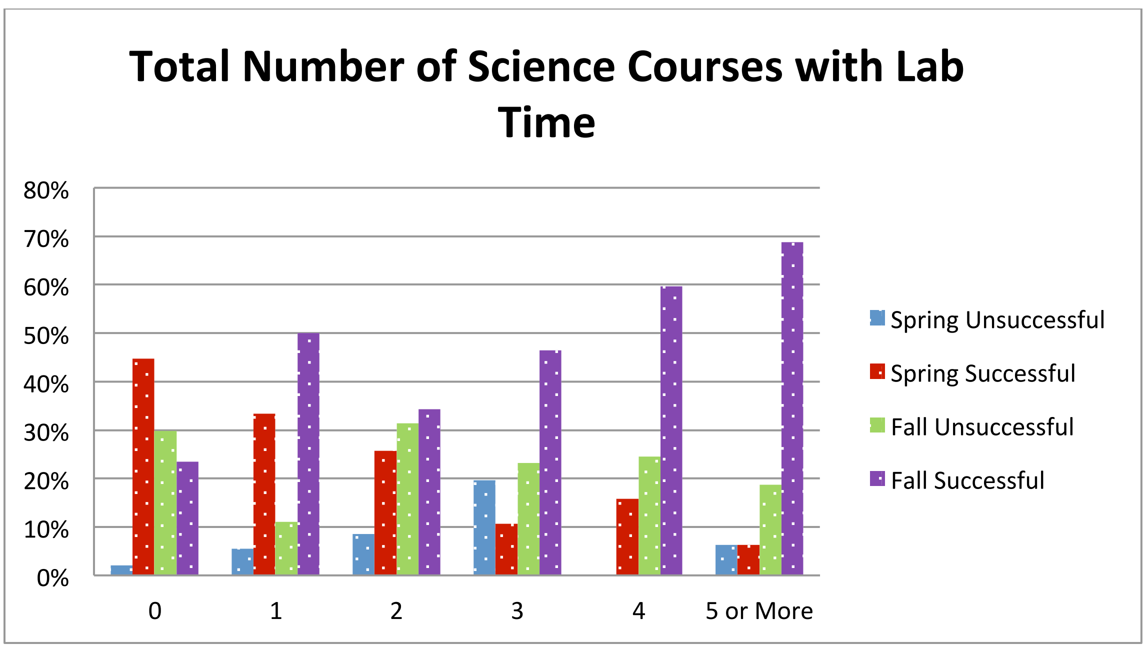

Figure 11 Bar graph representing a specific number of all science courses with lab time taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

Just like Figure 10, this bar graph provides support to the binomial generalized linear regression in that it appears that there exists a steady increase in the number of successful students in the fall semester within the greater number of science courses with groups with an opposite effect for those Fall 2012 unsuccessful students. However, the opposite trend observed in the unsuccessful fall students appears to also take place in the spring successful students. This may help explain why there did not exist a difference between the number of science courses taken by successful versus unsuccessful students in the Wilcoxon Signed Rank test.

D.) Bar Graph Representing a Specific Number of All Science Courses with lab time Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total science courses with lab time and the group in which they belong. For example, out of all the students that participated in this study that took a total 5 or more science courses with lab time courses while in high school, 75% were successful.

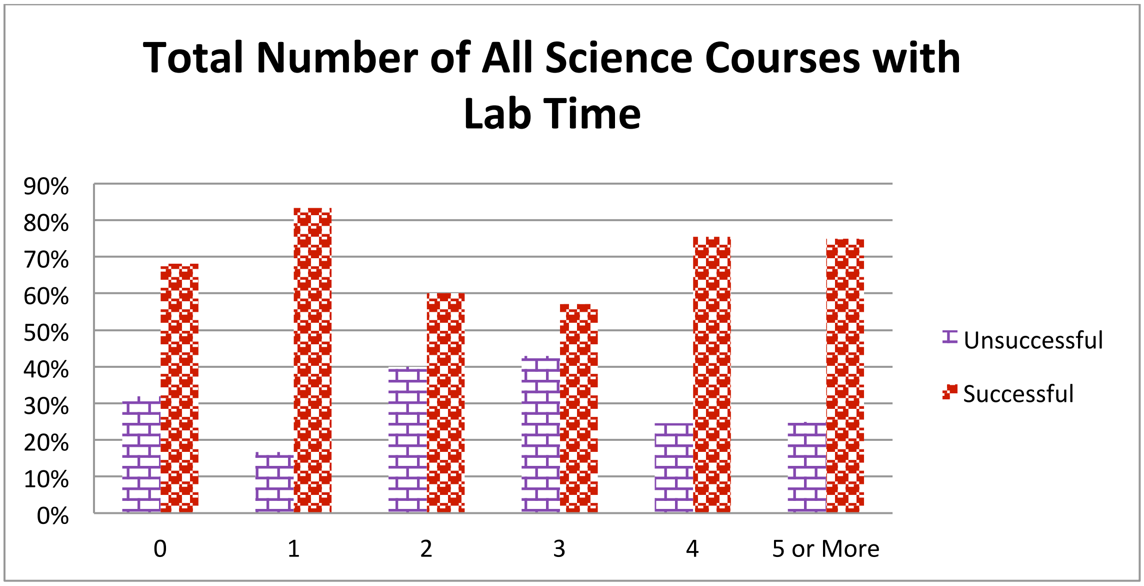

Figure 12 Bar graph representing a specific number of all science courses with lab time taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

This graph tends to blur the distinct differences observed with Figure 11 and the Wilcoxon Signed Rank test, and does not support the conclusion. However, this graph with the observed blurring of distinctions may support why term had a significant effect.

Sub-Question #2.2: Does the number of biology courses with lab time taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

A.) Wilcoxon Signed Rank Test for the Number of Biology Courses with Lab Time Taken

Because the data was non-parametric (Fall: p= <0.00001 (W=0.7436); Spring: p= <0.00001 (W=0.72)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of biology courses with lab time taken by successful versus unsuccessful students.

Number of Biology Courses with Lab Time		
Average Number of Courses	Fall	Spring
Successful	0.8835	0.3818
Unsuccessful	0.6667	0.9
Wilcoxon Value with P-value	0.0255 (W=3470)	0.0033 (W=333)

Table 13 Wilcoxon Signed Rank Test results from a comparison between the number of biology courses with lab time taken by successful and unsuccessful students.

To answer the question as to whether or not the number of biology courses with lab time taken by a student in high school would increase the likelihood of being successful, it was determined that, in the fall, there did exist a significant difference between the number of biology courses with lab time taken by successful students versus the number of biology courses with lab time taken by unsuccessful students with the higher mean number of biology courses with lab time falling to the successful students (p=0.0255; W= 3470). In the spring there did also exist a significant difference between the number of biology courses with lab time taken by successful students versus the number of biology courses with lab time taken by unsuccessful students (p= 0.0033; W=333). Also, between the fall and spring, there did exist a statistical difference in the number of biology courses taken by all students with the higher mean of students with biology courses with lab time being in the fall (p= 0.0005403; W=6921.5).

B.) Bar Graph of Percentages of Students Taking A Specific Number of Biology courses with lab time

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of biology courses with lab time taken. For example, out of the entire Fall Unsuccessful student group, 4% had taken 2 biology courses with lab time while in high school.

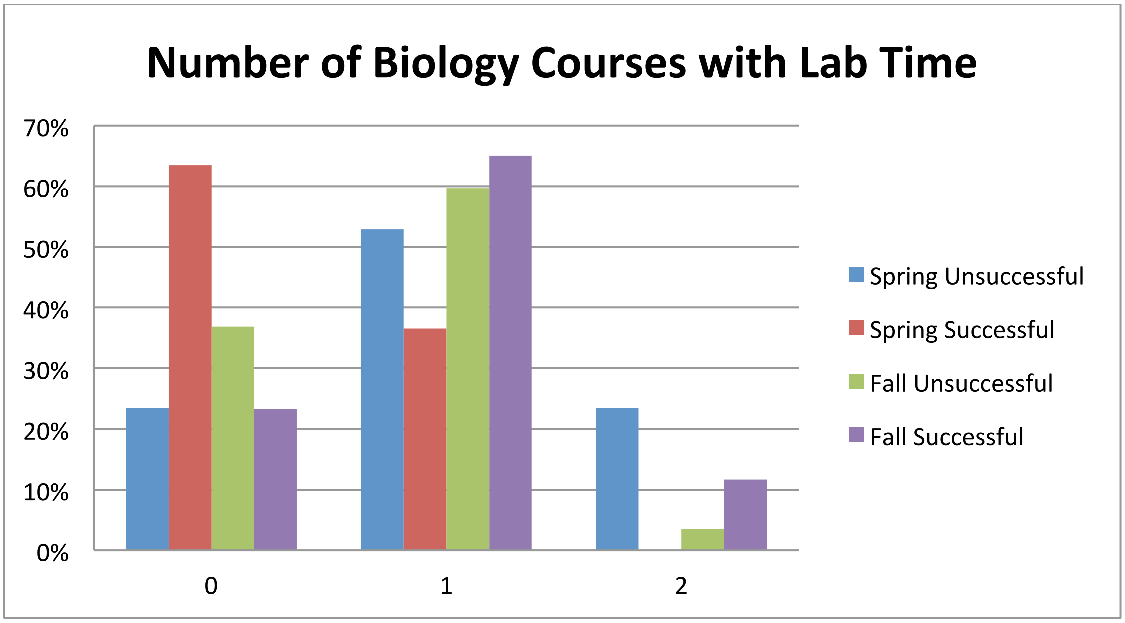

Figure 13 Bar graph of percentages of students taking a specific number of biology courses with lab time

This bar graph provides support to the binomial generalized linear regression in that it appears from Figure 10 that there exists a steady increase in the number of successful students in the fall semester that have taken an increased number of biology courses with lab. However, just like the regressions and bar graphs in Results section 2.1, there does not appear to be a trend with the spring data, or if there is a trend, it is the opposite trend to what would be expected from the Wilcoxon Signed Rank test. However, this graph does visually clarify the fact that the unsuccessful students in the Spring 2013 term had a larger mean number of biology courses taken with lab time than the unsuccessful students. This type of graph, aids in explaining discrepancies that may have not been easily visualized from the regressions and comparison tests alone.

C.) Bar Graph Representing a Specific Number of Biology courses with lab time Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Biology courses with lab time and the group and semester in which they belong. For example, out of all the students that participated in this study that took 1 Biology courses with lab time while in high school, 67% were successful (52% in the Fall; 15% in the Spring).

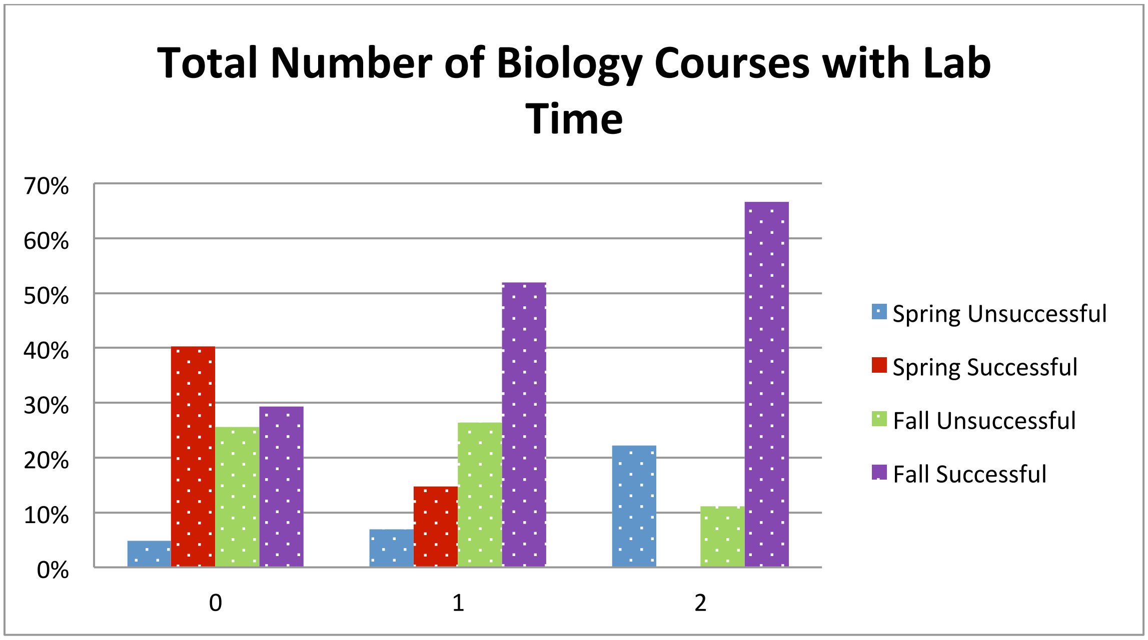

Figure 14 Bar graph representing a specific number of all biology courses with lab time taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

This figure supports what was concluded in Figure 13, in that there is a large percentage of successful students in the spring that have taken 0 biology courses with lab time (40% of the students that had taken 0 biology courses with lab time were successful students from the Spring 2013 term.

D.) Bar Graph Representing a Specific Number of All Biology courses with lab time Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total biology courses with lab time and the group in which they belong. For example, out of all the students that participated in this study that took a total 1 biology courses with lab time while in high school, 67% were successful.

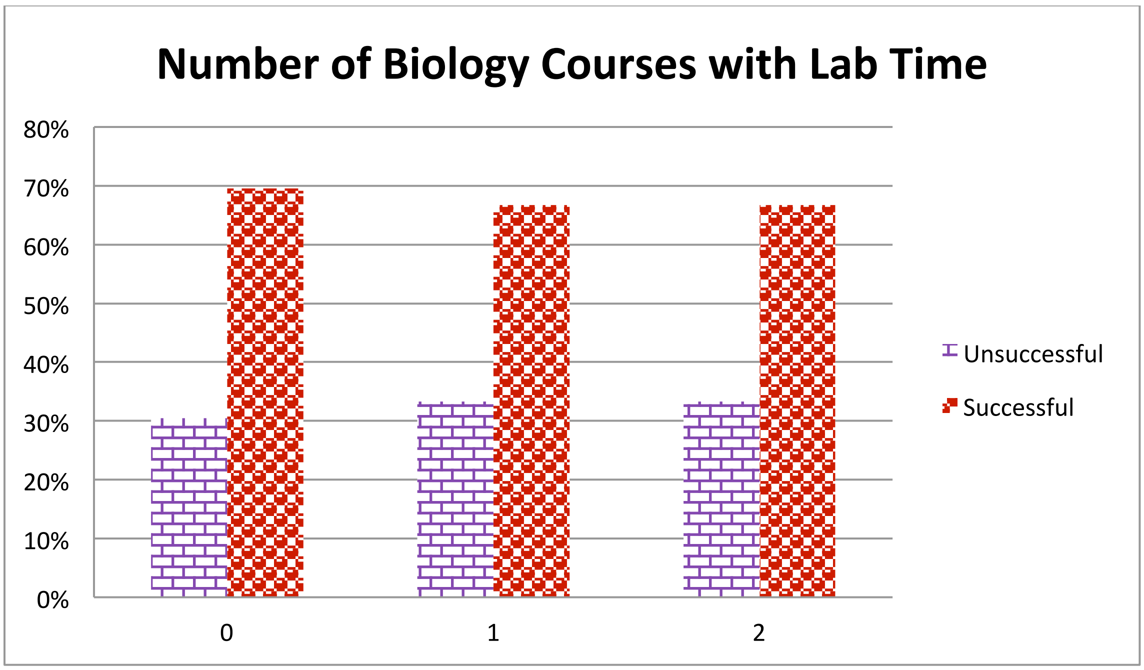

Figure 15 Bar graph representing a specific number of all biology courses with lab time taken in high school and the percentage of students within a group (Successful or Unsuccessful)

The use of this bar graph helps to bring out the discrepancies present in the number of biology courses with lab time taken by successful versus unsuccessful students. This graph highlights the fact that there does exist a true reason to analyze the data based within the terms instead of separating it. According to this graph, it would appear that overall, that the number of biology courses taken with lab time has no effect. For this spring data, this may be the case, but for the Fall 2012 term, there is an observable trend.

Question #3: Does the number of AP mathematics and science courses taken by a student in high school increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU?

Sub-Question #3.1: Does taking Advanced/ college placement mathematics courses in high school increase success in the introductory biology courses required for STEM majors offered at ASU?

A.) A binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of mathematics, general science courses, or biology courses taken were significant predictors of success. (See 1.1.A earlier in the Results section)

B.) Success = pre-Algebra+ Algebra+ Algebra 2+Geometry+ Trigonometry + Pre-Calculus + Calculus+ Calculus 2+ AP Calculus + Other Mathematics

The results of the generalized linear regression run that included the number of pre-Algebra, Algebra, Algebra 2, Geometry, Trigonometry (Trig), Pre-Calculus (Pre-Cal), Calculus, Calculus 2, Advanced Placement Calculus (AP Calculus), and Other Mathematics courses as variables are presented in the table below. The identification number 3.1.B mentioned earlier in Appendices D and E also corresponds to the write-up portion presented here.

Probability of Success											
Term	Inter.	Total # of Pre-Algebra Courses	Total # of Algebra Courses	Total # of Algebra 2 Courses	Total # of Geometry Courses	Total # of Trig	Total # of Pre-Cal	Total # of Calculus	Total # of Cal 2	Total # of AP Cal	Total # of Other Math
Fall	0.2843	0.9239	0	0	0	0.9349	0.75214	0.7575	1.253×10^{-7}	0.920729	0
Spring	0.8036	0	0	0	0	0	0	0	1	1.56155×10^{-8}	0.215

Table 14 Probability for success results for the generalized linear regression including just the mathematics courses taken as variables.

To answer the question as to whether or not the total number of AP mathematics courses has significant effect on success, it was determined that, in the fall, a student is 92.1% more likely to be successful if Advanced Placement Calculus taken in addition to where the student currently stands holding all other mathematics classes the same, and in the spring, a student is 1.56155×10^{-6} % more likely to be successful if Advanced Placement Calculus taken in addition to where the student currently stands holding all other mathematics classes the same. (Table 14). However small this effect may seem in the Spring 2013 term, it still supports the conclusion that having taken AP Calculus may effect student success in the Biology 1480 course at ASU, especially considering the strong effect that having taken AP Calculus has in the Fall 2012 term.

C.) Success = All the Algebra courses +Geometry+ Trigonometry +All Calculus Classes excluding Advanced Placement Calculus + Advanced Placement Calculus + Other Mathematics

The results of the generalized linear regression run that included the number of All Algebra Courses, Geometry, Trigonometry (Trig), All Calculus except Advanced Placement Calculus, AP Calculus, and Other Mathematics courses as variables are presented in the table below. The identification number 3.1.C mentioned earlier in Appendices D and E also corresponds to the write-up portion presented here.

Probability of Success							
Term	Inter.	Total # of All Algebra Courses	Total # of Geometry Courses	Total # of Trig	Total # of All Calculus w/o AP	Total # of AP Cal	Total # of Other Math
Fall	0.435	0	0	0.9995	0.6902	0.99999	0
Spring	0.932	0.3241	0	0	0	0.8732	0.247

Table 15 Probability for success results for the generalized linear regression including an edited version of the mathematics courses taken as variables.

In determining whether or not the total number of AP mathematics courses has significant effect on success, it was determined that, in the fall, a student is 99.9% more likely to be successful if Advanced Placement Calculus taken in addition to where the student currently stands holding all other mathematics classes the same, and in the spring, a student is 87.3% more likely to be successful if Advanced Placement Calculus taken in addition to where the student currently stands holding all other mathematics classes the same (Table 15). By grouping some of the common mathematics course sequences, the influence of AP Calculus is again significant. This lead the PI to believe that having taken AP Calculus does have an effect on success in the Principles of Biology introductory college biology class at ASU.

D.) Wilcoxon Signed Rank Test for the Number of AP Mathematics Courses Taken

Because the data was non-parametric (Fall: p= <0.00001 (W=0.2057); Spring: p-value could not be determined)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of Advanced Placement mathematics courses taken by successful versus unsuccessful students. The results are presented in the table below.

Number of AP Mathematics Courses		
Average Number of Courses	Fall	Spring
Successful	0.0679	0
Unsuccessful	0	0
Wilcoxon Value with P-value	0.04481 (W=3135)	NA

Table 16 Wilcoxon Signed Rank Test results of the comparison between successful and unsuccessful students that had taken and received college level course credit for the AP Calculus examination.

To answer the question as to whether or not taking an AP mathematics course would increase the likelihood of being successful in the introductory college biology course required for STEM majors offered at ASU, it was determined that, in the fall, there did exist a significant difference between the number of AP mathematics courses taken by successful students versus the number of AP mathematics courses taken by unsuccessful students with the higher mean number of AP mathematics courses falling to the successful students ($p=0.0045$; $W=3135$). However, in the spring it was not possible to determine if there existed a significant difference between the number of AP mathematics courses taken by successful students versus the number of AP mathematics courses taken by unsuccessful students due to the fact that there was not a large enough sample size of students that had completed the AP Calculus exam and received credit. Also, between the fall and spring, there did not exist a statistical difference in the number of AP mathematics courses taken by all students ($p= 0.1859$; $W=8.5$).

E.) Bar Graph of Percentages of Students Taking A Specific Number of AP Mathematics Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of Mathematics (AP Calculus) courses taken. For example, out of the entire Fall Unsuccessful student group, 100% had not taken AP Calculus courses while in high school.

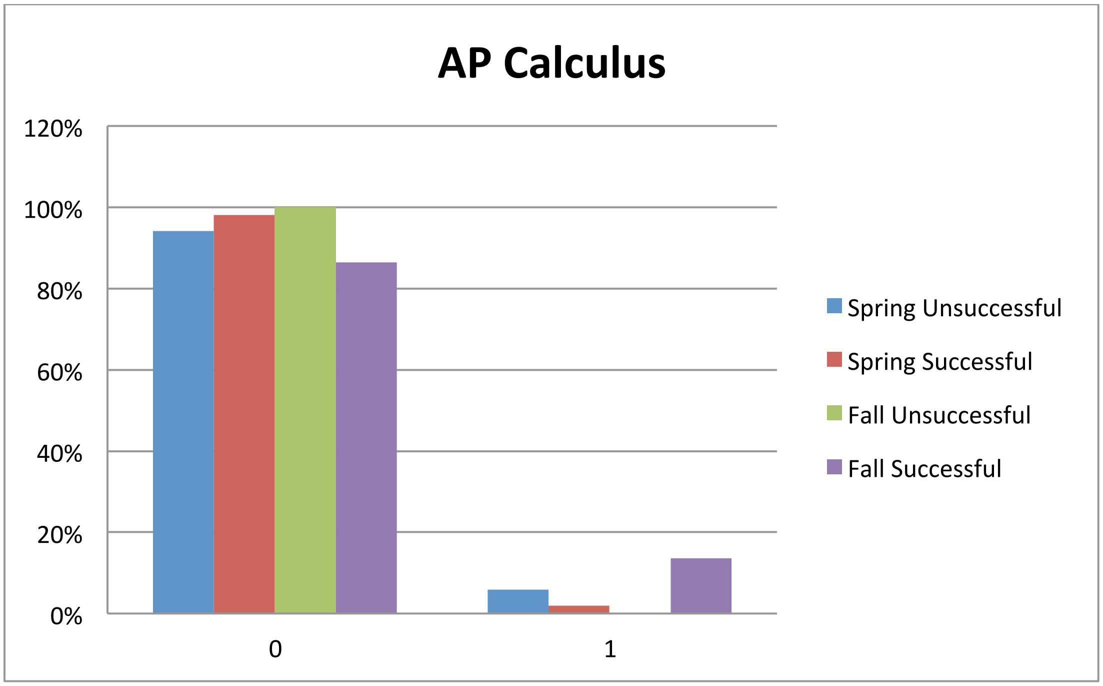

Figure 16 Bar graph of percentages of students taking a specific number of mathematics (AP Calculus) courses

This bar graph supports the conclusion obtained with the Wilcoxon Signed Rank test in that 100% of the Fall 2012 unsuccessful students had not taken AP Calculus.

F.) Bar Graph Representing a Specific Number of Mathematics (AP Calculus) Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of Mathematics (AP Calculus) courses and the group and semester in which they belong. For example, out of all the students that participated in this study that took AP Calculus while in high school, 94% were successful (88% in the Fall; 6% in the Spring).

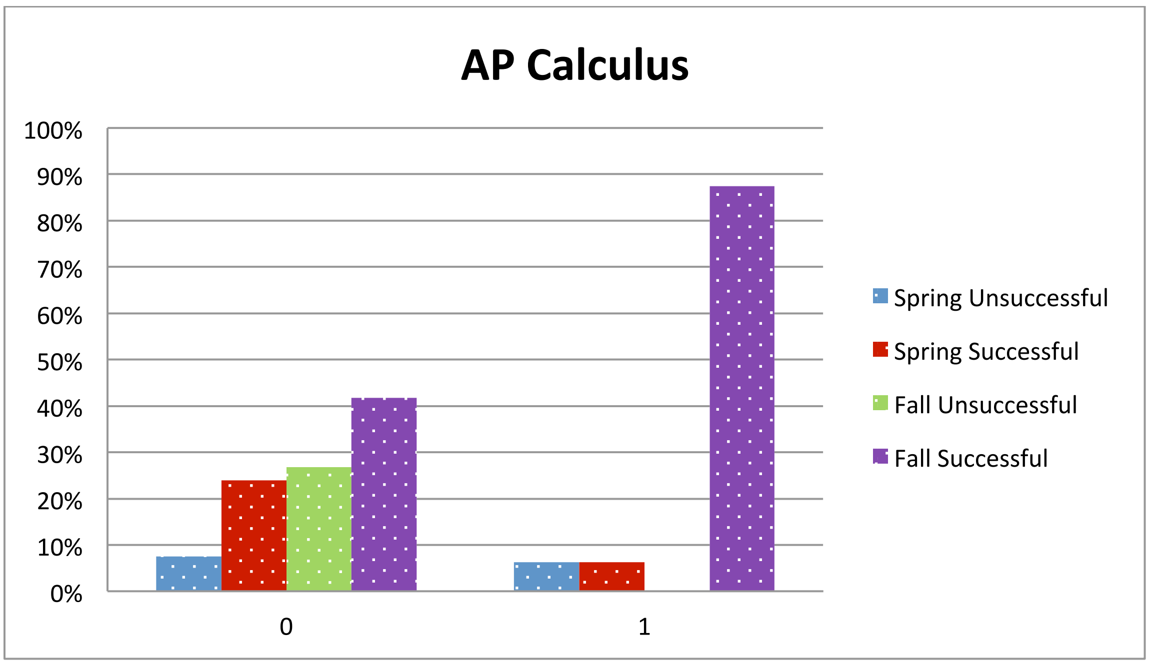

Figure 17 Bar graph representing a specific number of mathematics (AP Calculus) courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

Figure 17 supports the conclusion of the Wilcoxon Signed Rank test in that 5% of the students that had taken AP Calculus were successful in the spring and 5% were unsuccessful in the spring term essentially cancelling out any effect the spring semester could have determined.

G.) Bar Graph Representing a Specific Number of Mathematics (AP Calculus) Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of Mathematics (AP Calculus) courses and the group in which they belong. For example, out of all the students that participated in this study that took 5 or More Mathematics (AP Calculus) courses while in high school, 94% were successful.

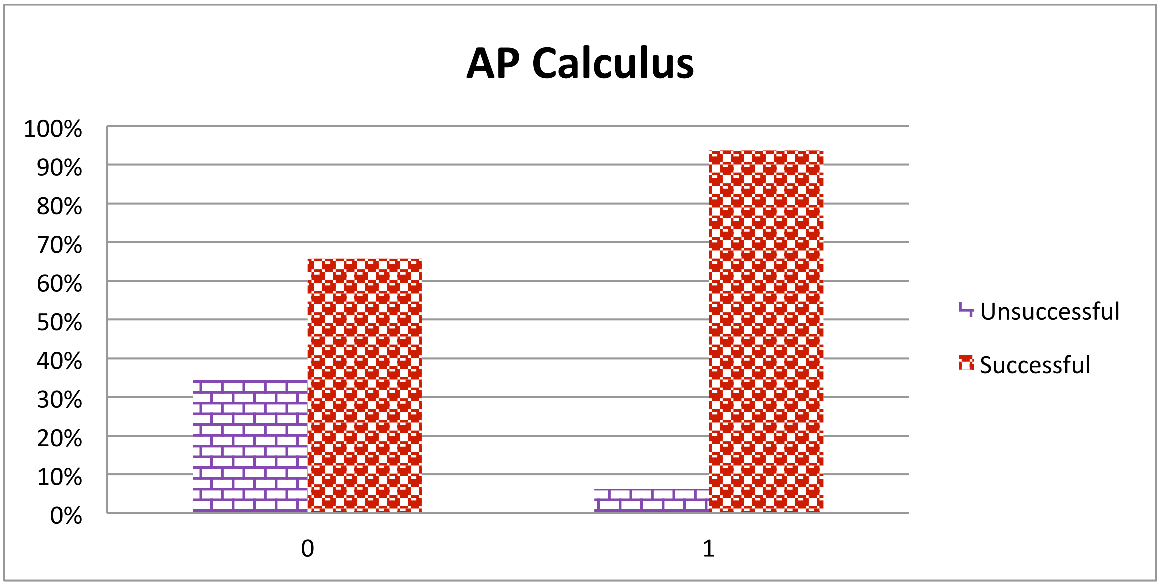

Figure 18 Bar graph representing a specific number of mathematics (AP Calculus) courses taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

Figure 18 demonstrates the large percentage of students having taken AP Calculus as being successful; however, this graph does not adequately inform the reader of the pull of the Fall 2012 term successful students in this category. Again, this graph provides support for analyzing the semester data separately.

Sub-Question #3.2: Does taking any Advanced/ college placement science courses in high school increase success in the introductory biology courses required for STEM majors offered at ASU?

A.) A binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of mathematics, general science courses, or biology courses taken were significant predictors of success. (See 1.1.A earlier in the Results section)

B.) Wilcoxon Signed Rank Test for the Number of AP Science Courses Taken

Because the data was non-parametric (Fall: $p= <0.00001$ ($W=0.2039$); Spring: $p= <0.00001$ ($W=0.9033$)), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of AP science courses taken by successful versus unsuccessful students

Number of AP Science Courses		
Average Number of Courses	Fall	Spring
Successful	0.1262	0.0182
Unsuccessful	0	0
Wilcoxon Value with P-value	0.04484 (W=3135)	0.5465 (W=560)

Table 17 Wilcoxon Signed Rank Test results of the comparison between successful and unsuccessful students that had taken and received college level course credit for any of the AP science examinations.

To answer whether or not the total number of AP science courses taken by a student in high school would have an effect on success in the introductory college biology course at ASU, the Wilcoxon Signed Rank Test was performed. In the fall, it was determined there did exist a significant difference between the number of AP science courses taken by successful students versus the number of AP science courses taken by unsuccessful students with the higher mean number of AP science courses falling to the successful students ($p=0.04484$; $W= 3135$). However, in the spring there did not exist a significant difference between the number of AP science courses taken by successful students versus the number of AP science courses taken by unsuccessful students ($p=0.5465$; $W= 560$). Also, between the fall and spring, there did not exist a statistical difference in the number of AP science courses taken by all students ($p= 0.2609$; $W=5684.5$) (Table 17). This table also supports the observations in many of the other tables and figures in which the fall and spring semester differ. This, too, lends support for the separation of the fall and spring semester during analyzing. From the test, we can assume that the number of AP science courses taken in high school does have effect, this effect is more readily visible in the fall semester.

C.) Bar Graph of Percentages of Students Taking A Specific Number of AP Science Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of AP Science Courses taken. For example, out of the entire Fall Unsuccessful student group, 100% had taken 0 AP Science Courses while in high school.

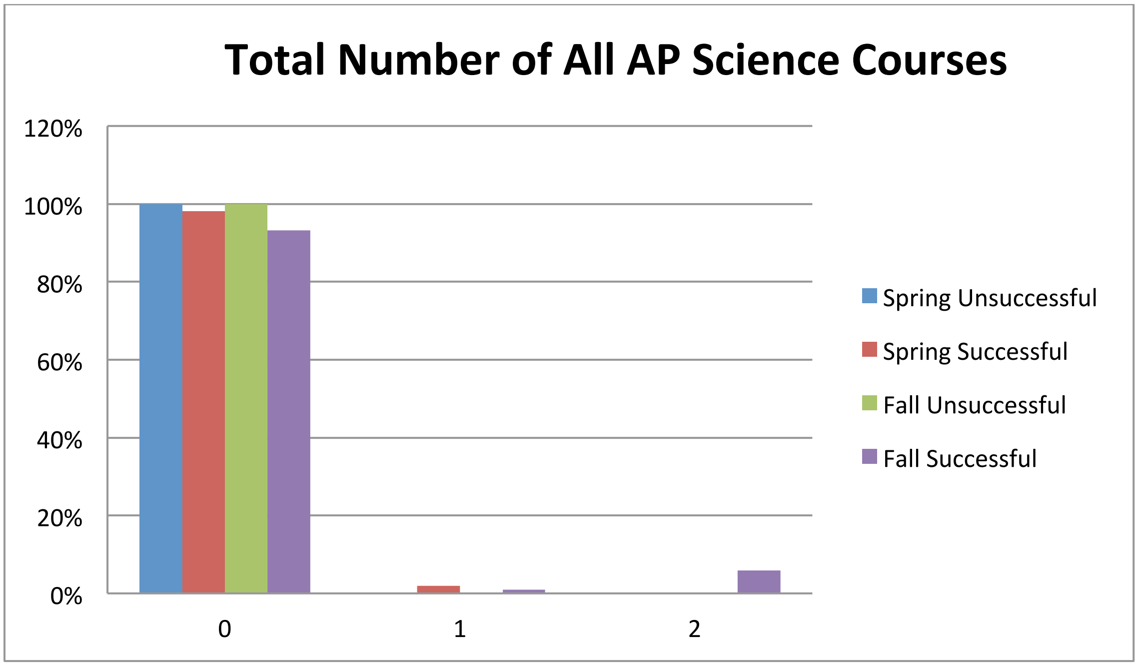

Figure 19 Bar graph of percentages of students taking a specific number of AP science courses

This figure provides support for the results obtained in the Wilcoxon Signed Rank test in which there was not a significant difference in the spring semester. This effect could be due to the small sample of spring students that had actually received college credit for AP science courses. For the Fall 2102 term there was a larger number of students that had received college credit.

D.) Bar Graph Representing a Specific Number of AP Science Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total AP Science Courses and the group and semester in which they belong. For example, out of all the students that participated in this study that took 2 AP Science Courses while in high school, 100% were successful (100% in the Fall; 0% in the Spring).

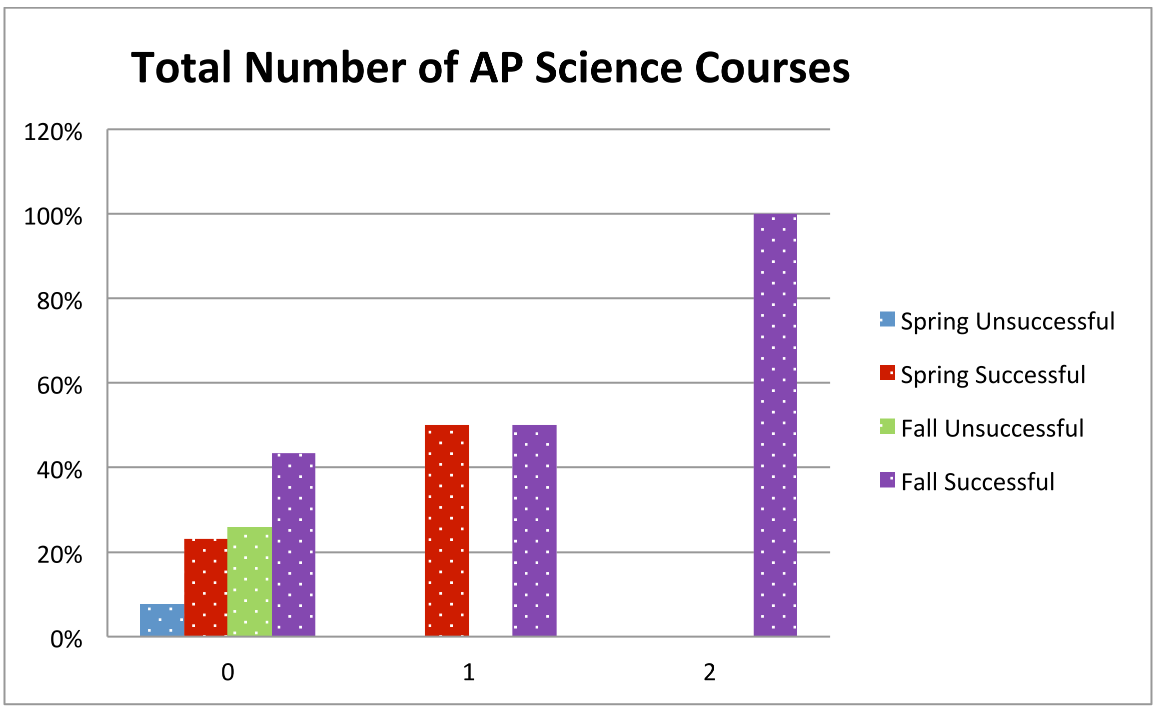

Figure 20 Bar graph representing a specific number of all AP science courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

This graph provides support for the overall trend present and supported also by the Wilcoxon Signed Rank test in which there is an increased percentage of successful students within the increased number of AP Science course number groups. This same trend is not as evident in the Spring 2013 data, and therefore, may explain why there was not a significant difference between successful and unsuccessful students in that term.

E.) Bar Graph Representing a Specific Number of All AP Science Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total AP Science Courses and the group in which they belong. For example, out of all the students that participated in this study that took a total 2 AP Science Courses while in high school, 100% were successful.

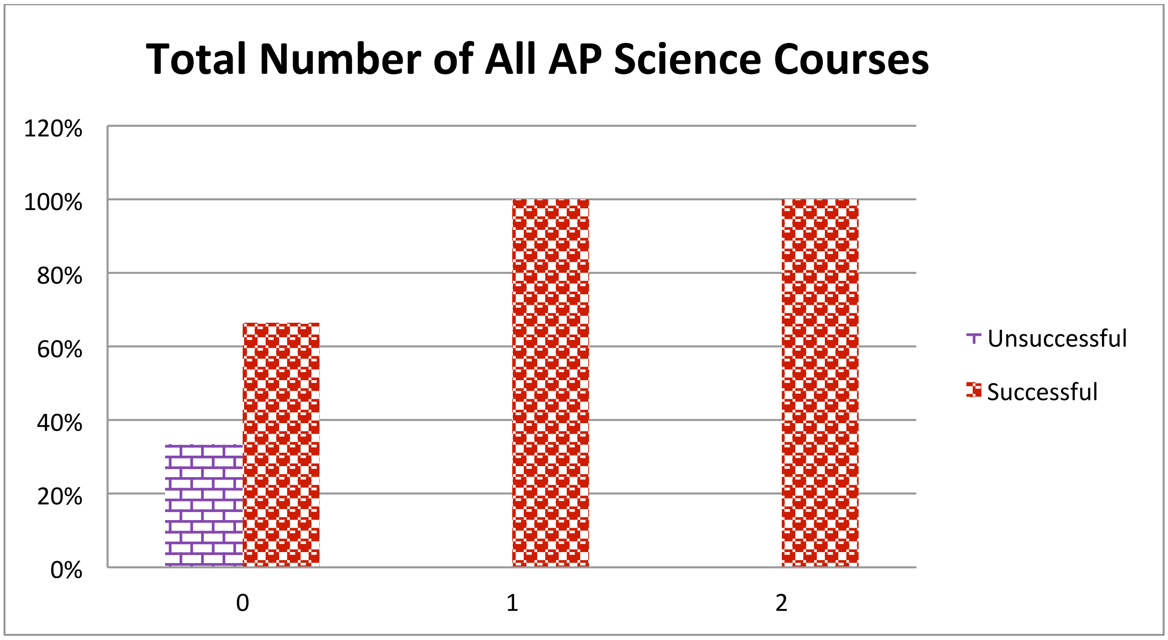

Figure 21 Bar graph representing a specific number of all AP science courses taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

Sub-Question #3.3: Does taking Advanced/ college placement Biology courses in high school increase success in the introductory biology courses required for STEM majors offered at ASU?

A.) A binomial generalized linear regression was also run including all non-background questions as variables to determine if the total number of mathematics, general science courses, or biology courses taken were significant predictors of success. (See 1.1.A earlier in the Results section)

B.) Success = Biology 1+ Biology 2+ Biology 3+ Pre-Advanced Placement Biology (Pre-AP Biology)+ Advanced Placement Biology (AP Biology)+ Anatomy+ Physiology+ Anatomy and Physiology (A and P) + Other Biology

The results of the generalized linear regression run that included the number of Biology 1, Biology 2, Biology 3, Pre-Advanced Placement Biology (Pre-AP Biology), Advanced Placement Biology (AP Biology), Anatomy, Physiology, Anatomy and Physiology (combination course), and Other Biology courses as variables are presented in the table below. The identification number 3.3.B mentioned earlier in Appendices D and E also corresponds to the write-up portion presented here.

Probability of Success										
Term	Inter.	Total # of Biology 1 Courses	Total # of Biology 2 Courses	Total # of Biology 3 Courses	Total # of Pre- AP Biology Courses	Total # of AP Biology Courses	Total # of Anatomy	Total # of Physiology	Total # of A and P	Total # of Other Biology
Fall	0.543	0.9239	0	0	0.73053	0	0.69275	0	0.66441	0
Spring	0.827	0	0.0643	0	0	0.12196	0.17236	0	0	0

Table 18 Probability for success results for the generalized linear regression including all of the biology courses taken as variables.

In determining whether or not the total number of AP biology courses has significant effect on success, this binomial generalized linear regression found that, in the fall, a student is not any more likely to be successful if AP Biology taken in addition to where the student currently stands holding all other biology classes the same, and in the spring, a student is 12.2% more likely to be successful if AP Biology is taken in high school in addition to where the student currently stands holding all other mathematics classes the same. (Table 18). This supports the fact that semester analysis was separated.

C.) Wilcoxon Signed Rank Test for the Number of AP Biology Courses Taken

Because the data was non-parametric (Fall: p= <0.00001 (W=0.2039); Spring: p= cannot be determined), a Two-Sample Wilcoxon Signed Rank test was run to determine if there was a significant difference between the number of AP biology courses taken by successful versus unsuccessful students.

Number of AP Biology Courses		
Average Number of Courses	Fall	Spring
Successful	0.1262	0
Unsuccessful	0	0
Wilcoxon Value with P-value	0.04484 (W=3135)	NA

Table 19 Wilcoxon Signed Rank Test results of the comparison between successful and unsuccessful students that had taken and received college level course credit for the AP Biology examination.

In the fall, there did exist a significant difference between the number of AP biology courses taken by successful students versus the number of AP biology courses taken by unsuccessful students with the higher mean number of AP biology courses falling to the successful students ($p=0.04484$; $W= 3135$). However, in the spring there did not exist a significant number of students that had taken AP biology to determine if a significant difference existed between the number of AP biology courses taken by successful students versus the number of AP biology courses taken by unsuccessful students. Also, between the fall and spring, there did not exist a statistical difference in the number of AP biology courses taken by all students ($p= 0.2146$; $W=8.5$). (Table 19). The differences between the semesters here, again, supports the separation of the data into separate analysis.

D.) Bar Graph of Percentages of Students Taking A Specific Number of AP Biology Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of AP Biology Courses taken. For example, out of the entire Fall Unsuccessful student group, 7% had taken 1 AP Biology Courses while in high school.

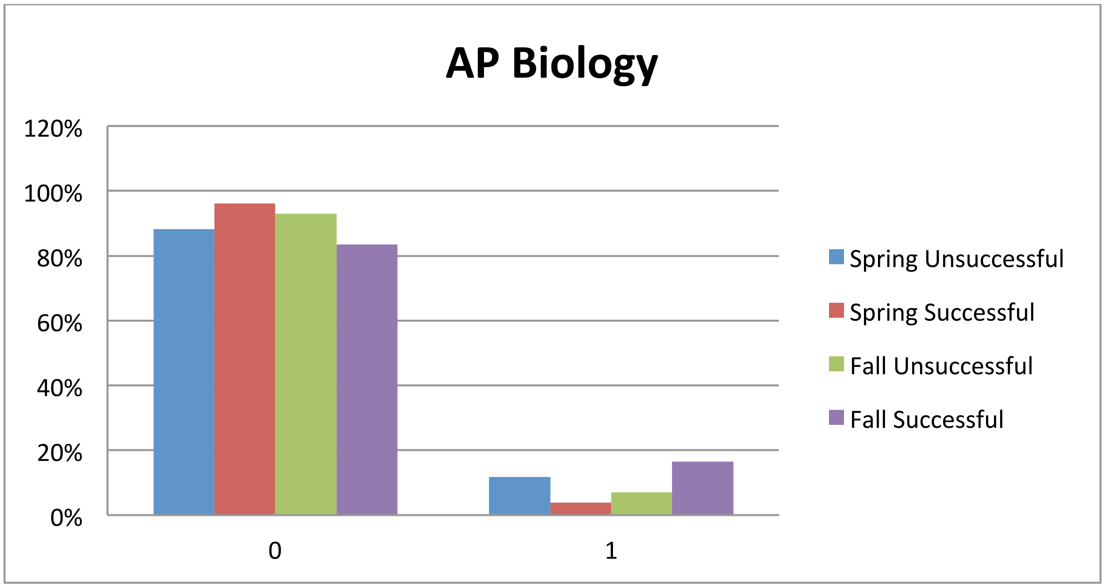

Figure 22 Bar graph of percentages of students taking a specific number of AP biology courses

The larger percentage of unsuccessful spring students than successful spring students having taken AP Biology provides support for Wilcoxon Signed Rank test results for the Spring 2013 term. There may not have been a large enough student sample size to adequately compare the two groups within the spring term. However, one can see the difference in the number of successful versus unsuccessful students having taken AP Biology. This visual difference helps support the significant difference between the number of students that have taken AP Biology in high school between the successful and unsuccessful students within the Fall semester.

E.) Bar Graph Representing a Specific Number of AP Biology Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total AP Biology Courses and the group and semester in which they belong. For example, out of all the students that participated in this study that took 1 AP Biology Courses while in high school, 76% were successful (68% in the Fall; 8% in the Spring).

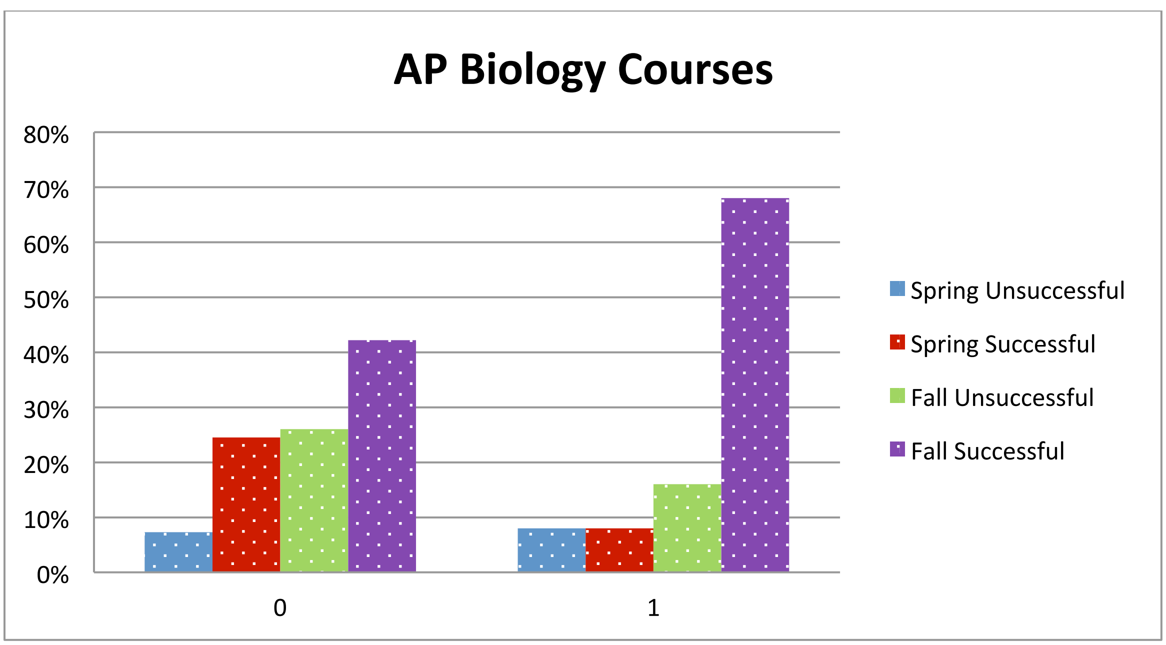

Figure 23 Bar graph representing a specific number of all AP biology courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

Figure 23 along with Figure 22, represent the visual differences between those students that took AP Biology and those that did not. It helps support the significant difference between the number of students that have taken AP Biology in high school between the successful and unsuccessful students within the Fall semester.

F.) Bar Graph Representing a Specific Number of All AP Biology Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total AP Biology Courses and the group in which they belong. For example, out of all the students that participated in this study that took a total 3 AP Biology Courses while in high school, 76% were successful.

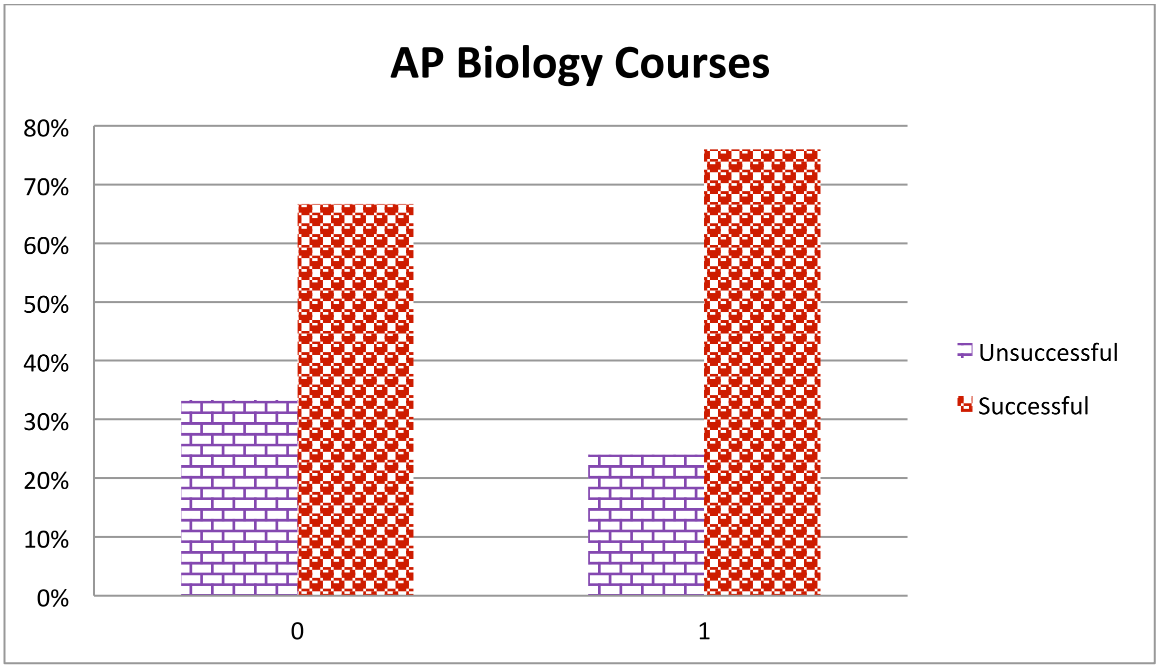

Figure 24 Bar graph representing a specific number of all AP biology courses taken in high school and the percentage of students only within a group (Successful or Unsuccessful)

This graph also supports the separation of the two terms when considering data analysis, and helps demonstrate how some discrepancies are visual when looking at more than one visual or table.

Extra Results

A.) Bar Graph of Percentages of Students Taking A Specific Number of Chemistry Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of Chemistry courses taken. It also demonstrates how successful students in the fall and spring semesters are the only students that have taken 3 chemistry courses.

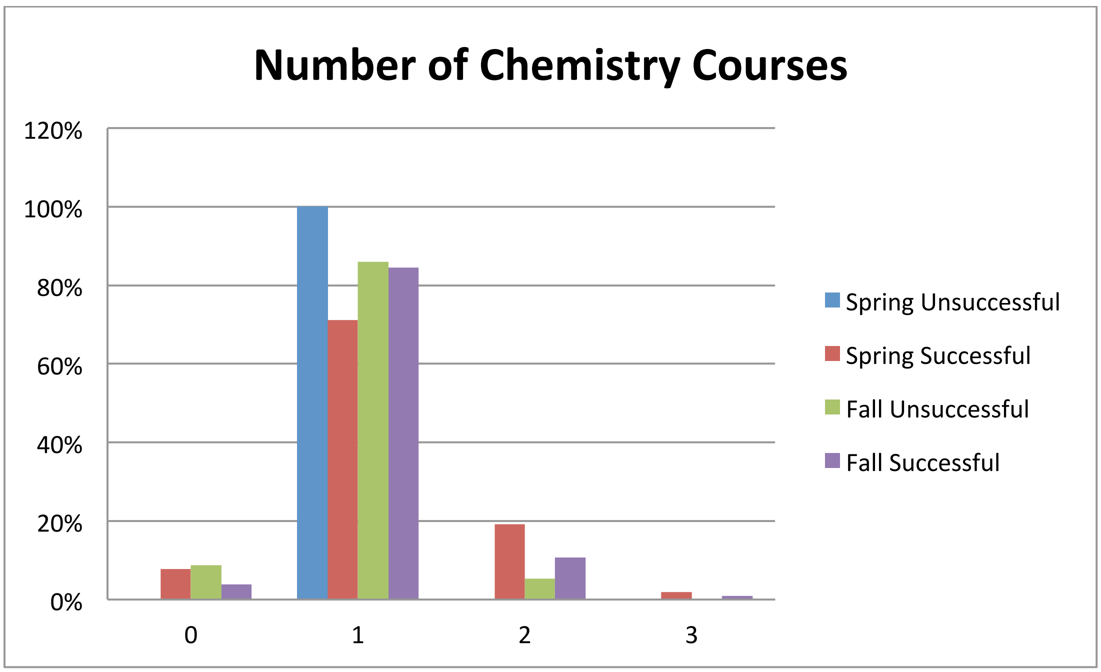

Figure 25 Bar graph of percentages of students taking a specific number of chemistry courses

B.) Bar Graph Representing a Specific Number of Chemistry Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Chemistry courses and the group and semester in which they belong. It also demonstrates how successful students in the fall and spring semesters are the only students that have taken 3 chemistry courses. However, Figure 26 does a great job presenting the trend of an increased percentage of successful students within the fall and spring semester within the increased numbers of chemistry courses taken and how the opposite trend is prevalent for unsuccessful students.

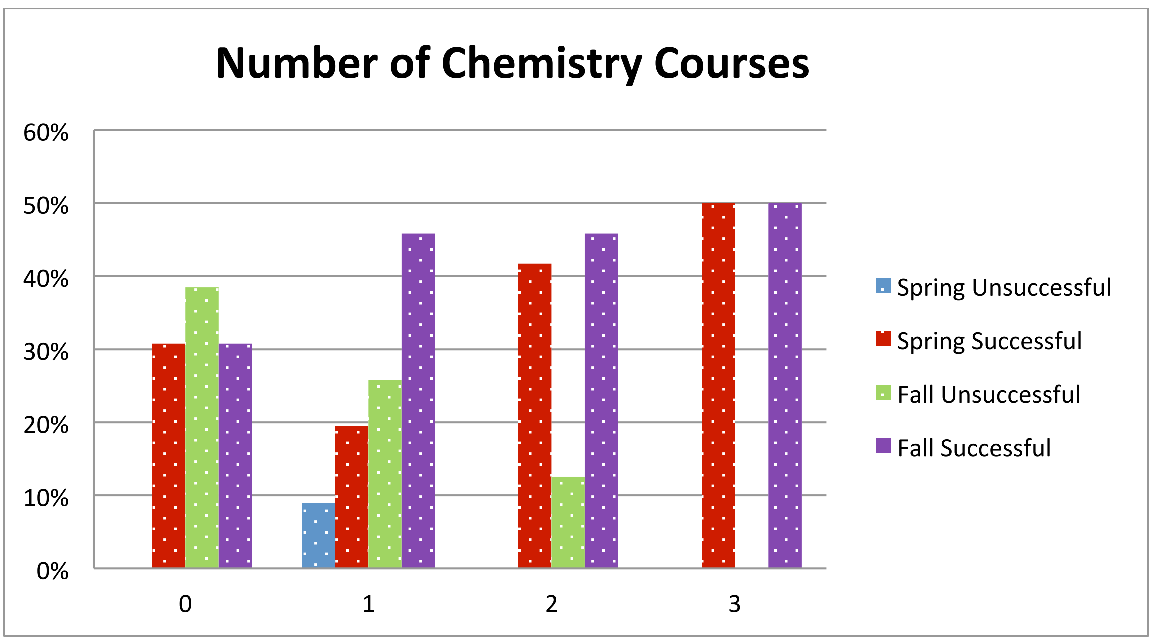

Figure 26 Bar graph representing a specific number of all chemistry courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

C.) Bar Graph Representing a Specific Number of All Chemistry Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Chemistry courses and the group in which they belong. Figure 27 does a great job presenting the simplified visual of the two opposing trends of an increased percentage of successful students within the fall and spring semester within the increased numbers of chemistry courses taken and a decreased percentage of unsuccessful students within the fall and spring semester within the increased numbers of chemistry courses taken.

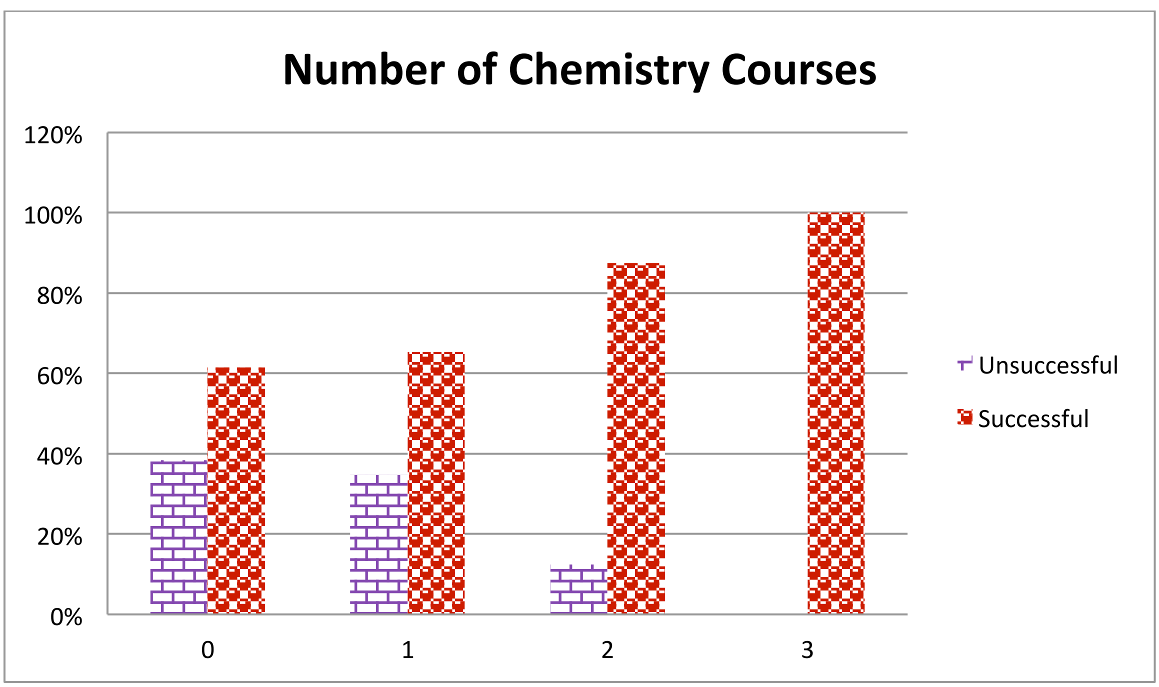

Figure 27 Bar graph representing a specific number of chemistry courses taken in high school and the percentage of students within a group (Successful or Unsuccessful)

D.) Bar Graph of Percentages of Students Taking A Specific Number of Physics Courses

The bar graph below demonstrates the percentage of students within a group (Successful or Unsuccessful) for each semester grouped by the number of Physics courses taken.

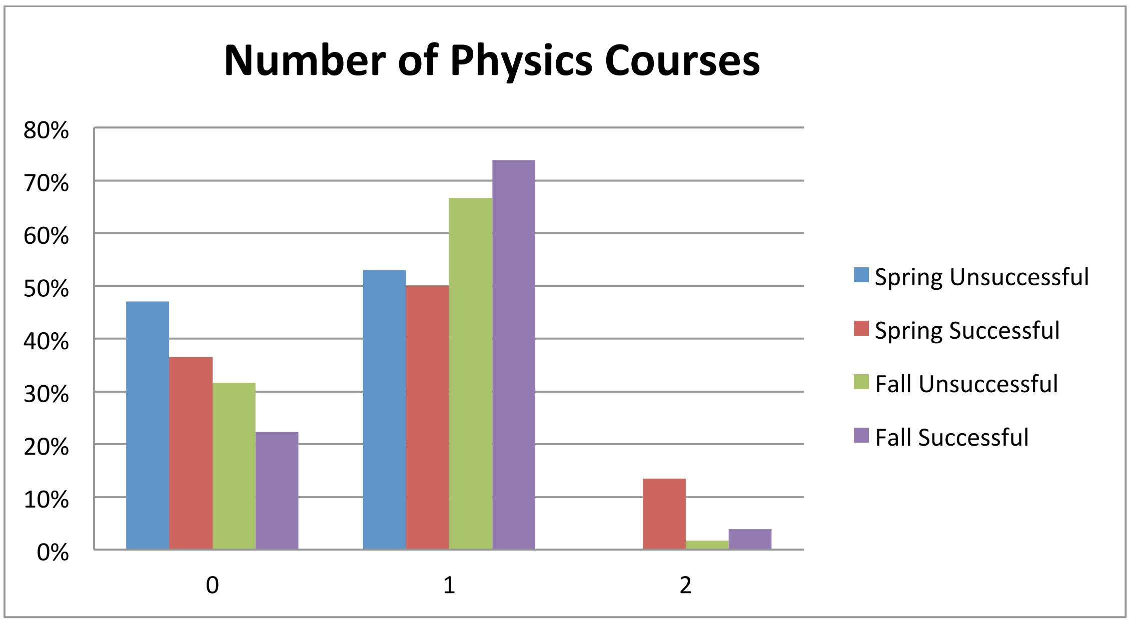

Figure 28 Bar graph of percentages of students taking a specific number of physics courses

E.) Bar Graph Representing a Specific Number of Physics Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful) and Semester

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Physics courses and the group and semester in which they belong. Figure 29 does an adequate job presenting a visual of the two opposing trends of an increased percentage of successful students within the spring semester within the increased numbers of physics courses taken and a decreased percentage of unsuccessful students within the spring semester within the increased numbers of physics courses taken. The Fall 2012 unsuccessful student trend is presented very effectively visually in Figure 29; however, that is not the case with the Fall 2012 successful students in which the positive trend is not as visually present.

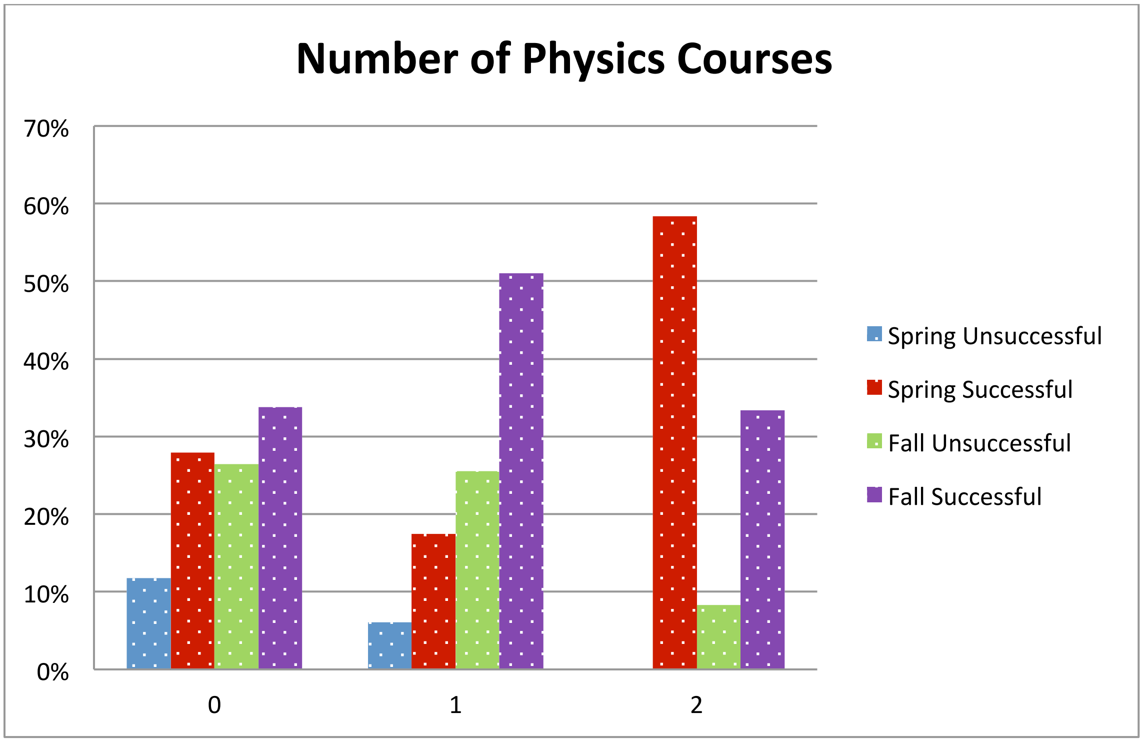

Figure 29 Bar graph representing a specific number of all physics courses taken in high school and the percentage of students within a group (Successful or Unsuccessful) and semester

F.) Bar Graph Representing a Specific Number of All Physics Courses Taken in High School and the Percentage of Students within a Group (Successful or Unsuccessful)

The bar graph presented below demonstrates the percentage of students within all the students that took a specific number of total Physics courses and the group in which they belong. Figure 30 does a great job presenting the simplified visual of the two opposing trends of an increased percentage of successful students within the fall and spring semester within the increased numbers of physics courses taken and a decreased percentage of unsuccessful students within the fall and spring semester within the increased numbers of physics courses taken.

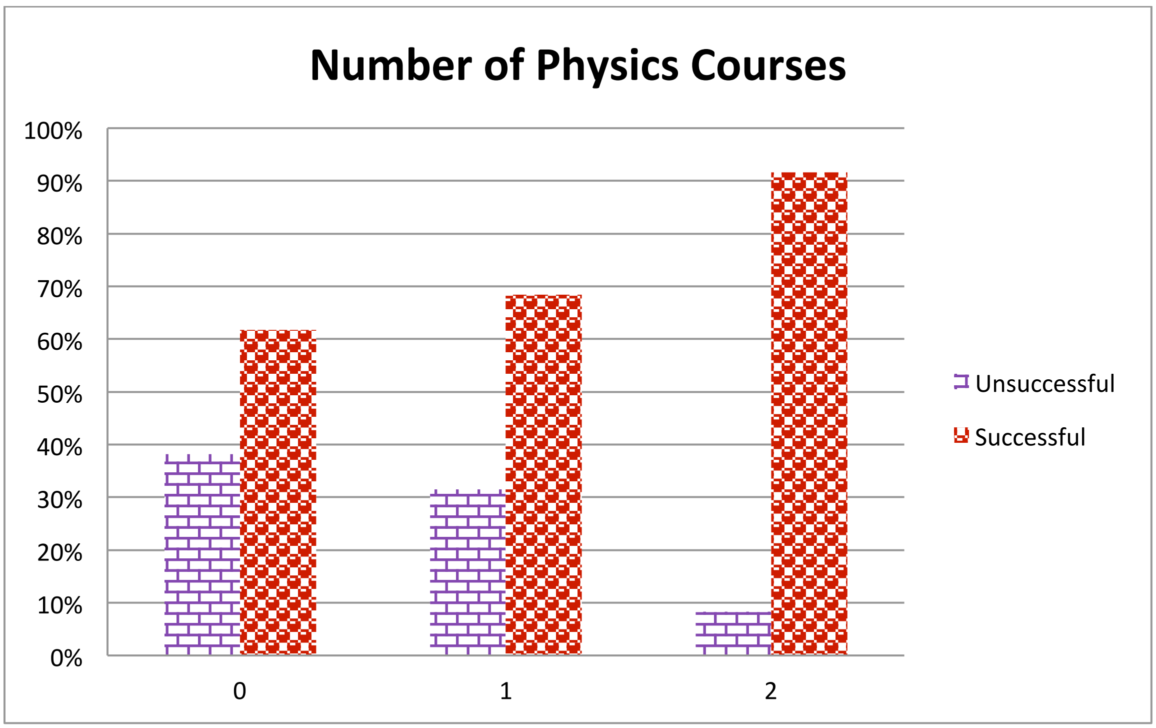

Figure 30 Bar graph representing a specific number of all physics courses taken in high school and the percentage of students within a group (Successful or Unsuccessful)

DISCUSSION

High school teachers tend to make it known that they are preparing their students for success in college courses (Sadler and Tai, 2000). While one of the major goals of this study was to aid high school STEM teachers in reflecting upon their courses they teach for college-bound students, the author understands that preparation for college is not the only reason to take STEM courses in high school (Sadler and Tai, 2000). Not only are many students state-mandated to take a certain number of STEM courses, many teachers are interested in encouraging students to take multiple STEM courses in an effort "promote scientific literacy in helping students to think analytically or in having students understand the impact of science on the world" (Sadler and Tai, 2000; Hoffer et al., 1996). Many teachers hope to optimize the future success of their students in science courses (Sadler and Tai, 2000); however, like in chemistry, the experiences of students in high school STEM courses around the United States are many and varied due to the variety of choices and forces that teachers face in their classroom (Tai et al., 2005). The preparation that high school teachers state is taking place in their classrooms is not often seen in the college classrooms (Sadler and Tai, 2000). In spite of the great level of preparation by the high school teachers, many college level professors are "dismayed by the difficulty that students have in their introductory courses" and express doubts about the value of some of these high school college preparation courses, not to mention that dropout rates are high in the "gate-keeping" courses (Sadler and Tai, 2000; Gainen, 1995; Gibson and Gibson, 1993; Halloun and Hestenes, 1985; Razali and Yager, 1994; Shumba and Glass, 1994).

In this study it was determined that the number of mathematics and science courses taken by a student does affect success in the introductory college biology for majors class at

ASU. Although a binomial generalized linear regression could not be run on all the non-background variables, the number of mathematics courses taken in high school had a significant effect on success in the fall Principles of Biology in three of the four binomial generalized linear regressions. There also existed a significant difference between the mean number of mathematics courses taken by successful versus unsuccessful students in the fall when analyzed using the Wilcoxon Signed Rank test with the higher mean favoring the successful students in the fall semester. For the spring, the number of mathematics courses taken in high school had a significant effect on success in the Principles of Biology introductory college biology courses in two of the four binomial generalized linear regressions, but there did not exist a significant difference between the number of mathematics courses taken by successful versus unsuccessful students in the spring when analyzed using the Wilcoxon Signed Rank test. Overall, it was determined that a student is approximately 37-62% more likely to be successful per each additional mathematics course that is taken in high school. This conclusion was also supported with the three bar graphs (Figure 1, Figure 2, Figure 3) in which the general trend of the successful students followed that of an increase in the number of mathematics courses taken.

This influence that the number of mathematics courses has on success in the introductory college biology course at ASU is also supported by the study performed by Gifford and Harpole (1968) in which they found that higher high school math grades were also associated with high grades in college physics. While this current study primarily focuses on the influence of students having taken a particular number of mathematics courses while in high school, the study by Hart and Cottle (1993) also found that high performing students in college physics at Florida State University had performed well in high school math. In order for a student to complete a particular number of mathematics courses, then he or she must have also completed (passed) all subsequent mathematics courses. Sadler and Tai (2000) also found that taking a calculus course in high school was highly correlated to doing well in college physics. The Education Trust (2003) stated that, of those three required mathematics courses many states require, student should be taking Algebra 1, Geometry, Algebra 2, and 1 more year of mathematics beyond Algebra 2 along with 3 years of natural science that include lab sciences such as biology, chemistry, and physics (The Education Trust, 2003). This is also supported by the binomial generalized linear regression in which students in the fall that took trig, pre-calculus, calculus 2, AP calculus were more likely to be successful.

The number of total science courses taken in high school had a significant effect on success in the fall Principles of Biology in the binomial generalized linear regression run. There also existed a significant difference between the number of science courses taken by successful versus unsuccessful students in the fall when analyzed using the Wilcoxon Signed Rank test with the higher mean number of science courses falling in the successful student categories. For the spring, the number of science courses in general taken in high school did not seem to have a significant effect on success in the Principles of Biology introductory college biology courses in the binomial generalized linear regression run, and there did not exist a significant difference between the number of science courses taken by successful versus unsuccessful students in the spring when analyzed using the Wilcoxon Signed Rank test. It was determined that, in the fall, a student is approximately 65.6% more likely to be successful per each additional science course that is taken in high school when all other variables in that regression are held constant. Figure 4 helps visually explain some of the discrepancies between the data. Due to the large number of spring unsuccessful students that have taken 5 or more science courses, the Wilcoxon Signed Rank test on the spring data did not detect a difference. This adds support to the separation of analysis of the two terms.

This concept is parallel with the concept of college readiness and research that suggests that students should take at least three years of both mathematics and science (ACT, 2008a; Teitelbaum, 2003). 97% of the successful students in the Fall 2012 term had taken 3 or more science courses in high school. This is consistent with the research of Teitelbaum (2003) and ACT (2008a). The fact that the number of science courses has an influence on introductory college biology success at ASU also coincides with the idea that it is recommended that students take higher –level mathematics and sciences courses in high school(ACT, 2008a; Robinson and Ochs, 2008; Teitelbaum, 2003). These higher – level mathematics and science courses will, in turn, help students gain more knowledge and become more proficient in mathematics and science (ACT, 2008a; Robinson and Ochs, 2008; Teitelbaum, 2003). Support for this result is also provided by the studies of Titelbaum (2003) and Robinson and Ochs (2008) in which the increased number of mathematics and science courses was positively associated with student achievement and students would be better prepared for college science courses that lead to STEM careers if they were to achieve a better groundwork in mathematics and science.

Even though a binomial generalized linear regression could not be run on all the non-background variables, the number of biology courses taken in high school had a significant effect on success in both the fall and spring Principles of Biology in all of the binomial generalized linear regressions that originally included biology as a variable. A significant difference also existed between the number of biology courses taken by successful versus unsuccessful students in the fall when analyzed using the Wilcoxon Signed Rank test, but there did not exist a significant difference between the number of biology courses taken by successful versus unsuccessful students in the spring when analyzed using the Wilcoxon Signed Rank test. This difference between the fall and spring semester can be represented visually in Figure 8 in which approximately 70% of the students that took no biology course in high school were successful and Figure 9 in which the trends present in Figure 8 for the Fall 2012 data become less pronounced. It was also determined that a student is approximately 32-65% more likely to be successful per each additional biology course that is taken in high school. The general opposing trends for the Fall 2012 data where larger percentage of successful students make up larger percentages of the increased number of biology courses taken in high school groups and larger percentage of unsuccessful students make up larger percentages of the decreased number of biology courses taken in high school groups presented in Figure 7. This is also supported by the study by Boon and Reid (2011) in which students performed best when they had completed biology in conjunction with chemistry in the senior year. In the study by Tamir (1969), it was also demonstrated that students who had no biology in high school were at a distinct disadvantage in college compared to those students that took biology and chemistry in high school.

It was determined that, in the fall semester term, there did exist a significant difference in the number of science courses with a lab taken in high school when comparing successful versus unsuccessful students in the introductory college biology course required for STEM majors at ASU. However, this trend, again, did not follow into the spring semester in which there did not exist a significant difference in the number of science courses with a lab taken in high school when comparing successful versus unsuccessful students in the introductory college biology course required for STEM majors at ASU. Just like the results from the Wilcoxon Signed Rank test, Figure 10 and Figure 11 support the overall conclusion in that there does not appear to be a trend with the spring data but a trend is present with the fall data leading one to believe that the number of science courses with lab time taken in high school does have an effect on success in the Bio 1480 course at ASU. However, the strength of the effect may be dependent on term data.

It was determined that, in the fall and spring semester term, there did exist a significant difference in the number of biology courses with a lab taken in high school when comparing successful versus unsuccessful students in the introductory college biology course required for STEM majors at ASU. Figure 14 supports the significant effect of the number of biology courses with lab time taken in the Fall 2012 semester term determined by the Wilcoxon Signed Rank test. However, the trend presented in Figure 13 and Figure 14 is the opposite the trend that one would expect from the Wilcoxon Signed Rank test. However, these graph do visually clarify the fact that the unsuccessful students in the Spring 2013 term had a larger mean number of biology courses taken with lab time than the unsuccessful students even with the presence of a significant difference. The larger influence of successful students in the lower number of biology courses with lab time provide insight into the flow of the data.

This outcome is similar to the study performed by Tamir (1969) in which students who had laboratory blocks in high school achieved significantly better in college biology than those without a laboratory block. In that study, it was also interesting that students that had a lab block in high school did not perform any better in the college level lab than those students that did not have a lab block (Tamir, 1969). The seemingly contradictory results from the study by Tamir (1969) may lend some insight into the difference between the presence of lab time significance between the fall and spring semester in which there was a larger mean number of biology courses with lab time taken by unsuccessful students. The positive significance is also supported by the study performed by Gifford and Harpole (1986) in which high school physics courses and high amounts of laboratory time in high school were associated with high performance in college physics. Lab grades play a partial part of the grade in the Principles of Biology course, and the influence of the lab in the introductory biology course, may explain the significance differences between the semesters. The lack of a significant difference in the lab section of the introductory biology course in the study by Tamir (1969) versus the significant differences in courses with high amounts of lab time in the study by Gifford and Harpole (1986) support the variation between the significance of lab time in this current study.

Having already taken AP Calculus in high school had a significant effect on student success in both the fall and spring Principles of Biology introductory college biology course at ASU in both of the math only binomial generalized linear regressions in which AP Calculus was included as a variable. There also existed a significant difference between the number of successful versus unsuccessful students that had taken AP Calculus courses in the fall when compared using the Wilcoxon Signed Rank test; however, a significant difference between the number of successful versus unsuccessful students that had taken AP Calculus courses in the spring could not be determined. The bar graph in Figure 16 supports this occurrence in that it can be seen that 100% of the Fall 2012 unsuccessful students had not taken AP Calculus. Figure 17 also supports this occurrence in that 5% of the students that had taken AP Calculus were successful in the spring and 5% were unsuccessful in the spring term essentially cancelling out any effect the spring semester could have determined. Through the regressions it was determined that a student can be up to 99% more likely to be successful if AP Calculus is taken in high school. This probability is also supported by the study performed by Tai and Sadler (2001) in which students with a background in calculus fared better in the two types of physics courses than those that did not have calculus (Tai et al., 2005). Again, it was stated by the Education Trust (2003) that, of those three required mathematics courses many states require, student should be taking Algebra 1, Geometry, Algebra 2, and 1 more year of mathematics beyond Algebra 2 along with 3 years of natural science that include lab sciences such as biology, chemistry, and physics (The Education Trust, 2003). This is also supported by the binomial generalized linear regression in which students in the fall that took trig, pre-calculus, calculus 2, AP calculus were more likely to be successful.

There also existed a significant difference between the mean number of successful versus unsuccessful students that had already taken AP science courses in the fall when compared using the Wilcoxon Signed Rank test; however, there did not exist a significant difference between the mean number of successful versus unsuccessful students that had taken AP science courses in the spring. This like several other Wilcoxon Signed Rank test help support the separate analysis of the terms. Supporting this result is the fact that in the study by Sadler and Tai (2007) show those students that received college level credit by taking a science AP exam were predicted to earn grades higher than the average student. Tamir (1969) stated that it is possible that students were not as willing to invest their time and effort in relearning the familiar subject matter that was covered in high school and preferred to put their time on less familiar and more demanding courses. In this sense, those students felt that they had already covered the material in class and should, therefore, perform well. However, other variables in that study had similar ratings (high school math grade, SAT math, highest math course taken in high school, and average science grade) and these variables may also have an effect in the current study as well (Sadler and Tai, 2007). From this it can be concluded that those other variables together may be stronger predictors for success than performance in the AP course and exam alone (Sadler and Tai, 2007). These conclusions are also visually.

However, there could be many reasons why AP exam students do not consistently attain high levels of performance and therefore, do not meet the College Board's expectations (Sadler and Tai, 2007). This could be due to the fact that the AP exams do not fully reflect the content of the college courses, the AP exam cannot cover and test ALL elements that the multiple exams in a traditional biology class cover, an over-generosity in the AP exam scoring, and the fact that this study does not have access to EVERY student that passed and received college credit for the AP exam (Sadler and Tai, 2007). Other reasons for discrepancies in the influence of AP exams could be due to the fact that all AP courses may not be equally rigorous, some students may not test well, and the AP exams do not always test process and critical thinking skills that are assessed in the Biology 1480 course at ASU. As mentioned earlier, ASU provides non-majors college level biology credit to students. This study did not have access to that group of students. As mentioned in the study by Sadler and Tai, there could be other reasons as well. Those students that took a rigorous AP course in high school could have been bored in the Principles of Biology course at ASU and therefore not as likely to work to succeed. Another interesting fact that sheds some light on the peculiar results mentioned above is presented in the study by Sadler and Tai (2007) in which half of the students they studied that receive an AP score of 5 (equivalent to an A according to the College Board) missed the A level performance (Sadler and Tai, 2007; College Board, 2004).

Having already taken AP Biology in high school had a significant effect on student success in the spring Principles of Biology introductory college biology course at ASU in the biology only binomial generalized linear regression in which AP Biology was included as a variable. There also existed a significant difference between the number of successful versus unsuccessful students that had previously taken AP Biology in high school for the fall semester when compared using the Wilcoxon Signed Rank test; however, similar to the results of 3.1, a significant difference between the number of successful versus unsuccessful students that had taken an AP Biology course in high school for the spring could not be determined. It was determined that a student in the spring semester term was 12.2% more likely to be successful if AP Biology was taken in high school. Figure 22 and Figure 23 support this information visually and provide some insight into the discrepancies of the Wilcoxon Signed Rank test. The graph in Figure 22 represents that a large percentage of each group within the two semesters have not taken any AP Biology courses. The Fall 2012 semester contained the largest percentage of students that had taken AP Biology (approximately 18% of all successful Fall 2012 students). There also existed a larger percentage of unsuccessful Spring 2013 that had taken AP Biology in high school than successful students. This visual provides great insight into the differences that existed between the semesters.

This overall conclusion is similar to the study by Sadler and Tai (2000) in which calculus and high grades in high school predicted higher than average grades in college physics. This information is similar to that determined by Tamir (1969) which students achieved significantly better in the fall semester but not in the spring. This also is similar to their study performed in 2007 in which students that reported AP exam scores of 3 or higher earned college grades that were higher than the student average. Many of the students in the study by Sadler and Tai (2007) felt that taking the AP course provided good preparation for the college science course and that they benefited from taking the actual college science course as well.

Even though observing the influence of Chemistry on success was not one of the primary goals of this study, the thesis author presents the information here due to its role in the results. Chemistry is considered as a “central science”, and course mastery along with mastery of the subjects are essential to not only other chemistry courses but also other STEM courses (Tai et al, 2005). Because chemistry is often required coursework in other majors, many other STEM majors may be deterred from that field (Tai et al, 2005). On its own, chemistry performs the gatekeeper function so commonly expected in the STEM fields. This is the case for ASU biology majors. The number of chemistry courses taken in high school had a significant effect on success in the fall Principles of Biology in one of the three binomial generalized linear regressions in which it was included as a variable. For the spring, the number of chemistry courses taken in high school had a significant effect on success in the Principles of Biology introductory college biology courses in two of the three binomial generalized linear regressions in which it was included as a variable. It was determined that a student is approximately 54-79% more likely to be successful per each additional chemistry course that is taken in high school. This conclusion is supported by studies like that of Tai et al. (2005), Ogden (1976), Nordstrom (1990), and Yager, Snider, and Krajcik (1988). It is also supported by Tamir (1969) in which the influence of chemistry could sometimes replace the influence of biology when looking at biology student success. In this study, the general trend is also supported by Figure 26 in which the largest percentage of students that account for having taken 2 or 3 chemistry courses are successful students in the fall and spring semesters.

In this study the number of physics courses taken in high school did not have a significant effect on success in the fall Principles of Biology in any of binomial generalized linear regressions in which it was included as a variable. This is interesting because physics is generally taken in the final stage of high school science and is "taken by the top 25% of students nationally" (Sadler and Tai, 2000; National Science Foundation, 1993). One would think that physics would have a significant effect on success in the introductory college biology classroom as it did in the studies performed by Sadler and Tai (2000), Gifford and Harpole (1986), Hart and Cottle (1993), and Alters (1995). This variability can be observed visually in Figure 28. In this figure, one can see how there is an overall greater percentage of successful students that have taken 2 physics courses and a large percentage of unsuccessful students that have taken no physics courses in high school; however, there is an equally large percent of unsuccessful and successful students that have taken at least 1 high school physics course (Figure 29). This result could be due to the fact that physics courses are not offered in abundance in the high schools in which the students taking the Biology 1480 course attended. However, this outcome could be somewhat expected because "high school physics courses appeared to make a much smaller contribution on college physics course grades", and if this is the case for college physics courses grades, one could also understand the limited applicability to the college biology course grades (Tai et al., 2005).

The significant effect of the semester term in the binomial generalized linear regressions could be due to several factors. Even though there was not a significant difference between the student composition and background between each of the semester terms, student background and the large numbers of freshmen in class composition in each semester term could play a large role (Fall 74%, Appendix C). The spring semester term is the second semester term for many freshmen (36%, Appendix C). It is also commonly known that the nature of the students in spring semester is often different. Although their background may be significantly similar, the students' college routine may be in place by that second semester term. This observation can also be supported by the fact that, within this study, 83% of students that were successful in the Spring 2013 term had taken 3 or more science courses in high school, but there was also 94% of unsuccessful Spring 2013 students that had taken 3 or more science courses. Discrepancies like this provide support for the analysis of the semester data separately. Visual representations of the data like that of Figure 15, Figure 12, Figure 9, and Figure 6 in comparison with separately analyzed data help bring many of thesis discrepancies to the foreground. Trends that are seemingly apparent with separately analyzed data tend to become less evident in some situations in which data is combined.

Those freshmen students that were completely new and overwhelmed in the fall may be well-organized and settled by the spring. Many students may not have taken Biology 1480 in the fall because they needed a remedial math course and then, in the spring semester, possess better analytical skills. The students may not have decided to move into a STEM field until after the end of the first semester, and unlike those students that wanted to be in a STEM major in the fall but after taking Biology 1480 switch out, these students may be more motivated to stay in the field. Just like in the study performed by Sadler and Tai (2000), students can take the introductory Principles of Biology course any of their 4 years at ASU. In their study, those students that waited and took the college physics course their sophomore or junior years performed one point higher for each year they waited after their freshman year. Also, many students unable to handle the pressures of school in the fall may not return to school in the spring leaving a far more stable and mature group of students in the spring.

Many first-generation students, in which approximately 40% of the students in the fall and spring semester belonged, may not realize the financial responsibility of attending a four-year university. Students may not realize the pressures of going to school and supporting themselves financially until their first semester. Being from many of the small feeder communities, in which a majority of the students in the Biology 1480 course are from, may play a large role in a student's difficulties during his or her first semester. Many smaller or poorer communities may not offer STEM courses (like physics) in the frequency or the variety that wealthier communities do (Sadler and Tai, 2000). Fewer students form economically poorer communities take a large number of STEM courses in high school and therefore may not be adequately prepared for these college level introductory STEM courses like the Principle of Biology course at ASU (Neuschatz and McFarling, 1999). These, and many more reasons, could help explain the significant effect of the semester term variable in the generalized linear regressions. The presence of a term as a significant effect may help explain why, in the fall, the mathematics, all sciences, and/ or biology courses taken in high school had a significant effect yet the effect was not seen in the spring. The population of students that take the spring semester of the Principles of Biology course at ASU may vary slightly enough, although not significantly, that this difference is observed.

The first semester sets foundation for many students. Academic success in first-year college science coursework can strongly influence the future career paths of students (Breckler et al., 2011). College students make decisions in their first semester that will greatly affect the rest of their college career. Introductory biology courses provide the essential foundation and act as scientific 'gateways' for students hoping to enter science and health professional careers (Wood, 2009; Tai et al., 2005), and failure in these courses shuts out career options and pushes students toward non-science fields (Sadler and Tai, 2000). If students do poorly in a first semester, it is incredibly difficult to pull up low Grade Point Averages (GPA) or get into and succeed in later courses. This is especially true in the Science, Technology, Engineering, and Mathematics (STEM) fields. In those STEM "gateway courses" it is necessary to do well the first time (Wood, 2009).

CONCLUSION

Academic success in a student's first year of college, especially in science course work, is important for future achievement. Those students that take the introductory college STEM courses are the students that wish to become the future science teacher, doctors, scientists, and engineers (Sadler and Tai, 2000). Many students often decide whether or not they will even continue to major in science based on their experiences in introductory courses (Seymour and Hewitt, 1997; Labov, 2004). All too often, students that enter college planning to major in a STEM field completely change their plans after completing (or not completing) an introductory course (Labov, 2004).

Many factors influence achievement in introductory biology courses. Research suggests that students should take at least three years of both mathematics and science courses (ACT, 2008a; Teitelbaum, 2003); however, which science and mathematics courses the student takes is often varied. It is the student that decides on which level to take a STEM course, how far he or she should go in high school mathematics, and how hard he or she should work in their STEM course (Sadler and Tai, 2000). This study suggests that for the introductory college Principles of Biology course at ASU, that the number of mathematics and science courses taken by a student in high school does affect success. This is especially apparent for the fall semester. The number of mathematics, science courses in general, and biology course number effect success of students in this introductory college biology course to varying degrees. Students are approximately 35 – 65% more likely to be successful in the Biology 1480 course at ASU for each additional math, science, or biology course taken in high school.

The variation between the semesters is something that can be very valuable to the instructors of the Principles of Biology course at ASU. It appears that the influence of the number of mathematics and science courses taken in high school has a higher influence in the fall than in the spring semester. This difference could be directly related to the fact that those returning students, generally, have at least one semester of college under their belt. Those students that did not take introductory biology in the fall may have been required to complete remedial mathematics courses and therefore, with the added benefit of having a semester of college under their belt, do not depend as heavily on the mathematics and science courses taken in high school. However, those students that are going directly into the Principle of Biology course at ASU, may rely more heavily on their experience in those high school mathematics and science courses taken in high school to succeed in the college course. This is something that the college and high school teachers can use to advise their students of the best plan of action. Those students that took a rigorous and more numerous selection of high school mathematics and science courses in high school should feel more comfortable in the Bio 1480 course at ASU where those that do not take a rigorous and more numerous selection of high school mathematics and science courses in high school should most likely wait to take the college introductory biology course in which success is important for so many STEM majors.

Whether not the number of science courses in general with a lab taken by a student in high school affects success in introductory biology courses required for STEM majors offered at ASU, is not as clear. There exists a significant difference in the number of science courses with lab time in the fall term, but if a significant difference exists in the spring, it cannot be determined. The number of biology courses with lab time appears to effect student success in both the fall and the spring. The visual results pose several questions about the results from the Wilcoxon Signed Rank test. While biology courses with lab time seem to affect success, science courses in general with lab time may or may not affect success in introductory college biology course. With this study, those results are not conclusive.

From this study, it can be concluded that the number of Advanced/ college placement mathematics does affect success in introductory biology courses required for STEM majors offered at ASU. A student is 99% more likely to be successful having taken AP Calculus. Whether or not taking any Advanced/ college placement science courses in general in high school or any Advanced/ college placement Biology courses in high school increases success in the introductory college biology courses is not as conclusive. Although there existed a significant difference in the fall in both the number of AP science courses in general and AP Biology courses taken by successful versus unsuccessful students, whether or not a significant difference existed in the number of AP Biology classes could not be determined, and the number of AP science courses in general taken in high school did not have a significant effect on success in the spring semester. This supports the conclusions of the Sadler and Tai (2007) study in which they stated that the AP exams may fall short in the predictive validity claimed by the College Board, and that students who pass the exams may benefit greatly from re-taking the college course in order to fully master the content.

This small-scale questionnaire study has some advantages that allow the author to identify variables that play a role in the wider population; however, because of the sampling numbers used, this study is limited in it generalizability of the outcomes (Tai et al. 2005). For this reason, the conclusions drawn can only be applied to a small extent. Enrolling in high school mathematics and science courses in general has a positive relationship with introductory college biology grades. The demographics and school variables most likely also play a large part in students success, but they could not be examined in this study due to sample size restraints.

High school teachers blame college faculty of archaic instructional approaches while college faculty blame high school teachers for failing to understand and teach the content (Frost, et al., 2010). In an effort to move past thesis grudges, college advisors can use this study to advise their students to proceed with caution if they have only taken 1 science course and 2 mathematics courses and expect to succeed in Biology 1480 at ASU. However, those advisors and instructors must also keep in mind when drawing from the big ideas of this study (like in the study of Tai et al. (2006)), that a large portion students' grades may not be factors attributable to themselves or the course. High school teachers and counselors can use this study to advise their students that wish to be doctors, pharmacists, physicians' assistants, or optometrists to proceed with caution if they have only taken 1 science course and 2 mathematics courses and expect to succeed in Biology 1480 at ASU.

Future Research and Drawbacks

One of the major drawbacks to this study is the fact that this study is not longitudinal. The author had to rely primarily on self-reported data. Another drawback would be that a larger sample size would have allowed for the inclusion of more variables, including demographic variables, in the regressions and allowed for the usage of mixed effects models that may have provided the opportunity to understand more of the underlying relationships with the students. Also, in this study, the author was only able to observe students in one majors biology class at one university. She was unable to get information from multiple universities and larger students populations thereby increasing the sample size and allowing for a large-scale study. Reversing any one of these drawbacks will provide a more conclusive study in the future.

Another interesting topic to research, would be determining if, like in the study by Tamir (1969), student achievement is significantly different or similar within the lab portion of the class between those students that had lab time in their high school biology course and those that did not. The Principles of Biology courses examined in this study determines grades based on lab influence, classwork, exams, and homework. The role that the number of mathematics and science courses play on success in the lab portion of the introductory college biology course at ASU was not examined in this study. The author would also like to determine a technique to use to calculate the quality of the courses taught in high school. In that sense, it could be determined whether or not a course taught with higher quality has a larger influence or predictive power over just the number of courses in general.

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Appendix A – IRB Consent Form

Angelo State University
Institutional Review Board (IRB)

Consent to Participate in an IRB-Approved Research Event

Project Title: Influence of High School Biology and Mathematic Courses on the Introductory College Biology Course Success at Angelo State University

Investigator Name/Department: Amanda P. Smiley, Biology Department
Investigator Phone: 662-801-6036

You are being asked to participate in a research event conducted with the approval of the Angelo State University Institutional Review Board (and if applicable, other relevant IRB committees). In order to participate, you are required to give your consent by reading and signing this document.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask any questions you have at any time before the project begins. A basic explanation of the project is written below. Please read and, should you decide to participate, sign this form in the presence of the person who explained the project to you. Upon request, you will be given an unsigned copy of this form for your records.

Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time without penalty. I understand also that it is not possible to identify all potential risks in an experimental procedure, and I believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

1. Nature and Purpose of the Project: To contribute to the understanding of what high school courses are beneficial to success in introductory biology courses.

2. Explanation of Procedures: You will be asked to complete a questionnaire that contains questions about background educational information and mathematics and science courses that you took while in high school.

3. Discomfort and Risks: There will be no penalty for refusing to participate in the study and non-participants will not be identified to participants. Participation or declining to participate will have no effect on your grade in this course. Your instructor will have no way of knowing if you participate in the study or not.

4. Benefits: While it may not seem there is any direct benefit to you by participating in this study, this study will provide us a better understanding of how to improve introductory biology courses around your prior knowledge.

5. Confidentiality: Student questionnaires will initially be matched by student ID number. These questionnaires will be handled entirely by the investigator or ASU faculty. Once matched data from questionnaires have been converted to electronic spreadsheets, a randomized ID

number will be assigned to the data and the student ID number will be deleted. Once this is done there will be no way to associate the data with the individual student from questionnaires. All data will be handled by the investigator, assistant investigators or ASU faculty. Once original questionnaires have been checked for accuracy, the student ID number associated with them will be removed or shredded. The original hard copies of records will be stored in a locked filing cabinet. Upon completion of the study, all original questionnaires will be shredded.

By signing this consent form, you are allowing the investigator or ASU faculty associated with this project access to your school records here at Angelo State University. Your signature grants the investigator permission to access these records; however, confidentiality will still be maintained throughout the project concerning student records.

The dated approval stamp on this consent form indicates that this project has been reviewed and approved by the Angelo State University Institutional Review Board (IRB) for the protection of human subjects in research and research related activities.

Any questions regarding the conduct of the project, questions pertaining to your rights as a research subject, or research-related injury should be brought to the attention of the IRB administrator, Dr. Kraig Schell (kraig.schell@angelo.edu) TEL: (325) 942-2219 x243.

Any question about the conduct of this research project should be brought to the attention of the investigator as listed on this form.

____

Participant Signature Date

____

Witness Signature Date

Appendix B - Questionnaire

Answer the Questions below:

1. Gender: (Check the answer that applies

   _______Male _______Female

2. Ethnicity: (Check the answer that applies

   _______Caucasian _____African American ______Hispanic ______Asian _______Other
   _______Prefer not to disclose

3. Age: _______ _______ Prefer not to disclose

4. Anticipated year graduating from ASU: ______________

5. Year graduated from high school: ______________

6. Concerning the last high school you attended:

   a. What type of high school did you attend?

      _______Public _______ Home schooled _______Private _______Vocational

   b. Which size community was it located?

      _______Large City _______Small City _______Suburbs

      _______Small town _______Rural Area

   c. What was the size of your graduating class?

      _______Less than 25 _______26-75 _______76-200

      _______201-400 _______More than 400

7. What was the highest level of education completed by your male parent or guardian?

   _______Did not finish high school _______Four Years of College

   _______High school _______College Degree

   _______Some College _______Graduate School

8. What was the highest level of education completed by your female parent or guardian?

_______Did not finish high school   _______Four Years of College

_______High school   _______College Degree

_______Some College   _______Graduate School

9. What year are you in college?

_______Freshman   _______Sophomore

_______Junior   _______Senior

_______5th Year Senior   _______Graduate Student

_______Other

10a. Have you ever taken ANY introductory college **biology** course(s) from ANY university, including Principles of Biology (Bio 1480) at ASU?

_______ Yes (If yes, continue on to part b of this question)   _______No (Skip to **12**)

10b. If the answer to 10a. was yes and the introductory biology course(s) was taken at a college ***OTHER*** than Angelo State University, please put the college name on the blank provided. Please also provide the LETTER grade you received in that course. If the answer to 10a. was yes, and the introductory biology course was taken at Angelo State University, continue on to number **10c**. If the answer to 10a. was yes and the introductory biology course was taken both at another university and at ASU complete the question below and continue to 10c.)

College Institution's name:____________________________________   Grade Received:________

10c. If the answer to 10a. was yes, and the introductory biology course was taken **AT ANGELO STATE UNIVERSITY**, please write in the Instructor's name, Grade Received, the semester (fall / spring) taken, and year taken for your introductory biology course taken at ASU. Continue to number **11**.

Instructor's name:____________________________________   Grade Received:________

Which semester (fall, spring) did you take originally Principles of Biology (Bio 1480) at ASU? (This is referencing your very first attempt at taking the course)

Fall / Spring   Year: _________

11. Have you taken Principles of Biology (Bio 1480) at ASU more than once? (Circle your choice)

Yes or No

12. Have you ever taken Principles of Biology (Bio 1480) at ASU before?

_______ Yes *(Have you answered 10c.?)* _______No

****

13. List the mathematics courses you took in high school from the earliest courses (First year in high school) to the latest courses (Senior Year), the school grade the course was taken, the grade earned, rate your attitude towards the professor (positive [3], neutral [2] or negative [1]), and then rate your attitude towards the subject matter (positive [3], neutral [2] or negative [1])

Attitude:

	Course:	School Grade:	Letter Grade:	Professor	Subject
1.	______________________	_______	_______	3 2 1	3 2 1
2.	______________________	_______	_______	3 2 1	3 2 1
3.	______________________	_______	_______	3 2 1	3 2 1
4.	______________________	_______	_______	3 2 1	3 2 1

14. Were any of the courses listed above Advanced Placement or College Preparation classes? (Circle the number next to those which apply)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above beside the course name. Circle which applies)

None 1. 2. 3. 4.

****

15. How many biology courses did you take in high school? (If none, skip to 21) (Circle which applies)

None 1 year 2 years 3 years 4 years Other_______(Specify)

16. List the biology courses you took in high school from the earliest courses (First year in high school) to the latest courses (Senior Year), the school grade the course was taken, the grade earned, rate your attitude towards the professor (positive [3], neutral [2] or negative [1]), and then rate your attitude towards the subject matter (positive [3], neutral [2] or negative [1]) Attitude:

	Course:	School Grade:	Letter Grade:	Professor	Subject
1.	______________________	_______	_______	3 2 1	3 2 1
2.	______________________	_______	_______	3 2 1	3 2 1
3.	______________________	_______	_______	3 2 1	3 2 1

4.	______________________	_______	_______	3 2 1	3 2 1

17. Were any of the courses listed above Advanced Placement or College Preparation classes? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3. 4.

18. Did any of the courses listed above have labs? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3. 4.

19. Of the courses listed above that had labs, how many laboratory experiments did you perform, on average, each month.

1. _____ 2. ______ 3.______

20. Of the courses listed above, how would you characterize your biology course (Put the numeral in the blank that applies)

Small number of topics in great depth (I II III IV V) Many topics in little depth

1. _____ 2. ______ 3.______ 4.______

****

21. How many chemistry courses did you take in high school? (If none, skip to 26) (Circle which applies)

None 1 year 2 years 3 years 4 years Other_______(Specify)

22. List the chemistry courses you took in high school from the earliest courses (First year in high school) to the latest courses (Senior Year), the school grade the course was taken, the grade earned, rate your attitude towards the professor (positive [3], neutral [2] or negative [1]), and then rate your attitude towards the subject matter (positive [3], neutral [2] or negative [1]) Attitude:

	Course:	School Grade:	Letter Grade:	Professor	Subject
1.	______________________	_______	_______	3 2 1	3 2 1
2.	______________________	_______	_______	3 2 1	3 2 1
3.	______________________	_______	_______	3 2 1	3 2 1

23. Were any of the courses listed above Advanced Placement or College Preparation classes? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3.

24. Did any of the courses listed above have labs? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3.

25. Of the courses listed above that had labs, how many laboratory experiments did you perform, on average, each month.

1. _____ 2. ______ 3.______

****

26. How many Physics courses did you take in high school? (If none, skip to 31) (Circle which applies)

None 1 year 2 years 3 years 4 years Other_______(Specify)

27. List the physics courses you took in high school from the earliest courses (First year in high school) to the latest courses (Senior Year), the school grade the course was taken, the grade earned, rate your attitude towards the professor (positive [3], neutral [2] or negative [1]), and then rate your attitude towards the subject matter (positive [3], neutral [2] or negative [1])

	Course:	School Grade:	Letter Grade:	Attitude: Professor	Attitude: Subject
1.	______________________	_______	_______	3 2 1	3 2 1
2.	______________________	_______	_______	3 2 1	3 2 1
3.	______________________	_______	_______	3 2 1	3 2 1

28. Were any of the courses listed above Advanced Placement or College Preparation classes? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3.

29. Did any of the courses listed above have labs? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3.

30. Of the courses listed above that had labs, how many laboratory experiments did you perform, on average, each month.

1. _____ 2. ______ 3.______

****

31. How many other science courses did you take in high school? (If none, skip to 36) (Circle which applies)

None 1 year 2 years 3 years 4 years Other_______(Specify)

32. List the other science courses you took in high school from the earliest courses (First year in high school) to the latest courses (Senior Year), the school grade the course was taken, the grade earned, rate your attitude towards the professor (positive [3], neutral [2] or negative [1]), and then rate your attitude towards the subject matter (positive [3], neutral [2] or negative [1])

				Attitude:	
	Course:	School Grade:	Letter Grade:	Professor	Subject
1.	______________________	________	________	3 2 1	3 2 1
2.	______________________	________	________	3 2 1	3 2 1
3.	______________________	________	________	3 2 1	3 2 1

33. Were any of the courses listed above Advanced Placement or College Preparation classes? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3.

34. Did any of the courses listed above have labs? (Circle which applies)

Yes / No

If so, which ones? (The numbers below correspond to the numbers listed above. Circle which applies)

None 1. 2. 3. 4.

35. Of the courses listed above that had labs, how many laboratory experiments did you perform, on average, each month.

1. _____ 2. ______ 3.______

36. Concerning your involvement and interest in science outside of regular school activities:

* Did you enter projects in the high school science fair?

________Never ________Once ________Twice ________More than one year

Appendix C – Student Demographics

Student demographic information is outlined in the table below.

		Bio 1480 2012	Bio 1480 2013	Bio 1480 2012 Percent	Bio 1480 2013 Percent
Students		187	85		
Success	Successful	103	52	55.1%	61.2%
	Unsuccessful	57	17	30.5%	20%
	Withdrawn	27	16	14.4%	18.8%
Sex	Male	75	43	40%	51%
	Female	112	42	60%	49%
	Prefer Not to Disclose	0	0	0%	0%
Classification	Freshmen	139	31	74%	36%
	Sophomore	29	33	16%	39%
	Junior	15	12	8%	14%
	Senior	4	7	2%	8%
	Post Bac	0	2	0%	2%
	Prefer Not to Disclose	0	0	0%	0%
Ethnicity	Caucasian	122	43	65%	51%
	African American	7	5	4%	6%
	Hispanic	50	28	27%	33%
	Asian	1	1	1%	1%
	Other	4	7	2%	8%
	Prefer Not to Disclose	3	1	2%	1%
Age	17	6	0	3%	0%
	18	122	19	65%	22%
	19	32	29	17%	34%
	20	14	16	7%	19%
	21	4	3	2%	4%
	22	4	6	2%	7%
	23 or older	15	12	8%	14%
Years since HS graduation	1	129	41	69%	48%
	2	28	16	15%	19%
	3	11	10	6%	12%

	4	5	4	3%	5%
	5	4	6	2%	7%
	6	2	5	1%	6%
	7	1	0	1%	0%
	8	2	0	1%	0%
	9	0	0	0%	0%
	10 or greater	0	3	0%	4%
Type of High School	Public	180	83	96%	98%
	Private	6	1	3%	1%
	Other	1	1	1%	1%
Community Size	Large City	21	17	11%	20%
	Small City	50	24	27%	28%
	Suburbs	12	8	6%	9%
	Small Town	83	28	44%	33%
	Rural Area	17	8	9%	9%
	Did Not Disclose	4	0	2%	0%
Graduating Class size	<25	25	6	13%	7%
	26-75	40	21	21%	25%
	76-200	32	10	17%	12%
	201-400	38	14	20%	16%
	>=401	52	34	28%	40%
Repeaters	Took enrolled course more than once	16	16	9%	19%
Paternal Education	Did not finish High School	30	10	16%	12%
	High School	39	22	21%	26%
	Some College	54	25	29%	29%
	Four Years of College	9	4	5%	5%
	College Degree	33	20	18%	24%
	Graduate School	18	4	10%	5%
	Did Not Disclose	4	0	2%	0%
Maternal Education	Did not finish High School	19	7	10%	8%
	High School	37	20	20%	24%
	Some College	58	25	31%	29%

	Four Years of College	15	6	8%	7%
	College Degree	37	23	20%	27%
	Graduate School	20	4	11%	5%
	Did Not Disclose	4	0	2%	0%
Students with transfer	Transfer student	19	17	10%	20%
# HS Math Courses taken	0	1	2	1%	2%
	1	3	1	2%	1%
	2	3	2	2%	2%
	3	31	17	17%	20%
	4	142	60	76%	71%
	5 or Greater	7	3	4%	4%
# HS Biology Courses taken	0	4	6	2%	7%
	1	84	46	45%	54%
	2	85	28	45%	33%
	3	11	4	6%	5%
	4 or Greater	3	1	2%	1%
# of AP biology Courses taken	0	162	79	87%	93%
	1	25	6	13%	7%
	2	0	0	0%	0%
# Biology courses with labs	0	55	44	29%	52%
	1	117	37	63%	44%
	2	15	4	8%	5%
	3 or Greater	0	0	0%	0%
# HS Chemistry Courses taken	0	10	4	5%	5%
	1	162	70	87%	82%
	2	14	10	7%	12%
	3 or Greater	1	1	1%	1%
# HS Physics Courses taken	0	47	28	25%	33%
	1	135	49	72%	58%
	2	5	8	3%	9%
	3 or Greater	0	0	0%	0%
# HS other science Courses taken	0	114	54	61%	64%
	1	62	26	33%	31%
	2	9	7	5%	8%
	3 or Greater	2	1	1%	1%
# AP science courses	0	152	69	81%	81%
	1	28	11	15%	13%

	2	6	5	3%	6%
	3 or Greater	1	0	1%	0%
# AP science/math courses	0	145	66	78%	78%
	1	30	12	16%	14%
	2	8	7	4%	8%
	3 or Greater	4	0	2%	0%
# Science courses	0	0	1	0%	1%
	1	3	2	2%	2%
	2	13	8	7%	9%
	3	38	18	20%	21%
	4	101	43	54%	51%
	5 or Greater	32	13	17%	15%
# Science courses with labs	0	30	25	16%	29%
	1	16	8	9%	9%
	2	26	16	14%	19%
	3	46	21	25%	25%
	4	55	13	29%	15%
	5 or Greater	14	2	7%	2%
Students with Dual Credit STEM coursework		1	1	1%	1%

Appendix D – Natural Log of the Odds

Student demographic information is outlined in the table on the next page. The results of the different binomial generalized regression models are provided below. The table presents the variable coefficients produced from the binomial generalized linear regression after model simplification has occurred demonstrating only significant variables. Due to the type of generalized linear regression, the variable coefficients shown are in a Natural Log of Odds format. The group comparison is made against unsuccessful students; therefore, the information presented is in comparison to unsuccessful students. "The Regression Model Run" column provides the initial list of variables included in the model (the initial binomial generalized linear regression model set up). The information for the Fall 2012 data is included first followed by the Spring 2013 data. The identification numbers under the "The Regression Model Run" column under the Spring 2013 section correspond to the identification numbers listed above in the "The Regression Model Run" column in the Fall 2012 section of this table. The identification numbers presented in the Results section.

Biology Fall 2012	*Natural Log of Odds*						
Regression Model Run	*Intercept*	*Total Number of Math Courses*	*Total Number of Science Courses*	*Total Number of Biology Courses*	*Total Number of Chemistry Courses*		
1.1.B Success = Total # of Mathematics class * Total # of Science classes taken	-1.7183	0	0.6023				
1.1C Success = Total # of Mathematics class * Total # of Biology classes taken	-4.4145	0.5255		0.6893			
1.1.D Success = Total # of Mathematics class+ Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken	-0.02258	0.11902		0.13425			
1.1.E Success = Total # of Mathematics class+ Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics	-0.02258	0.11902		0.13425			

classes taken+ Total # of Other Science classes taken+ Mathematics course # *(Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken)							
1.3.E Success = Total # of Biology classes taken+ Total # of Chemistry classes taken+ Total # of Physics classes taken+ Total # of Other Science classes taken+ Mathematics course #	-1.0905			0.6593	0.6207		
Mathematics	*Intercept*	*Pre-Algebra*	*Trig*	*Pre-Cal*	*Calculus*	*Cal 2*	*AP Calculus*
3.1.B Success = pre-Algebra+ Algebra+ Algebra 2+Geometry+ Trigonometry + Pre-Calculus + Calculus+ Calculus 2+ Advanced Placement Calculus + Other Mathematics	-0.9234	2.4977	2.6647	1.1101	1.1394	-15.8922	2.4523
Edited Mathematics	*Intercept*	*Trig*	*All Cal w/o AP*	*AP Cal*			
3.1.C Success = All the Algebra	-0.2602	18.4376	0.8011	18.025			

courses +Geometry+ Trigonometry +All Calculus Classes excluding Advanced Placement Calculus + Advanced Placement Calculus + Other Mathematics							
Biology	*Intercept*	*Pre-AP Biology*	*Anatom y*	*A and P*			
3.3.B Success = Biology 1+ Biology 2+ Biology 3+ Pre-Advanced Placement Biology (Pre-AP Biology)+ Advanced Placement Biology (AP Biology)+ Anatomy+ Physiology+ Anatomy and Physiology (A and P) + Other Biology	0.1739	0.9973	0.813	0.683			
<u>Biology</u> ***<u>Spring 2013</u>***							
Regression Model Run	*Intercept*	*Total Number of Math Courses*	*Total Number of Science Courses*	*Total Number of Biology Courses*	*Total Number of Chemistry Courses*		
1.1.B	1	*0*	*0*				
1.1C	3.7384	-0.5296		-0.5089			

1.1.D	0.7039	0		-0.127	0.1888		
1.1.E	0.7039	0		-0.127	0.188		
1.3.E	0.67887			-0.723	1.3293		
Mathematics	*Intercept*	*Cal 2*	*AP Cal*	*Other Math*			
3.1.B	1.409	33.132	-17.975	-1.291			
Edited Mathematics	*Intercept*	*All Algebra*	*Other Math*				
3.1.C	*-2.6209*	*-0.7351*	*-1.1147*				
Biology	*Intercept*	*Biology 2*	*AP Biology*	*Anatomy*			
3.3.B	*1.569*	*-2.677*	*-1.974*	*-1.569*			

Appendix E – Odds Ratio Table of the Data

The results of the different binomial generalized regression models are provided on the next page. The following table presents the variable coefficients produced from the binomial generalized linear regression after model simplification has occurred demonstrating only significant variables. Due to the type of generalized linear regression, this table represents the modified variable coefficients. In the following table, the variable coefficients are in an Odds Ratio format. The group comparison is made against unsuccessful students. Similar to the previous table (Appendix D), "The Regression Model Run" column provides the initial list of variables included in the model (the initial binomial generalized linear regression model set up). The information for the Fall 2012 data is included first followed by the Spring 2013 data. The identification numbers under the "The Regression Model Run" column corresponds to the identification numbers listed above in Appendix D under the "The Regression Model Run" column in the Fall 2012 section. The identification numbers also correspond to the Results section.

Biology Fall 2012	*Odds Ratio*						
Regression Model Run	*Intercept*	*Total Number of Math Courses*	*Total Number of Science Courses*	*Total Number of Biology Courses*	*Total Number of Chemistry Courses*		
1.1.B	0.1794	0	1.8263				
1.1C	0.0894	1.6913		1.9334			
1.1.D	0.9777	1.264		1.1437			
1.1.E	0.9777	1.264		1.1437			
1.3.E	0.3360			1.9255	1.8602		
Mathematics	*Intercept*	*Pre-Algebra*	*Trig*	*Pre-Calculus*	*Calculus*	*Cal 2*	*AP Calculus*
3.1.B	0.3972	12.155	14.3636	3.03467	3.1249	<0.001	11.6150
Edited Mathematics	*Intercept*	*Trig*	*All Calculus w/o AP*	*AP Calculus*			
3.1.C	0.7709	101706319.7	2.22799	67322159.17			
Biology	*Intercept*	*Pre-AP Biology*	*Anatomy*	*A and P*			

3.3.B	1.1899	2.71095	2.25466	1.9798			
<u>Biology</u> ***<u>Spring 2013</u>***							
Regression Model Run	*Intercept*	*Total Number of Math Courses*	*Total Number of Sci Courses*	*Total Number of Bio Courses*	*Total Number of Chemistry Courses*		
1.1.B	42.0307	*0.58884*	*0.60116*				
1.1C	3.7384	-0.5296		-0.5089			
1.1.D	2.0216			0.8807	1.2078		
1.1.E	2.0216			0.8807	1.2078		
1.3.E	1.97			0.4853	3.7784		
Mathematics	*Intercept*	*Cal 2*	*AP Cal*	*Other Math*			
3.1.B	4.0919	<0.0001	<0.0001	0.27499			
Edited Mathematics	*Intercept*	*All Algebra*	*Other Math*				
3.1.C	13.7481	0.4795	0.328				
Biology	*Intercept*	*Biology 2*	*AP Biology*	*Anatom y*			
3.3.B	4.802	0.0688	0.1389	0.208			