How does taking Algebra 1 by 8th Grade effect Students' High School Science Course-taking Patterns?

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Abstract

The objective of this study is to examine the impact of students accessing Algebra 1 in the 8th grade on their science course-taking patterns in high school in a large district in the Mid Atlantic of the United States. This is an important question because many studies have shown that Algebra 1 is a "gatekeeper" course (Adelman, 1999, 2006) but there has not been much research around the impact of who has taken Algebra 1 by 8th grade and what science courses they took as a result of having access to that particular course (Xin Ma, 2009). The data will be supplied by the school district of the last two cohorts of graduating seniors who were in the district from the seventh grade on, so the analysis can be conducted on those who were subject to the same opportunities and policies. The demographic information that will be requested are: Free/Reduced Meal students (FRMS) as a proxy for socio-economic status (SES), gender, race, English as a Second Language (ESOL) level, Special Education (SPED), what grade the students took Algebra, and the science classes they took while they were in high school. The research questions will be analyzed using JMP, a statistics program supplied by Virginia Tech to see if there are any significant differences in which groups of students took Algebra 1 by 8th grade and what kinds of science courses they took. The major findings were that more White and Asian students, and higher SES students accessed Algebra 1 by 8th grade and were enrolled in more rigorous science classes in their high school career than their Black, Hispanic, low SES, Special Education or English Language peers. The results of this study could inform large school districts about the impact of Algebra 1 by 8th grade on students' science course-taking patterns and promote conversations about their policies they create about access to critical courses.

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General Audience Abstract

The objective of this study is to examine the impact of students accessing Algebra 1 in the 8th grade on their science course-taking patterns in high school in a large district in the Mid Atlantic of the United States. This is an important question because many studies have shown that Algebra 1 is a "gatekeeper" course (Adelman, 1999, 2006) but there has not been much research around the impact of who has taken Algebra 1 by 8th grade and what science courses they took as a result of having access to that particular course (Xin Ma, 2009). The major findings were that more White and Asian students, and higher SES students accessed Algebra 1 by 8th grade and were also enrolled in more rigorous science classes in their high school career than their Black, Hispanic, low SES, Special Education or English Language peers. The results of this study could inform large school districts about the impact of Algebra 1 by 8th grade on students' science course-taking patterns and promote conversations about their policies they create about access to critical courses. The research could be used by school leaders as context for when they examine the participation of students in their upper level science classes. It could also be used by school counselors to better communicate with families about the importance of mathematics preparation and readiness and the impact of those on other college track courses.

Dedication

This dissertation is dedicated to my husband and son for their unwavering support through this experience. Derek, thank you for taking care of so many things in our life so that I could pursue this lifelong dream of mine. Nicholas, thank you for stepping in to help our family "work" which freed me up to go to class and do research. You both are not only fun to be around but kind, supportive and showed me that you can put someone else before yourselves. I love you both to the moon and back.

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My sister, brother and mother pretended to be interested in my research just like they did when I was in college and I would talk about the material I would learn in my science classes. I am very grateful to them because they helped me keep going and reminded me that my dad would be so proud of me every time I seemed to falter. That reminder of how he had always said his daughter was going to be a doctor perked me right up and helped me refocus and reprioritize so I could achieve this.

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Chapter 1- Background

Society faces challenges which are only able to be solved with the collaboration of scientists and mathematicians; from communication to finance to environmental crises to economics. The future will depend on scientific progress which requires in-depth understanding of and application of mathematics (Wright & Chorin, 1999). A reciprocal relationship exists between science and mathematics whereby mathematics is a critical component of science and expresses a large part of scientific thinking. Science instigates and prompts mathematics by raising new questions and demanding explanations of natural phenomena (Wright & Chorin, 1999). Medical, technological, engineering and economic advances in our world and problems are solved due to the strong ties that exist between mathematics and science.

> Science provides mathematics with interesting problems to investigate, and mathematics provides science with powerful tools to use in analyzing data.... Science and mathematics are both trying to discover general patterns and relationships, and in this sense they are part of the same endeavor (American Association for the Adancement of Science, 1990, p. 17)

This relationship is not a particularly a new concept. Ancient Greek mathematicians measured the volume of pyramids. Parchments from the 13th century found in Istanbul demonstrated an understanding of hydrostatics. Renaissance astronomers used trigonometry to explain the movement of stars and planets (Rosenthal, 1951). Modern science was established in the 17th century with the work from Galileo, the Flemish engineer Stevin, and the mathematician Valerio. Through their advances in calculus, we are able to determine the area under a curve (Rosenthal, 1951). Economically there were years where harvests were robust, and storage of foods and wines needed to be calculated. The intersection of mathematics and science helped civilizations calculate storage space, costs, and methods of food preservation (Rosenthal, 1951). Ancient explorers and more modern boat makers employed Archimedes geometric proofs to carry them around the world in sea-faring craft to explore new worlds.

A modern intersection of science and mathematics is obvious in the study of epidemiology and the study of infectious disease. To calculate the rate of infection over time is highly dependent on the scientists' understanding of calculus (Michelle, 2018). In the scientific approach, or steps to address this challenge, observation and experimentation, theory development and then modeling, all demand their explanation to be done in the language of science—which is mathematics (Wright & Chorin, 1999).

Mathematics is the Language of Science

Mitra (2012), in his essay "Mathematics: The Language of Science," provides a comprehensive overview of the interdependence of mathematics and science. He writes,

> To give a broad analogy, the position of Mathematics vis—vis (sic) the Sciences has been likened to that of the main trunk constituting the vast Tree of Knowledge, while the Sciences occupy positions corresponding to the different branches sprouting successively outwards in decreasing order of theoretical basis (p. 1).

Physics developed rapidly and could only do so with the "mathematical machinery" (Mitra, 2012, p. 1) that allowed for the concepts to be expressed and for it to be modeled for further learning. Further, "[s]cientific theory is always expressed in mathematical language," because when scientific phenomena are expressed, in any scientific realm and with deeper understanding, it eventually becomes quantified thus further establishing a "chicken and egg" scenario where either cannot exist without the other (Wright & Chorin, 1999). Feynman (1994) in his book *The Character of Physical Law* concludes about the relationship between science and mathematics,

> To those who do not know mathematics it is difficult to get across a real feeling as to the beauty, the deepest beauty, of nature ... If you want to learn about nature, to appreciate nature, it is necessary to understand the language that she speaks in (Feynman, 1994).

Many concepts and relationships are shared between mathematics and science as well as the symbols and systems used to communicate the work (Lehrer & Schauble, 2002). Essentially, the theoretical and conceptual processes of mathematics are given meaning when presented in the context of science (National Council of Teachers of Mathematics [NCTM], 2000). Thus, "mathematics is the chief language of science" (American Association for the Adancement of Science, 1990, p. 8).

Modern Science

Until recently, study in Life Science has not depended on the use of high level mathematics as this genre of science was descriptive without the fundamental natural constants of physics (May, 2004). However, with the development of new technology, more rigorous experiments could be designed, which has brought in an increased use of mathematics, specifically to support advances in our understanding: patterns in bioinformatics, models in evolution, epidemiology and statistics (May, 2004). As the scientific community sequences the human genome, mathematics allows the technology to break apart sections and identify the patterns of the nucleic acids, which provides clarity and precision between what is empirically determined and previous understanding (May, 2004).

Weather forecasting is another example of how mathematics permeates modern science. Our daily weather predictions are based on data collected from satellites and the Navier-Stokes (N-S) equations. Those equations consider the chaotic dynamics of weather patterns which when combined with powerful computers can generate accurate models for up to 10-20 days out (May, 2004).

Our understanding of Ecology has deepened because of the "mathematicised" problems and equations which has allowed generalizations across biomes, decades and issues such that solutions are more accessible. A fundamental aspect of Biology is the study of how systems of living things interact with both the living and the nonliving world. It is not necessarily true that these systems can or will behave like the laws of gravity, which has been shown to be deeply related with mathematics. However, there are the laws of Mendelian Genetics and the principle of natural selection which, when explained mathematically, both adhere to "laws" much like Newton's phenomena did and are able to provide incredible insight into these complex webs of life (Karsai & Kampis, 2010)

Calculus. One of the most significant intersections of mathematics and science is the development of calculus, which has been used to explain physics and the movement of the stars. Sir Isaac Newton and Gottfried Leibniz have been credited as the founders of Calculus (Rosenthal, 1951). Due to the critical role calculus plays in the study of physical chemistry and physics (Hoban, Finlayson, & Nolan, 2013), students must have access to this course if they wish to study physics and chemistry at their highest levels. For example, in a physical chemistry course students must apply their understanding of indeterminate forms and limiting agents (L'Hôpital's rule) which is an application of calculus, logic and symbolism (Segurado, Manuel A.P, Silva, Margarida F.B., Castro, 2011). In a traditional high school mathematics course sequence, calculus is taken typically either in the Junior or Senior year and either prior to or concurrently with the high-level chemistry or physics course. To access a calculus course, the student must have completed Algebra, Geometry, Algebra 2 and Precalculus with Trigonometry. Calculus would be the fifth course in that sequence which would require Algebra to be taken in either 7th or 8th grade (Domina, Penner, & Conley, 2015).

Science course opportunities are dependent on mathematics opportunities and preparation in American high schools (Xin Ma, 2009). It is critical that all students have access to the science and mathematics opportunities and preparation they wish to pursue in high school so they can create their own route to their desired college and career path (Cogan, Schmidt, & Wiley, 2001; Crissey & Wilkinson, 2005; Gamoran & Hannigan, 2000; Loveless, 2016; Schiller & Muller, 2003; Stein, Kaufman, Sherman, & Hillen, 2011).

Statement of the Problem

Science and math education have taken on increased importance in our society. For more than half a century, policy makers have been concerned about science education in the United States. This concern traces back to the launch of Sputnik (Rutherford, 1998) and various reports showing problems in American education, such as *A Nation at Risk* (National Commission on Excellence in Education, 1983), *Rising Above the Gathering Storm,* and *Rising above the Gathering Storm, Revisited* (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; 2010).

Several lessons were learned from these events. The first was that education reform must be considered through a long-term lens, not just to simply solve an immediate crisis. A second lesson was that education reform must include all students. It is not enough that there be an elite group of people trained and educated to ensure the United States' position as a global power. The talent pool needed to expand to include more than white male students in an advanced physics class (Rutherford, 1998).

When a student takes Algebra 1 determines if they will have access to mathematics classes past Algebra 2, which has been shown to be an indicator of completing a college degree in four to five years (Adelman, 1999, 2006). However, there have been several studies that demonstrate that even if a student completes Algebra 1 by 8^{th} grade, not all of them will take advanced mathematics or science courses in high school (Ma, 2000; Spielhagen, 2006). Additionally, high school science courses have mathematics course prerequisites. For example, if a student wishes to enroll in Honors Chemistry in 10th grade, they must either have completed Algebra 2 or be concurrently enrolled in the course. Students are prevented from accessing a science class unless they have successfully met the mathematics requirement, which they can only meet if they have accessed Algebra 1 no later than 8th grade. However, numerous studies that have examined which students have early access to Algebra 1 have shown that not every student has the same access to this critical course (Cogan, Schmidt, & Wiley, 2001; Loveless, 2013; Schmidt, McKnight, Curtis, Cogan, Jakwerth, & Houang, 2002; Stein, Kaufman, Sherman, & Hillen, 2011).

Access to Algebra

There are many reasons why certain students might not have the same access to Algebra in 8th grade that are related to student demographics: race, socio-economic status (SES), and level of parent education (Cogan, Schmidt, & Wiley, 2001; Domina, Penner, Penner, & Conley, 2015; Gamoran & Hannigan, 2000; Walston & McCarroll, 2010; Oakes, 2005; Rickles, 2013). Data also reveal why those groups tend not to be enrolled at the same rate in Algebra by 8th grade. Eighth grade algebra enrollment is lower among Black and Hispanic students, according to several studies (Cogan, Schmidt, & Wiley, 2001; Gamoran & Hannigan, 2000; Walston & McCarroll, 2010). Students who live at a lower SES are also not enrolled in Algebra in 8th grade at the same rate as their peers who live at a higher SES (Filer & Chang, 2008; Gamoran & Hannigan, 2000; Walston & McCarroll, 2010). Students' whose parents have fewer years of education were also not enrolled in Algebra at the same rate as students whose parents had more years of education (Walston & McCarroll, 2010). Lastly, other interesting data also from Walston and McCarroll (2010) show that more prepared girls access algebra in 8th grade (70%) than prepared boys (56%). Apparent themes throughout the studies as to why these groups had a lower rate of enrollment were that students from these groups could be less prepared, plus subjective placement factors possibly deter otherwise prepared students (Stein, Kaufman, Sherman, & Hillen, 2011). An important consideration in all of these studies is the fact that, "[e]ven when variables are added into models to 'control' for selection factors, the criterion for students' selection into early algebra can be subjective and relate to factors beyond what is measured or measurable" (Stein, Kaufman, Sherman, & Hillen, 2011, p. 466).

Rationale and Significance of the Study

Science and mathematics are the foundation of our modern society. Through their interdependence, the challenges that threaten humanity can be examined. Students can only become the scientists who examine these challenges if they are prepared. This study will put numbers to the issue of who is prepared to access the highest-level science classes by measuring the one class that is the keystone to both the science and mathematics course sequences: Algebra 1.

Adelman (1999, 2006) discussed how Algebra 1 is a "gatekeeper" to college degree completion in four to five years. His work demonstrated that more students graduate from college when they successfully master mathematics content in high school from two courses after Algebra 2 (Adelman, 1999, 2006; Lazzaro, Jones, Webb, Grover, Di Giacomo, & Marino, 2016). Robert Moses from the Algebra Project, a community-based effort to bring algebra to historically underserved middle school students, likened access to Algebra as a "civil right" (Moses & Cobb, 2001). When these two ideas are combined, a hypothesis can be developed about the equity of who has access to the highest-level science and mathematics courses in high school, access to college, and success in college. In order to take two courses beyond Algebra 2, students must take Algebra 1 in middle school, followed by Geometry and Algebra 2 in subsequent years. As discussed above, access to these math courses also impacts who can access higher level science classes because of the mathematics prerequisites to science courses. This study will identify those students that have access to upper level science classes because they have met the Algebra 1 prerequisite.

Chapter 2- Literature Review

When a student enrolls in Algebra 1 in their high school career has implications on many other academic opportunities in their high school experience. The greatest of those opportunities are the science courses they can access, which are critically dependent on student success in Algebra 1 in 8^{th} grade. Science and mathematics have a very close relationship in the way both are taught and how the teachers who teach those courses are prepared by universities. Moreover, both science and mathematics standards are interrelated at the national and local levels. Because of the standards being so closely tied together, an established set of prerequisites exists in many American school districts where students must complete mathematics requirements to access upper level science classes. Algebra 1 is the keystone course for both sets of prerequisites and there is a lot in the literature about the role of this course in high school course sequences. Much of the literature about Algebra 1 focuses on which students are enrolled in the course as 8th graders and the processes used by schools and districts to determine which students are permitted to enroll in the course in 8th grade.

This literature review will discuss two very broad topics about student enrollment in Algebra 1 in 8th grade; how science and mathematics are related educationally and who the students are that are enrolled in the course. There are many dependent relationships between science and mathematics instruction, specifically; how both of types of teachers are prepared, the curriculum standards articulated, science and mathematics course prerequisites and the specific role Algebra 1 plays in course sequences. The second broad topic; which students are enrolled in Algebra 1 in 8th grade, has several smaller components, specifically; the impact of subjective course selection factors on course enrollment and the role that tracking plays on which students are enrolled in the course.

Science and Mathematics are Related Educationally

When science and mathematics are taught in context of each other, students develop deeper understandings and can solve more complex problems which raises scientific and mathematic literacy. Meier, Nichol & Cobbs (2010) argue that it is critical to coordinate between math and science instruction. This issue will be discussed in the contexts of instruction, teacher preparation, the math and science standards, and course prerequisites in the following sections.

General instruction. Heflich, Dixon, and Davis (2001) argue that when students are exposed to science content using real world phenomena, their scientific understanding can increase, and because natural phenomena are expressed mathematically, they could have deeper mathematical understanding. Essentially, mastery of both science and mathematics content can be strengthened when students can understand the relationship between the two (National Research Council (U.S.), 1996). Unlike humanities or other subjects, science and mathematics are subjects where the content/courses build on one another, "so that a students' position in the sequence at the end of high school provides insight into his/her exposure to complex learning environments and his/her accumulation of certain skills and resources" (Crissey & Wilkinson, 2005, p. 7).

According to the National Academy of Engineering and National Research Council (2014) because they have similar problem-solving approaches, mathematics and science are more integrated than any other content disciplines. The American Association for the Advancement of Science (1990) clarifies that "mathematics provides the grammar of science—the rules for analyzing scientific ideas and data rigorously" (p. 18), which when implemented in a high school science class means the science teacher must examine his/her instructional goals about the science content and the mathematics skills that the students must have to meet the science objectives. Once the students' mathematical skills have been determined, the science teacher will need to incorporate mathematical instruction into the science content instruction if needed (Frykholm & Meyer, 2002), because "the science teacher is not able to cover most topics without calling on mathematical concepts and skills" (Frykholm & Meyer, 2002, p. 505). And finally, the *Next Generation Science Standards* (NGSS Lead States, 2013) outlines the ways students approach problem solving, the ways they learn processes and how they understand their knowledge and how they are critical for scientific and mathematical literacy.

Preservice teacher preparation. Educators have tried to help teacher make the connection between math and science. Teacher preparation programs for both mathematics and science educators "expect their preservice teachers to develop both a depth and breadth in the content knowledge in science and mathematics" +(Niess, 2005, p. 510). However, there have been many studies conducted to increase the integration of mathematics and science instruction in the mid to late 1990s with preservice teachers. There was more success with preservice elementary teachers than for secondary preservice teachers for these lessons to be integrated in full time teaching due to "the discipline background of participating teachers, differences in how science and mathematics teachers solved problems, differences in how science and mathematics teachers use mathematics, and differences in science and mathematics textbooks (e.g., graphing techniques)" (Berlin & White, 2010, p. 100). Some studies show that the vision for preservice teachers should be that they see the integration of the two subjects, and technology may be the vehicle that allows that to happen (Berlin & White, 2010). "Science and mathematics are important to the understanding of the processes and meaning of technology. Their integration with the technology education curricula is vital" (Johnson, 1989, p. 3).

Mathematics and science standards. After Sputnik and the various government reports on educational policy in the United States, efforts were made to increase in course requirements for high school graduation for all students (Teitelbaum, 2003). Most states (42) increased their graduation requirements but did not adopt the recommended number of courses for each content (three mathematics and three science). Only 3 of those 42 states adopted those recommendations by 1990 (Clune & White, 1992).

The increase in graduation requirements had the side effect of increasing math and science course access of disadvantaged students. Goodman, Currie and Figlio et. al, (2009), using data from the High School and Beyond Survey, found increases in Black males completing more math courses in states with more rigorous high school mathematics graduation requirements. The same study also found that each increased year of mathematics had a significant impact on lifetime economic earnings with the highest impact for the Black male subgroup. However there are cautions in the literature that just raising requirements will not improve student proficiency or achievement in those content areas (Goodman et al., 2009). It is a positive trend that more students are accessing more science and mathematics courses, but it is not clear if student achievement in those subjects has increased (Buddin & Croft, 2014).

The National Council of Teachers of Mathematics (2000) and the National Research Council (1996) have taken the position that there should be discipline-specific standards, but due to reforms in curriculum design, instructional approaches and assessment practices in science and mathematics teaching, both have acknowledged and advocated that there be more intentional opportunities for these subjects to be taught in concert. The NCTM (2000) states:

> The opportunity for students to experience mathematics in a context is important. Mathematics is used in science, the social sciences, medicine, and commerce. The link between mathematics and science is not only through content but also through process. The processes and content of science can inspire an approach to solving problems that applies to the study of mathematics (p. 66)

Similarly, the National Research Council (1996) in The National Science Education Standards suggests how if mathematics and science instruction were coordinated there could be greater student understanding of both mathematics and science concepts. The American Association for the Advancement of Science (1996) outlined the ways that the conceptual relationship between mathematics and science is enhanced because they share,

> a belief in understandable order; an interplay of imagination and rigorous logic; ideals of honesty and openness; the critical importance of peer criticism; the value placed on being the first to make a key discovery; being international in scope; and even, with the development of powerful electronic computers, being able to use technology to open up new fields of investigation (p. 18).

The workplace requires people to integrate skills and solve problems, however schools have been historically frozen in how classes are taught and how the content is isolated (Adelman, 2006; Evan, Gray, & Olchefske, 2006), unless events spur change. After Sputnik, the country was spurred into action to examine how students were being educated in science and mathematics. This trend spurred further investigation into how US students were performing in other subjects on the global stage (Rutherford, 1998). Ultimately, this caused us to examine our pedagogy to inspire and fuel reform, teacher preparation and the standards used in classrooms so our students are globally competitive (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2010; Adelman, 2006; Allensworth, Nomi, Montgomery, & Lee, 2009; Meier, Cobbs, & Nichol, 2010; National Commission on Excellence in Education, 1983). The results of these studies and reforms show us that science and mathematics education have a very strong relationship between how the contents, pedagogy and procedures are taught in high school classrooms (Xin Ma, 2009).

Course prerequisites. In most states, students are required to earn three science credits in two different science genres (Teitelbaum, 2003). For example, a student could take Biology, Chemistry and Human Anatomy (a Biology type course) to meet the graduation requirement. The first-year courses, or ones accessed in 9^{th} grade, tend to not have a mathematics corequisite, but all the upper level science courses do which creates groups of students who can access those courses and those who cannot.

Upper level high school science courses have mathematics course prerequisites in addition to meeting the previous science course requirement. For example, if a student wishes to enroll in Honors Chemistry in 10th grade, they must either have completed Algebra 2 or be concurrently enrolled in the course (“FCPS Course Catalog,” 2018). Students are prevented from accessing that science course unless they have successfully met the mathematics requirement, which they can only meet if they had accessed Algebra 1 no later than 8th grade. Another example is when a student wishes to take Advanced Placement (AP) Physics C. They must have already completed either AP Calculus AB/BC or be concurrently enrolled in either course as the physics course is a calculus-based curriculum. The mathematics course sequence only allows a student to be enrolled in either calculus course if they were enrolled in Algebra 1 in 8th grade.

The Algebra 1 course plays a critical role for students to access “higher level mathematics and science courses, the drivers of high school graduation, college readiness, and college completion” (Evan, Gray, & Olchefske, 2006, p. 2). This course has been shown to be so critical to science and mathematics education that many studies have been conducted to examine the factors that impact course enrollment and achievement. The research related to Algebra 1 will be discussed in the following section.

Role of the Algebra class in course sequences. Smith (1996) conducted an essential study of the role of the Algebra course for high school students. It examined the critical role of when a student accesses the Algebra course in their secondary school career and found a significant impact on the student’s overall transcript. She analyzed the transcripts from the High School and Beyond (HS&B) longitudinal survey of the sophomore class of 1980, a sample of more than 9,100 sophomores who would graduate two years later in 1982. There were two critical findings from this study that clarify the impact:

> early access to algebra has a sustained positive effect on students, leading to more exposure to advanced mathematics curriculum and, in turn, higher mathematics performance by the end of high school; and students who entered high school with algebra already on their transcripts continued to take academic mathematics courses. These students stayed in the mathematics pipeline longer and advanced farther than their contemporaries who took algebra in high school (p. 148).

The literature shows that the students who are enrolled in Algebra tend to be nonwhite, from an upper socio-economic status (SES) level and test to be well behaved.

Who Is Taking Algebra in Middle School?

The literature about which students are enrolled in Algebra in middle school is rich in studies conducted that specifically examined which students have access to Algebra in middle school and what factors, other than demographics, influence enrollment in Algebra in middle school. The 1983 *A Nation at Risk* report warned against a "rising tide of mediocrity that threatens our very future" (National Commission on Excellence in Education, 1983, p. 7), and the authors proposed that all Americans needed to be subjected to a more demanding school curriculum. Educators and scholars seized that opportunity to assert to policy makers and educational leaders that increased access to advanced courses by poor and minority students would be critical to narrowing the achievement gap (Oakes, 2005). And this access would be "narrowing educational inequality" (Domina et al., 2015, p. 3).

Student course selection factors. Two apparent themes emerge from the literature as to why there are different enrollment rates in Algebra: certain groups of students could be less prepared, and the use of subjective mathematics placement factors could unfairly favor certain student groups over others. The themes were clear in the large metanalysis of the impact of algebra done by Stein, Kaufman, Sherman, and Hillen in 2011.

Lack of preparation. The influence of the lack of preparation can be seen in decreased student outcomes when districts increase access to Algebra, leading to a popular phrase in the literature that underprepared students had been "misplaced" (Loveless, 2013; Loveless, 2016). For example, a study that examined the impact of the California state mandate that all students enroll in Algebra in 8th grade found that “mathematics achievement growth between 6th and 10th grade slowed, and the achievement advantages associated with 8th grade Algebra declined” (Domina, Penner, Penner, & Conley, 2015, p. 2). Further, the findings demonstrated that there were unintended consequences on overall student achievement from this mandate. Similarly, Walston and McCarroll (2010) also found that in schools with more than 75% of 8th grade students enrolled in Algebra, student achievement was lower than in schools where there was less than 75% of 8th graders enrolled in Algebra.

Loveless found that the differences in preparedness have a racial/ethnic component. He examined several national and international tests that measured mathematics achievement with a lens on who takes Algebra in 8th grade. He found that Black students, Hispanic students or students from a lower SES level achieve at a lower level than their White or Asian peers (Loveless, 2013; Loveless, 2016). Whether the students are “misplaced,” underprepared or mandated to be in the course, overall mathematics achievement is flat, minority and lower SES mathematics achievement is lower than their peers and there are fewer underrepresented students accessing Algebra in 8th grade (Loveless, 2013; Loveless, 2016; Loveless, 2018).

Subjective placement factors. Several subjective factors impact Algebra enrollment in 8th grade: a recommendation process and academic advising, the use of an assessment tool solely to identify students or determine readiness, and peer or family influence on academics.

Teacher recommendations. Faulkner, Stiff, Marshall, Nietfeld, and Crossland (2014) articulated the many ways that adult bias could play a role in which students could enroll in Algebra 1 in 8th grade. Specifically, they examined the impact of teacher recommendations of student performance in mathematics versus student demonstrated performance in mathematics on the odds of the student being placed into algebra in 8th grade.

The team analyzed the Kindergarten class of 1998-1999 from the Early Childhood Longitudinal Study national database of about 21,260 children countrywide for their 3rd grade, 5th grade and 8th grade performance and math placement. The group of interest was the highest performing Black students (3,055 students were the actual sample size), because it was the group of interest in how they were recommended for their mathematics class as compared to their prior math achievement. These students were "qualified" for the opportunity because of prior achievement and therefore should have been automatically recommended for Algebra in 8th grade. The critical component of this study was the comparison of what the teacher recommendation was versus their previous math performance and which students were placed in Algebra 1 in 8th grade. When those two factors were compared for Black and White students, prior mathematics performance was a more powerful indicator for White students whereas, teacher evaluation was a more powerful indicator for Black students whether the student was placed in Algebra 1. The data from the study show a lesser rate of enrollment in Algebra 1 in 8th grade for the Black students as compared to the White students. The implication from this study is that Black students who should have been in the "higher track" based on their prior math achievement were less likely to be recommended to be there. Further, this study reveals how teacher recommendations can be biased by factors not related to math performance and that the bias reduced Algebra 1 course taking of higher performing Black students. Therefore, the researchers concluded that academic advising around Algebra 1 needs to be done in conjunction with a readiness test or other diagnostic process to ensure that as many students as possible access this "gatekeeper" course (Adelman, 1999, 2006; Walston & McCarroll, 2010; Rickles, 2013).

Academic advising. Another subjective placement factor theme apparent in the literature about who has access to Algebra in 8th grade is the role of academic advising (Rickles, 2013; Schiller & Muller, 2003; Stein, Kaufman, Sherman, & Hillen, 2011). Fewer students of color, fewer lower SES students, and fewer students whose parents have less education are enrolled in Algebra in 8th grade, along with a selection bias of the students accessing algebra in 8th grade as part of academic advising in course selection (Dorn et al., 2014; Loveless, 2013; Walston & McCarroll, 2010; Rickles, 2013; Schiller & Muller, 2003; Stein, Kaufman, Sherman, & Hillen, 2011). Whether it exists either through teachers recommending unprepared students, prepared students not being recommended or students from high SES families being more likely to enroll in advanced courses because of higher parental education (Byun, Irvin, & Bell, 2014).

Singular diagnostic test. In several districts throughout the United States, schools select students to enroll in 8th grade Algebra based on a diagnostic readiness test or for school officials to choose them (Walston & McCarroll, 2010). Many studies noted that when a specific test was administered or when adults selected the students, there were groups of students who were excluded from this opportunity, specifically marginalized groups of students (Domina, Penner, & Conley, 2015; Walston & McCarroll, 2010; Stein, Kaufman, Sherman, & Hillen, 2011). Students who might not score well on the particular diagnostic test used but who otherwise show readiness and are excluded from Algebra in 8th grade tend to also be Black, Hispanic or from a lower family SES (Domina, Penner, Penner, & Conley, 2015; Walston & McCarroll, 2010; Stein, Kaufman, Sherman, & Hillen, 2011). A smaller or secondary area of inequity comes to light in those same studies in which students score well on the diagnostic test and/or their classroom behavior is excellent, so adults select them for the course, but the students have no other evidence of readiness.

Encouragement from peers and parents. Another factor which has been shown to influence students' course selection and enrollment in Algebra in 8th grade is encouragement from peers and parents (Bol & Berry, 2005). Cogan, Schmidt, and Wiley (2001) found that, even when controlling for SES, peer and parent encouragement were significantly related to student's enrollment in 8th grade algebra. However, Filer and Chang (2008) determined that the parent influence had a stronger impact on 8th grade algebra attendance and mathematics achievement than the peer influence. Peer influence however, had a larger impact than the SES level of the student. Further, according to Byun, Irivin and Bell (2014): "our results indicated that the strong relationship between advanced math course taking and student outcomes were largely due to other student, family, and school factors rather than advanced math course taking itself" (p. 12).

School location. The data from the Cogan, Schmidt, and Wiley (2001) study show that urban and rural schools had a lesser chance, as compared to suburban schools, of the districts' ability to offer algebra in 8th grade. The school students must attend due to the systemic issue of school boundary assignment must be considered as a factor in who enrolls in Algebra in 8th grade. "Approximately one third of U.S. 8th graders attending a school that did not offer an 8th grade algebra course in 1995…40% of schools in rural and urban areas did not offer 8th grade algebra, compared to 20% of the schools in suburban areas" (p. 338).

Common core. A recent complication, which has reversed much of the progress of higher enrollment of prepared students in Algebra by 8th grade, is the impact of the Common Core State Standards. Loveless (2018) states, "Many educators consider acceleration of some students (but not all) as antithetical to the 'common' in Common Core. If all students can't take Algebra1 in 8th grade, this point of view reasons, no one should be allowed to take it" (p. 21).

Gender differences. Although there has been an increase in girls accessing science and mathematics classes, data still show that girls do not choose those types of classes as often as boys do. Only the students who have access to the pipeline are provided the classroom experiences and content, so these become the only students invited to select courses such as precalculus and calculus. If girls do not choose to access this pipeline for a variety of reasons, they too might not access algebra and self-select not to be a part of this pipeline (Burkam, Lee, & Smerdon, 1997; Schiller & Muller, 2003).

The different studies in the literature, which explain how students access Algebra in 8th grade, shed light on the illusion that states and school districts are objective about who is enrolled in algebra in 8th grade. It is exceptionally clear how influential the “factors” are on which students have access to the course and how simple it is to explain why the class demographic is primarily White or Asian students from high SES families. However, there are other studies that provide different insight to explain this phenomenon: tracking.

Tracking. Tracking in the United States can typically be defined as “within school curriculum differentiation that varies the curriculum from course to course” (Cogan et al., 2001, p. 324)In elementary school, tracking tends to occur more informally: ability clustering of students in the same classroom or groups of students who are all working at the same pace (Cogan, Schmidt, & Wiley, 2001). It can look very different at middle and high school where prerequisite requirement completion can determine access to an entirely different course sequence for some students than for others (Bromberg & Theokas, 2014). This “content tracking” (Cogan, Schmidt, & Wiley, 2001) began at the start of the twentieth century in the American public education system to provide a differentiated curricular system, which was thought to be in the best interest of meeting the needs of an increasingly diverse student population (Ballón, 2008). Support for tracking exists because the slower pace of some classes with less challenging material may allow students to access the content of the course, and heterogeneous instruction could actually harm or diminish the learning of advanced students (Burris, Heubert, & Levin, 2006; Loveless, 2016; Loveless, 2018). However, critics of tracking believe that the best or the "enrichment curriculum" typically used in advanced classes would best serve all students, especially lower achieving students more effectively from the start than a remedial class or program could (Burris, Heubert, & Levin, 2006; Domina, Penner, Penner, & Conley, 2015; Oakes, 2008).

The literature soundly shows that "tracking fails to improve student achievement, even as it exacerbates educational inequality" (Domina et al., 2015 p. 2). Two members of the Bush and Reagan presidential administrations (Checker Finn and Diane Ravitch) singled out tracking as a cause of student poor performance on the National Assessment of Educational Progress (NAEP) tests of history and literature (Loveless, 2016). In the United States all children have a right to a free and appropriate public education, and this idea of equal access to educational opportunities seems to be at odds with the concept of tracking (Cogan, Schmidt, & Wiley, 2001; Domina, Penner, Penner, & Conley, 2015; Oakes, 2005). According to Oakes (2005), "tracking contributes to mediocre schooling for most secondary students" (p. 2). Also, the process tends to be fraught with arbitrary obstacles such that the least advantaged children in America are systematically cut out and cannot access certain classes such as Algebra in 8th grade (Burris, Heubert, & Levin, 2006; Domina, Penner, Penner, & Conley, 2015; Oakes, 2008; Watanabe, 2008).

The literature further explains a layer of complexity about why students cannot just "change tracks" and pursue a more rigorous course sequence because of the classroom instruction that occurs in the different level classes (Watanabe, 2008). When that is combined with data about the demographics of the students who are enrolled in advanced classes, racial, economic and social disparities are perpetuated (Ballón, 2008; Oakes, 2008; Watanabe, 2008). In a powerful study conducted of a North Carolina Middle School in 2008 that examined how the same content was taught in different classroom tracks, the findings demonstrated how students in the lower tracks were instructed with low quality materials, worksheets and a lot of drill. Those classes were comprised of more students of color and from a lower SES level than the students in the advanced classes. The district and school policy stated that there were the same high expectations for all students, but Watanabe (2008) found the students in the lower tracked classes did a lot of test prep so students could meet those high expectations on the state accountability tests. While in the "gifted" classes, students wrote and read much higher-level material and were exposed to a variety of instructional practices to prepare them for the same tests.

> As teachers adjusted their instruction to help students score well on high-stakes, "standards-based" tests, the teachers offered subtle, but powerful differences in students' educational opportunities. Students in the "academically gifted" classes read and wrote more widely, tackled more thought provoking assignments, and got more feedback than their peers in the "regular" classes where test-preparation occupied the lion's share of instructional time (Watanabe, 2008, p. 706).

The most critical aspect of this issue is that because of the rigid linear progression and hierarchical nature of mathematics course sequences, and the pace of classroom instruction, which is very different in the higher-tracked classes than in the lower-tracked classes, when students are tracked in mathematics, there are dramatic differences in what they can learn Schmidt, McKnight, Curtis, Cogan, Jakwerth, & Houang, 2002).

Summary

The interdependent relationship between mathematics and science allows researchers to simultaneously investigate educational issues in both subjects(Xin Ma, 2009). Such research provides insights regarding both of them and is in most cases, necessary to completely answer the question (Xin Ma, 2009). Additionally, high school mathematics and science course offerings are highly sequential, so access to higher level mathematics and science courses is determined by the successful completion of prerequisites. The completion of those prerequisites determines not only which students can access higher level courses but also how many advanced courses a student can take in their high school career (Crissey & Wilkinson, 2005).

The literature is very rich about the role of Algebra 1 in course sequences, what types of students tend to be enrolled in the course in 8th grade, and the possible reasons for the demographics of the course's enrollment. Much of the research also examined the impact of Algebra 1 completion to when/if students earn a college degree and/or how many other mathematics classes students enroll in. But, there is little research on the relationship between when students take Algebra 1 and their further mathematics and science course-taking patterns (Xin Ma, 2009). Also, previous studies have used national data, randomized students, or huge cohorts of students to create the sample that is studied. The prior studies leave a gap in the literature to conduct a transcript study on the impact of Algebra 1 on science and mathematics course-taking patterns in a large district where the students are subject to the same policies and opportunities. The methodology used to conduct the study will be described below.

Overview of Proposed Methodology

Transcript data will be collected from this large district and, using different statistical tests, this study will attempt to put numbers to which students are enrolled in Algebra in 8th grade; demographics, SES, race and gender. Of those that did take Algebra 1 in 8th grade, what further science courses did they take. Of those students that did not take Algebra 1 in 8th grade what science courses did they take. Finally, based on the data, try to establish what policy implications there could be about equity and access to this course opportunity.

Conceptual Framework

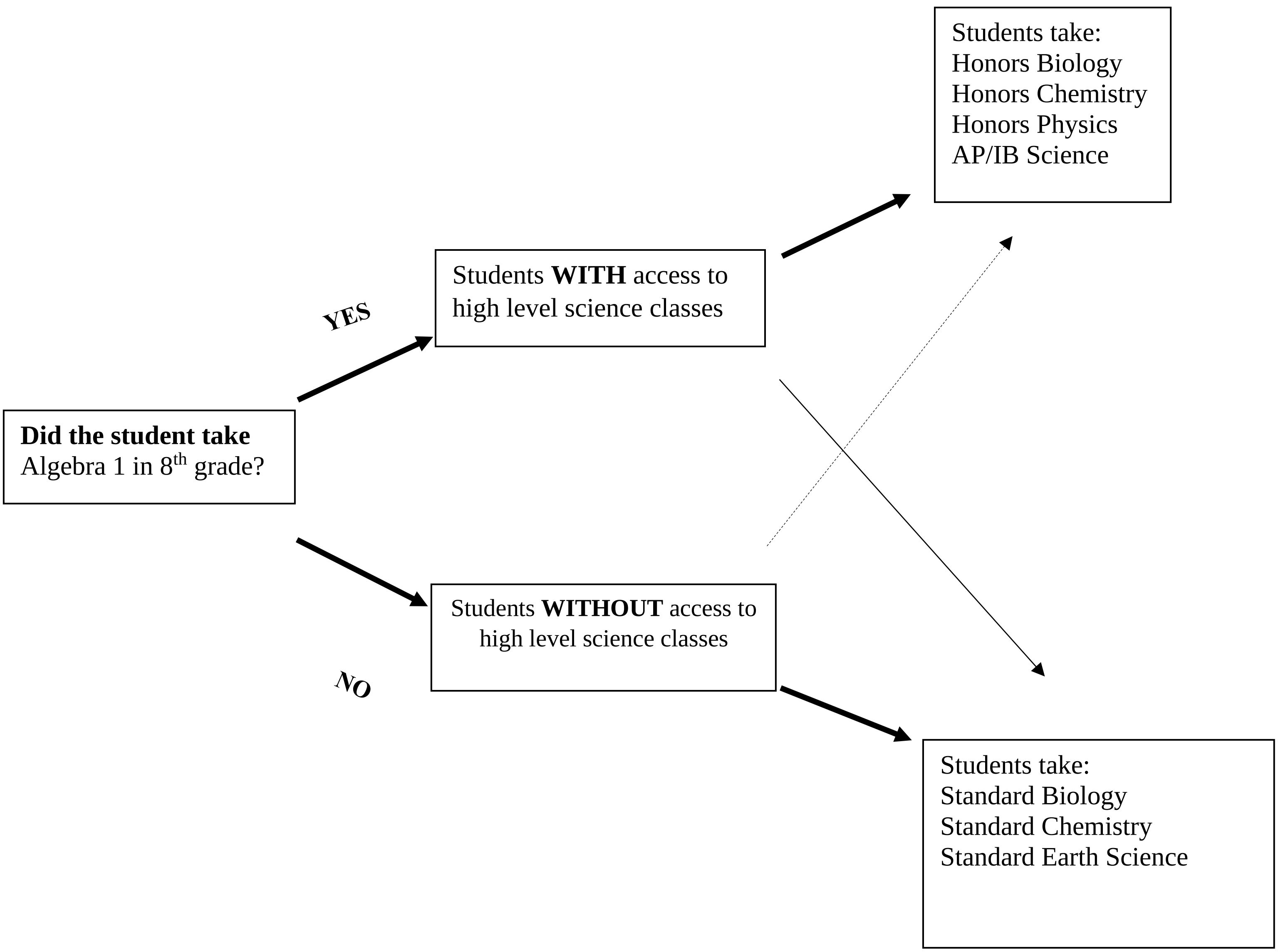

Figure 1. Conceptual Framework. Hypothesized science class choices based on whether students successfully completed Algebra 1 by 8th grade.

Research Questions

1. What are the significant differences in students who took Algebra 1 by 8th grade based:
    a. SES/FRM
    b. Race Ethnicity
    c. Gender
    d. ESOL level
    e. SPED/504
2. What are the differences in science course-taking patterns for students who took Algebra 1 by 8th grade versus students who did not take Algebra 1 by 8th grade?
3. Controlling for demographic factors how does taking Algebra 1 by 8th grade predict whether a student will take:
    a. Honors Biology
    b. Honors Chemistry
    c. Honors Physics
    d. Any AP Science class or a 2nd year of an IB Science class
4. For students who took Algebra 1 before high school, how do demographic factors predict whether a student will take:
    a. Honors Biology
    b. Honors Chemistry
    c. Honors Physics
    d. Any AP Science class or a 2nd year of an IB Science class
5. For students who did not take Algebra 1 before high school, how do demographic factors predict whether a student will take:

a. Honors Biology

b. AP or 2nd year of IB Biology or IBESS

Limitations/Delimitations

The data for this study will come from a the 11th largest school district in the United States (National Center for Educational Statistics, 2015) which has about 189,000 students enrolled from a suburban area outside of Washington, D.C. This district was chosen due to its demographic and socioeconomic diversity and size to provide insight that could be statistically significant about the research questions. I have spent the last 11 years of my career in this district which also allows access to the data in a reasonable manner. I did not want to confound the analysis with other districts which have different curriculum access policies and preparation methods. Also, the sample size will be around 20,000 students (2 cohorts of students) which, if it were to be even bigger, could “hide” important data points.

Chapter 3- Methodology

This chapter discusses the methodology that will be used in this study of students who are enrolled in Algebra 1 in 8th grade in a large suburban school district on the East Coast of the United States. This study will examine the demographics of students who took Algebra 1 by the 8th grade as compared to those students who did not do so. It will also analyze whether differences in science course-selection patterns exist based on when students took Algebra 1 and/or student demographics. As discussed below, this study hypothesizes that students who took Algebra 1 in 8th grade tended to enroll in more rigorous science courses than the standard option (Honors Biology vs. Standard Biology), while students who did not have access to Algebra 1 in 8th grade tended to enroll in standard science course options.

This study will address the gap in the literature regarding the relationship between when students take Algebra 1 and their further science course-taking patterns (Xin Ma, 2009). Most of the prior data are from national data sets of students or of randomized students; (National Assessment of Educational Progress, Programme for International Student Assessment). In this study, however, data will be derived from students enrolled at one school district who were subject to the same policies and opportunities. The importance of early access to Algebra 1 will be particularly important in this school district because it has an open access policy where students can enroll in the level of the course they choose (standard, Honors, AP/IB), if they have met the course prerequisites.

This study addresses five research questions:

1. What are the significant differences in student characteristics of those who took Algebra 1 by 8th grade versus those who did not, based on:
    a. Socioeconomic status (SES)

b. Race/Ethnicity
c. Gender
d. English language learner (ELL) level
e. Special education status (SPED)

2. What are the differences in high school science course-taking patterns for students who took Algebra 1 by 8th grade versus students who did not take Algebra 1 by 8th grade?
3. Controlling for demographic factors, how does taking Algebra 1 by 8th grade predict whether a student will take:
   a. Honors Biology
   b. Honors Chemistry or the first year of IB Chemistry
   c. Honors Physics or the first year of IB Physics
   d. Any Advanced Placement (AP) Science class or the second year of any International Baccalaureate (IB) Science class
4. For students who took Algebra 1 before high school, how do demographic factors predict whether a student will take:
   a. Honors Biology
   b. Honors Chemistry
   c. Honors Physics
   d. Any AP Science class or the second year of any IB Science class
5. For students who did not take Algebra 1 before high school, how do demographic factors predict whether a student will take:
   a. Honors Biology

b. AP Biology or the second year of IB Biology or IB Environmental Systems

The topics covered in this chapter include the conceptual framework for the study, a description of the targeted participants in the study, and an explanation about the research design for the study.

Conceptual Framework

The grade in which a student takes Algebra 1 strongly influences whether the student will have access to mathematics classes past Algebra 2. Those advanced math classes have been shown to be an indicator of completing a college degree in four to five years (Adelman, 1999, 2006). Additionally, high school science courses have mathematics course prerequisites, especially Honors, AP, and IB science courses. For example, if a student wishes to enroll in Honors Chemistry in 10th grade, he or she must either have completed or be concurrently enrolled in Algebra 2. Schools prevent students from accessing certain science classes unless they have successfully met the mathematics requirement, which can be nearly impossible to meet if the students took Algebra 1 after 8th grade.

A variety of important equity issue relate to these course-taking patterns. For instance, numerous studies have shown that access to this critical course varies even among equally qualified students based on a variety of demographic factors (Cogan, Schmidt, & Wiley, 2001; Loveless, 2013; Schmidt, McKnight, Curtis, Cogan, Jakwerth, & Houang, 2002; Stein, Kaufman, Sherman, & Hillen, 2011). The unequal access to Algebra 1 creates equity issues related to science course access throughout high school due to the mathematics prerequisites for many high science classes. Another important issue concerns the fact that several studies have demonstrated that many students who complete Algebra 1 by 8th grade and are on track to take advanced science courses in high school choose not to take such course (Xin Ma, 2009). Based on these issues, a framework has been developed, shown in Figure 1, that depicts the various high school science course options available to students based on whether they took Algebra 1 by 8th grade.

The thick lines in Figure 1 point to the science classes to which students have access based on whether they took Algebra 1 by 8th grade. The thickness of the line represents the hypothesis that most students enroll in the science courses for which they have met the prerequisites. The thin line that leads down from the group that accessed Algebra 1 by 8th grade to the lower level science classes represents the hypothesis that a smaller, but not negligible, number of students choose to take lower level science classes despite being on track to take high level classes. The dashed line that points up to the most rigorous science classes from the group that did not enroll in Algebra 1 in 8th grade represents the hypothesis that an extremely small number of students who did not take Algebra 1 in 8th grade enroll in upper level science.

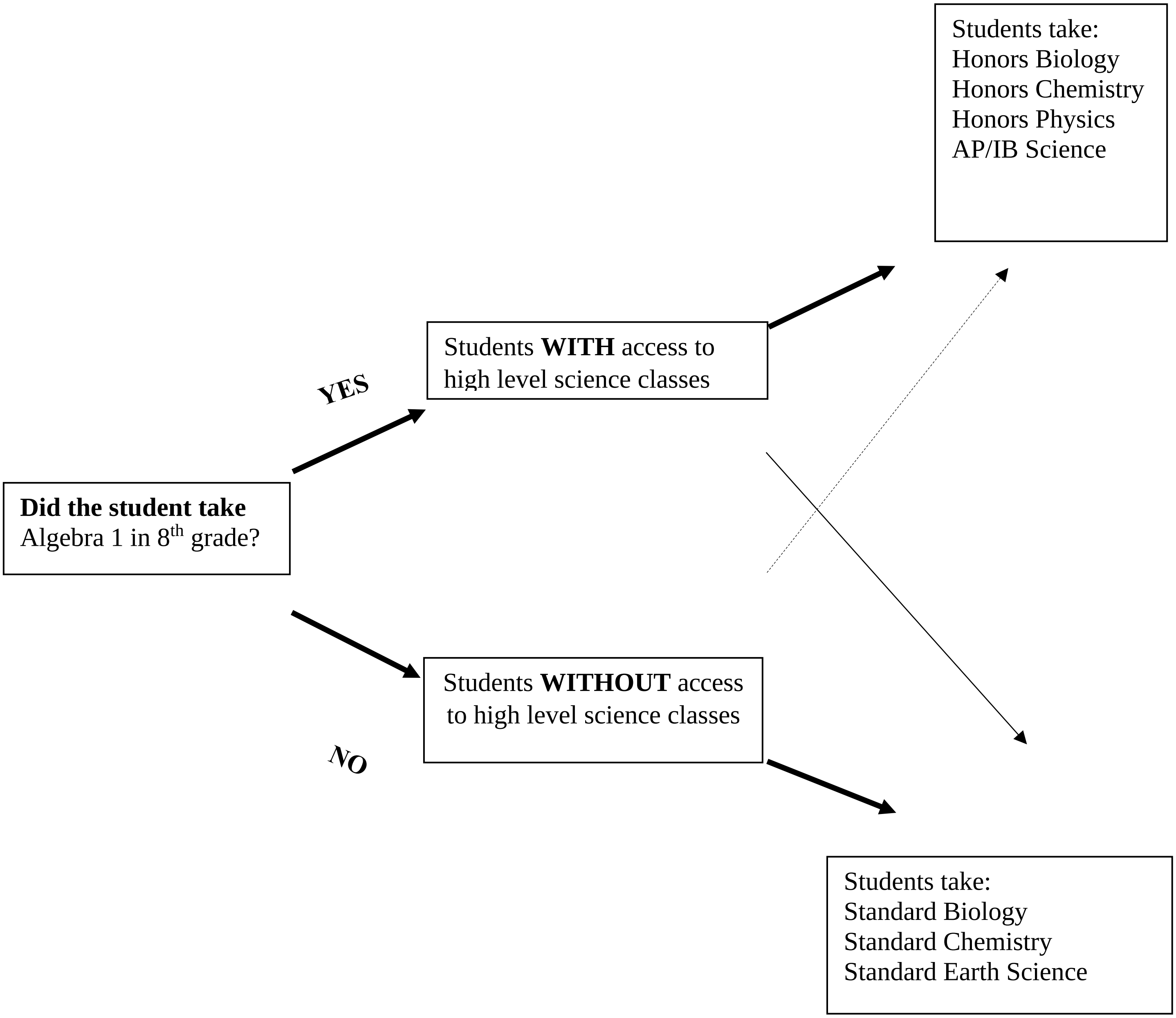

Figure 1. Conceptual Framework. Hypothesized science class choices based on whether students successfully completed Algebra 1 by 8th grade.

The definitions used for the demographic variables are taken from the American

Psychological Association and are briefly explained in Table 1 below.

Table 1

Demographic Definitions/Explanations

Demographic Variable	**Definition**
Socioeconomic Status (SES)	Socioeconomic status (SES) includes "educational attainment, financial security, and subjective perceptions of social status and social class…quality of life attributes as well as the opportunities and privileges afforded to people within society" (*SOCIOECONOMIC STATUS*, n.d.). It is not just defined as the income level of the student. The data will be provided as to whether a student received free or reduced meals as a proxy for this demographic variable.
Race/Ethnicity	The Census Bureau defines race "as a person's self-identification with one or more social groups. An individual can report as White, Black or African American, Asian, American Indian and Alaska Native, Native Hawaiian and Other Pacific Islander, or some other race", (Census Bureau, n.d.) Also, according to the Census Bureau ethnicity refers to whether someone identifies as

	Hispanic or not. The data will be provided for each student as it was self-reported at initial enrollment.
Gender	Gender is the student's biologically assigned sex at birth. The data will be provided as either Female or Male.
English Language Learner (ELL)	Students who have participated in the WIDA test or the ESOL program in the district. These are students who are classified in the WIDA leveling process as Levels 1-6.
Special Education (SPED)	Students who receive special education interventions for a Specific Learning Disability, an Other Health Impairment or an Emotional Disability in the general education setting in their base school.

Participants

The target population for this study will be students from a large, suburban school district on the East Coast. This district was chosen due to its large student enrollment and the diversity of the students in the district. The sample will be made up of two consecutive cohorts of students in this district until their graduation for a total sample size of approximately 20,000 students. This study will attempt to obtain the most recent data for the study that the district will allow. The students at graduation will range in age from 16 years old to 22 years old and represent many ethnic subgroups, all English proficiency levels, students with disabilities, and all socioeconomic situations.

Students in the cohorts will be excluded from the study only for only a few reasons: (1) they pursued a modified diploma or a graduation certificate or (2) they were not enrolled in the district in seventh grade or (3) they were out of the district for more than one school year. Students who earn a modified diploma or a graduation certificate do not enroll in the classes being studied in this project and have different course credit requirements than the standard or the advanced diploma. Students receiving these tend to have severe mental impairments. Students also will be excluded if they enrolled in the district after seventh grade. This will allow examination of only those students who were subject to the same policies and who had the same opportunities to access Algebra 1, because they were in the district for at least one year prior to 8^{th} grade. Students who moved out of the district or dropped out of school after they completed 7^{th} grade will be included in the data for the time they were enrolled in the district after the seventh grade.

Research Design

This study will use a quantitative approach in order to allow examination of relationships between student demographic variables, 8^{th} grade Algebra 1 enrollment, and science course-taking patterns of a large group of students. A quantitative approach to this study will enable identification of valuable relationships, patterns, and tendencies likely to arise from the data with reference to a large group of students who were subject to the same district level policies and opportunities.

Instruments/Measures

The school district will be requested to provide the data for this study in an Excel file.

The data will be uploaded to JMP, a statistics program. The demographic variables about the students include: Free and Reduced Meal (FRM) status (as a proxy for student SES), race/ethnicity, gender, special education status, ELL level, which academic year that the student took Algebra 1, and all the science courses the student took. The demographic variables will be "dummy" coded, so the categories of data will be converted to binary variables. For example, the Algebra 1 variable will be "dummy" coded to indicate if they took Algebra 1 in 8th grade or sooner. The science classes will also be "dummy" coded to indicate whether the students took them.

Data Analysis Procedures

The data will be analyzed using two types of statistical analyses: logistic regression and Chi Square tests. Questions 1, 3, 4, and 5 will be analyzed using logistic regression, enabling analysis of data when the dependent variable is binary and explain any relationships that exist between the dependent binary variable and one or more independent variables (Fang, 2013; "What is Logistic Regression? - Statistics Solutions," n.d., Howell, 2014). Question 2 will be analyzed using Chi Square, because this test allows examination of differences between observed data and expected data; to test relationships between categorical variables ("Chi Square Test - Statistics Solutions," n.d.; McHugh, 2013, Howell, 2014).

Research question 1. This question examines whether differences in demographic variables at least partially explain which students took Algebra 1 by 8th grade. To analyze this question, the full sample of students will be included in a logistic regression in which the independent variables are the demographic factors and the dependent variable is whether the student had taken Algebra 1 by 8th grade. This test will determine if the data show significant demographic differences between the group of students who took Algebra 1 by 8th grade and the group that did not. The literature shows that middle/upper middle class, White students who are not English Language Learners and who are not in special education take Algebra 1 by 8th grade more often than their peers (Domina et al., 2015).

Research question 2. This question asks about the differences in science course-taking patterns for students who took Algebra 1 by 8th grade versus students who did not take Algebra 1 by 8th grade. Data analysis for question two will be done by examining the full sample of students using a Chi Square test to test whether the observed frequency of science course selections differ from the expected frequency of science course selections based on a student's enrollment in Algebra 1 by 8th grade. This will test the relationships between the categorical data (or frequency data) of students who took Algebra 1 in 8th grade and which science classes they took in their high school career. This will help us see if students are enrolling in science courses by chance or if their Algebra 1 course impacts their science course enrollment. Is there a difference between the observed data and the expected courses the students signed up for? Is the door closed to higher level science classes by 8th grade for students who do not access Algebra 1 then?

Research question 3. This question controls for student demographic factors to examine if whether a student took Algebra 1 by 8th grade can predict whether a student will take Honors science courses and any AP science class or a 2nd year of an IB Science class. The whole sample will be studied to see if there are any other predictors of science course-taking patterns other than Algebra 1 and demographic variables. The independent variables are whether the student took Algebra 1 by 8th grade and the demographic variables. The dependent variable would be the science course-taking patterns.

Research question 4. Research question four examines, for students who took Algebra 1 before high school, how demographic factors predict whether a student will take honors science classes and any AP Science class or a 2^{nd} year of an IB Science class. Only the sample of students who did take Algebra 1 in 8^{th} grade will be studied to see if demographic factors had any significant role in the whether the students took the classes they had met the prerequisites for. The independent variables are all of the demographic factors, and the dependent variable will be the counts and rigor of the science courses the students enrolled in. This test will illuminate the science course-taking patterns when the students have met the mathematics requirements for any science course. It will not show the reasons why the students chose to enroll in those courses, but it will establish a baseline for enrollment patterns.

Research question 5. For research question five, only the sample of students who did not take Algebra 1 by 8^{th} grade will be examined to see how strongly demographic factors predict whether a student will take the most rigorous science classes that do not have the same math prerequisites as most other science courses: Honors Biology or AP or 2^{nd} year of IB Biology or AP Environmental Science or IB Environmental Science Systems. The data will be studied using a logistic regression to see which students access the highest level of science courses they can without having had access to Algebra 1 by 8^{th} grade. There are science classes with fewer or lower mathematics prerequisites: Honors Biology, AP Biology, the 2^{nd} year of IB Biology, or AP Environmental Science or IB Environmental Science Systems. Which students access those classes in their high school career?

Strengths and weaknesses of the logistic regression test. There are several strengths of the logistic regression test. It can correlate all variables at once, consider more than one variable as a predictor, and it can control for any or all the demographic variables. It works well to predict categorical outcomes (i.e. science class), but it cannot predict a continuous outcome, for which a linear regression would be appropriate. Essentially, this technique is most useful for understanding the influence of several independent variables on a single dichotomous outcome variable (whether students took a given science class).

However, there are limitations to the model, such as multicollinearity, overfitting, and the data in the data set. These weaknesses are common to many forms of regression. A weakness unique to logistic regression is the data can be harder to interpret because of the complexity of the output. ("What is Logistic Regression? - Statistics Solutions," n.d.) The outcome in a logistic regression is not a continuous variable but rather the probability that the result will be one of the two binary options (which science classes) (Plant, Springer-Verlag, & Wiley, 1997). The "probability" will be what is interesting but what can be harder to interpret due to unforeseen input of confounding variables. Essentially, what are the odds that the student will enroll in very rigorous science classes because of exposure to Algebra 1 in 8th grade. However, there could be some difficulty interpreting that result because of the multivariable going into the question; for example, SES, race and gender.

Strengths and weaknesses to the Chi Square test. There are several strengths to the Chi Square test. The first strength is that it is considered one of the easier tests to compute using JMP. It uses nominal types of data (categorical scale), and the test makes no assumptions about the distribution of the population, such as normality. ("Chi Square Test - Statistics Solutions," n.d.; McHugh, 2013)

The limitations for Chi Square are that the participants must be independent of each other, the data used must be frequency/count data, the data set must have more than 50 data points, and the results of the test do not indicate whether the relationship (if there is one) is strong or weak, just that there is a relationship (Howell, 2014). These concerns are minimal for this study. Students either do or do not take Algebra 1 in 8^{th} grade, so they will be independent of each other. The data will be made up of the counts of the classes students take, so it is frequency data. There will be far more than 50 data points as the sample size is expected to be around 20,000 students.

Reliability and validity. Reliability of a type of test refers to the extent that it is consistent with each administration. For example, if a student takes the ACT four different times, he/she should get about the same score for each administration. However, this study does not use test scores as data points, it uses the counts of science classes students enrolled in while they were in high school. The internal reliability for this study should be very strong because the students either took the classes or did not take them (Fang, 2013). This study aims to identify relationships and patterns from the course-taking patterns of students from one school district on the East Coast. This is only about one school district, so external validity may be low, because the patterns may not be generalizable for every school district. It is possible these results will be generalizable only to other large, diverse school districts where the students are subjected to the same policies and opportunities (Arafat, Chowdhury, Qusar, & Hafez, 2016). However, the internal validity should be quite strong, because course-taking patterns of students who did or did not take Algebra 1 in 8^{th} grade will be examined, noting the significant differences that exist between groups. There are few to no confounding variables in any of the tests as they are laid out to avoid having alternate explanations to describe the data.

Methodology Summary

This is a quantitative study of high school science course-taking patterns and their relationship to when the students took Algebra 1 from a large public-school district on the East Coast. There are five research questions that will be analyzed using either a logistic regression (1, 3, 4 and 5) or a Chi-Square test (2) to examine if there are significant demographic differences in the students who took Algebra 1 in 8^{th} grade and their science course-taking patterns. A quantitative approach is necessary because of the value of the patterns and tendencies that can arise from the data. The data will be provided by the school district and will be analyzed using JMP, a statistics program provided by Virginia Tech. The independent variables are largely made up of demographic variables (FRM as a proxy for SES, race, gender, SPED, ESL level, the grade they took Algebra 1), and the dependent variables are largely the science courses the students took in their high school career. Figure 1 is the conceptual framework for the study which outlines the different hypotheses; certain groups will be smaller and are represented by thin or dashed lines while other groups are estimated to be larger and are represented by thicker lines.

The study addresses a gap in the literature that exist regarding the relationship between when students take Algebra 1 and their further science course-taking patterns (Ma, 2009). It addresses a second gap in the literature, because it aims to examine one school district's students who were subject to the same policies and opportunities. The sample will be made up of two cohorts of very recent graduates who were in the district from the 7^{th} grade through graduation. Few students will be excluded, including those who cannot earn a standard or advanced diploma and those who moved into the district after 7^{th} grade. The study uses 7^{th} grade because of its relationship to when most students take Algebra 1, and it allows inclusion of only those students who were subject to the same policies and who had the same opportunities to access Algebra 1 because they were in the district for at least one year prior to 7^{th} grade. This study will have high internal reliability because there are only counts of classes not test scores. It will not have high external validity because it is only an examination of one large, diverse school district so it might not be very generalizable. However, it should have high internal validity, because the tests are laid out to only have one explanation for the data, not several explanations.

Chapter 4- Results of Study

Purpose

The interdependent relationship between mathematics and science creates the need to investigate both subjects simultaneously (Xin Ma, 2009). The completion of mathematical prerequisites shapes not only which students can access higher level science courses but also how many advanced courses a student can take in his/her high school career (Crissey & Wilkinson, 2005). High school mathematics and science course offerings follow specific sequences, so the successful completion of prerequisites largely determines access to higher level mathematics and science courses. The literature abounds with studies of the role of Algebra 1 in course sequences, what types of students tend to be enrolled in the course in 8th grade, and the possible reasons for the demographics of the course's enrollment. Many researchers also examined the impact of Algebra 1 completion on when/if students earn a college degree and/or how many other mathematics classes students enroll in. But, few scholars have analyzed the relationship between when students take Algebra 1 and their further mathematics and science course-taking patterns (Xin Ma, 2009).

This study examined the differences in science course-selection patterns of high school students from a large suburban district on the East Coast of the United States based on when the students took Algebra 1. It also compared the demographics of the students who took Algebra 1 by the 8th grade to those students who did not do so.

Most prior studies used large data sets of students (e.g., National Assessment of Educational Progress, Programme for International Student Assessment) to analyze these issues. Unlike in those studies, the students in this study attended schools in one school district for several years, thus being subject to the same policies and receiving similar opportunities. One such policy that influences course selection involves the district's open access policy, in which students could enroll in the level of the course they chose (standard, Honors, AP/IB), if they had met the course prerequisites.

Research Questions/Hypotheses

This study addressed five research questions:

1. What were the significant differences in student characteristics of those who took Algebra 1 by 8th grade versus those who did not, based on:
    a. Socioeconomic status (SES)
    b. Race/Ethnicity
    c. Gender
    d. English language learner (ELL) level
    e. Special education status (SPED)
2. What were the differences in high school science course-taking patterns for students who took Algebra 1 by 8th grade versus students who did not take Algebra 1 by 8th grade?
3. Controlling for demographic factors, how did taking Algebra 1 by 8th grade predict whether a student took:
    a. Honors Biology
    b. Honors Chemistry or the first year of IB Chemistry

c. Honors Physics or the first year of IB Physics
d. Any Advanced Placement (AP) Science class or the second year of any International Baccalaureate (IB) Science class

4. For students who took Algebra 1 before high school, how did demographic factors predict whether they took:
   a. Honors Biology
   b. Honors Chemistry
   c. Honors Physics
   d. Any AP Science class or the second year of any IB Science class
5. For students who did not take Algebra 1 before high school, how did demographic factors predict whether a student took:
   a. Honors Biology
   b. AP Biology or the second year of IB Biology or IB Environmental Systems

It was hypothesized that students who took Algebra 1 by 8th grade tended to enroll in more rigorous science courses throughout their high school career than the standard options (Honors Biology vs. Standard Biology). The hypothesis should hold given the above discussed sequencing requirements for math and science classes.

Research Design

This study used a quantitative approach to determine if any relationships existed between student demographic variables, 8th grade Algebra 1 enrollment, and science course-taking patterns of a large group of students. This approach was also chosen to determine if any valuable relationships, patterns, and tendencies existed in the data for a large group of students who were subject to the same district-level policies and received similar opportunities.

The data were analyzed using two types of statistical analyses: logistic regression and Chi Square tests. Questions 1, 3, 4, and 5 were analyzed using logistic regression to determine whether one or more of the independent variables contributed to predicting whether student took or did not take a variety of math and science classes (Fang, 2013; "What is Logistic Regression? - Statistics Solutions," n.d., Howell, 2014). Question 2 was analyzed using Chi Square to determine whether any differences arose between the observed course-taking patterns and the null hypothesis that no differences in course-taking patterns would exist based on whether a student took Algebra 1 by 8th grade ("Chi Square Test - Statistics Solutions," n.d.; McHugh, 2013, Howell, 2014).

Data collection techniques. Data was received from the large school district in an Excel file. It was reviewed to ensure that each student entry met the data requirements: the student enrolled in the district from 7th grade on and earned a standard or advanced diploma. The file was also reviewed to ensure that it included demographic variables such as gender and race. Data was dummy coded in order to put the variables in the numerical formula needed for the statistical software program to calculate the statistical tests. The dummy coded variables are defined in Table 2.

Once the data was ready to be analyzed, the file was uploaded into JMP, a statistical software program related to SAS. Table 3 presents the frequency counts of who was enrolled in Algebra by 8th grade.

Table 2

Variable Dummy coding

Variable	Received	Dummy code/treatment
Algebra 1	School year student was enrolled in the course	1= student took Algebra 1 prior to the student's ninth grade year
Gender	Male or female	1=female
Race/Ethnicity	White Black Asian Hispanic Undeclared Native American Multi-Racial	A column was created for each racial/ethnic group except White. Students from a given group receive a value of 1 in the column that equates to their race/ethnicity
Socio-economic status	Free or Reduced Meals (FRM)	1=FRM
Honors Science class	The honors science courses the students took during their high school career	Honors classes=1 For questions 3, 4 and 5, the classes of interest will be a 1 and the other classes will be a 0.
Advanced Placement/International Baccalaureate class	The AP/IB science courses the students took during their high school career	AP/IB classes=1 For questions 3, 4 and 5, the classes of interest will be a 1 and the other classes will be a 0.
SPED	SPED	SPED=1
ESOL	ELL Level	ELL=1

Table 3

Frequency Counts for Study Sample

	Students in the Group	Percentage of the Sample
All Students	19359	
Gender		
Female	9603	49.61%
Male	9756	50.40%
Race/ethnicity		
White	8922	46.09%
Black	1816	9.40%
Asian	3865	19.97%
Hispanic	3753	19.39%
Native American	39	0.20%
Undeclared	20	0.10%
Multi-Racial	944	4.88%
Socio-Economic Status		
FRM	4213	21.77%
NOT FRM	15144	78.24%
ESOL students		
Levels 1-6a, and 6b	569	2.94%
NOT ESOL	18790	97.06%
SPED students		
Students who receive SPED services	2357	12.18%
NOT SPED	17002	87.82%
Algebra 1		
Prior to 9th grade	13719	70.87%
During/after 9th grade	5640	29.13%

Students were excluded from the data file for several reasons: not being awarded a standard or advanced diploma, if the standard diploma had credit accommodations (i.e. if their transcript included Geometry Part 1 class as a full year of mathematics credit), if they were out of the school division for more than one school year, or if the student entered after 7th grade. There were 25,867 students in the original files from the district, but 6,508 students were excluded to leave a sample size of 19,359 students. Table 4 displays the demographics of the students who participated in Algebra 1 by 8th grade.

Table 4

Algebra participation in/by 8th grade

	Students in Algebra in/by 8th grade	Percentage of the demographic in Algebra in/by8th grade	Students not in Algebra in/by8th grade	Percentage of the demographic not in Algebra in/by 8th grade
All Students	13719	70.87%	5640	29.13%
Gender				
Female	6950	72.37%	2653	27.63%
Male	6769	69.38%	2987	30.62%
Race/ethnicity				
White	6933	78.38%	1929	21.62%
Black	950	52.31%	866	47.69%
Asian	3191	82.56%	674	17.44%
Hispanic	1848	49.24%	1905	50.76%
Native American	19	48.72%	20	51.28%
Undeclared	16	80.00%	4	20.00%
Multi-Racial	702	74.36%	242	25.64%
Socio-Economic Status				
FRM	2061	48.89%	2154	51.10%
NOT FRM	11657	76.97%	3487	23.02%
ESOL students				
Levels 1-6a, and 6b	85	14.94%	484	85.06%
NOT ESOL	13634	72.56%	5156	27.44%
SPED students				
Students who receive SPED services	624	26.47%	1733	73.53%
NOT SPED	13095	77.02%	3907	22.98%

Certain student demographics raise some interesting points worth discussing prior to addressing the research questions. The sample contained nearly the same number of boys as girls enrolled in Algebra 1 by 8th grade. White and Asian students enrolled in Algebra 1 by 8th grade at about 78% and 83%, respectively, while only about 52% of Black students and 48% of Hispanic students, respectively, enrolled in Algebra 1 by eighth grade. Multi-racial students enrolled in Algebra 1 by 8th grade at a rate of 74%. The data also show that students who received Free or Reduced Meals (FRM) enrolled in Algebra 1 by 8th grade at a much lower rate than those students who were not FRM, 49% to 77%, respectively. It should be noted that only 85 out of the 589 students classified as ESOL level 1-6b, who graduated from this district, were enrolled in Algebra 1 by eighth grade. Additionally, the data show that 26.47% of students who received special education services were enrolled in Algebra 1 by eighth grade while about 77% of students who did not receive special education services enrolled in Algebra 1 by eighth grade.

Research Question Results

Question 1: What were the significant differences in student characteristics of those who took Algebra 1 by 8th grade versus those who did not, based on:

a. Socioeconomic status (SES)
b. Race/Ethnicity
c. Gender
d. English language learner (ELL) level
e. Special education status (SPED)

Question 1. Logistic regression was used to estimate the probability of students who enrolled in Algebra 1 by 8th grade in the sample of 19,359 students from a large school district in the mid-Atlantic of the United States. In Table 5, the ten predictor variables—FRMS, Black, Hispanic, Native American, Asian, Undeclared, Multi-Racial, ELL and Special Education Status—were used in the analysis. As shown in Table 6, the overall predictive model was statistically significant (likelihood ratio chi square= 4092.663 [9], p <.0001). SES, several Race/Ethnicity variables, ELL, and Special Education status were significant predictors of whether a student would participate in Algebra 1 by 8th grade

Table 5

Significance of demographic factors in which students take Algebra 1 by 8th grade(n=19,359)

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.41	0.49	0.45
Race/Ethnicity					
	Black students	<.0001*	0.36	0.45	0.40
	Hispanic students	<.0001*	0.39	0.48	0.44
	Native American students	<.0001*	0.14	0.52	0.27
	Asian students	<.0001*	1.28	1.60	1.42
	Undeclared students	0.7020	0.38	4.14	1.26
	Multi-Racial students	0.0931	0.73	1.02	0.87
Females		0.2278	0.97	1.12	1.04
English Language Learners		<.0001*	0.19	0.32	0.25
Special Education Status		<.0001*	0.11	0.14	0.13

*Note: * designates significant statistic*

The results discuss the odds ratios for the various independent variables when controlling for the other independent variables. All discussions in this dissertation regarding logistic regression results are made with the understanding that the results are those calculated when controlling for the other variables. Students who did not receive Free or Reduced Meals were 123% more likely than those who did receive Free or Reduced Meals to be enrolled in Algebra 1 by 8th grade. White students were 150% more likely than Black students, 130% more likely than Hispanic students, and 274% more likely than Native American students to participate in Algebra 1 by 8th grade. Asian students were 42% more likely than White students to be enrolled in Algebra 1 by 8th grade. Students who were not Special education were 683% more likely than those who did receive Special Education services to be enrolled in Algebra 1 by 8th grade. Students who did not receive English Language services while in high school were 306% more likely than those who did receive English Language services to participate in Algebra 1 by 8th grade. The predictive value of the model was good with an overall rate of correct classification of 76.89%. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.18.

These results make very clear which students in the sample took Algebra 1 by 8th grade. Gender was not a significant predictor of whether students would take Algebra 1 by 8th grade. Being a multi-racial student or a student whose race was Undeclared also did not significantly predict whether the student took Algebra 1 by 8th grade, as compared to White students. Black students, Hispanic students, students who received Special Education services, students who were English Language Learners, and students who received Free or Reduced Meals were significantly less likely to take Algebra 1 by 8th grade.

Question 2: What were the differences in high school science course-taking patterns for students who took Algebra 1 by 8th grade versus students who did not take Algebra 1 by 8th grade?

To investigate science course-taking patterns of students based on whether they took Algebra 1 by the 8th grade, 19,359 students' science courses were examined. There were several Honors Science Courses in which a student could enroll: Honors Biology, Honors Chemistry, Honors Physics and then the Advanced Placement (AP)/International Baccalaureate (IB) levels, as well as a wide variety of standard courses. A chi square was used to test for whether a significant relationship existed between when students took Algebra 1 and whether they took higher level or standard science classes. The data and Chi Square results are displayed in Table 6 and the results of the Chi Square test are discussed below.

Table 6

Science course-taking patterns of students based on if they did or did not take Algebra 1 by 8th grade

	Algebra 1%	NOT Algebra 1%	Chi Square
HN Biology	64.47	11.95	4850.41
HN Chemistry	57.23	2.84	6072.83
HN Physics	71.76	50.34	395.84
AP/IB Biology	22.14	4.72	520.03
AP/IB Chemistry	14.96	1.13	1082.07
AP/IB Env. Sci.	21.52	8.19	550.59
AP/IB Physics	11.82	0.48	963.45

**note: all of the course enrollments were significant p <0.0001*

The null hypothesis for each of the Chi Square tests was the percentage of students enrolled in the higher-level science course would be the same for the group who took Algebra 1 by the 8^{th} grade and the group who took it in 9^{th} grade or later. The results show that a much higher percentage of students who were enrolled in Algebra 1 by the 8^{th} grade also enrolled in each of the advanced science classes compared to students who took Algebra 1 in the 9^{th} grade or later. The results for the respective courses were Honors Biology X^2 (1) = 4410.28, $p < 0.0001$; Honors Chemistry X^2 (1) = 4874.401, $p < 0.0001$; Honors Physics X^2 (1) = 812.11, $p < 0.0001$; AP/IB Biology X^2 (1) = 857.19, $p < 0.0001$, AP/IB Environmental Science X^2 (1) = 488.66, $p < 0.0001$, AP/IB Chemistry X^2 (1) = 784.90, $p < 0.0001$; and AP/IB Physics X^2 (1) = 660.09, $p < 0.0001$. Therefore, the null hypothesis that there were no differences in course enrollments between the two groups of students was rejected.

These results confirm the importance of taking Algebra 1 before the 9th grade for a student to have access to the higher-level science curriculum. All the Chi Square tests for higher level science course enrollment were significant. This finding makes most sense for the Honors Chemistry class, taken in 10th grade and for which Algebra 2 is a co-requisite. The normal math sequence is Algebra 1, Geometry, and Algebra 2, so for a student to take Algebra 2 by the 10th grade, s/he most likely needs to take Algebra 1 by the 8th grade. The math requirement explains the fact that only 160 students (2.84%) who did not take Algebra 1 by 8th grade enrolled in Honors Chemistry. It is probable that these students took a summer Geometry class to "catch up" and be eligible for Algebra 2 and Honors Chemistry in 10th grade, or they were misadvised.

It is interesting to note the that the strongest Chi Square value was for Honors Chemistry, but the Honors Biology Chi Square was a close second. The Honors Biology Chi Square shows a very strong relationship between students having taken Algebra 1 by 8th grade and enrolling in Honors Biology when they are in 9th grade. It is understandable that the Chi Square was so strong for Honors Chemistry, due to the math prerequisite and the strict course sequence. However, there is no math prerequisite for Honors Biology. This raises issues related to causality, namely, does taking Algebra 1 in 8th grade help students see themselves taking Honors Science in 9th grade, or is it the type of student who takes Algebra 1 in 8th grade also tends to be the type to challenge themselves with an Honors science class?

Biology and Chemistry are taken in that order by almost all students in 9th and 10th grades, respectively, but students have a choice for their 11th and 12th grade science courses. This sets up an opportunity for many students to take Honors Physics as a senior where they could have "caught up" with the math prerequisite of the completion of Algebra 2 or could have taken a summer math course to be eligible to enroll in that course. Many students take advantage of this opportunity when it is afforded them. Only 2.84% of the sample enrolled in Honors Chemistry when they had not taken Algebra by 8th grade but 50.34% of the sample took Honors Physics when they had not taken Algebra by 8th grade.

The Chi Square values for the AP/IB science courses were also quite strong, but it is important to note several things about them: the highest Chi Square was for AP/IB Chemistry, the second highest was for AP/IB Physics, and both the AP/IB Biology and AP/IB Environmental Science Chi Square values were similar. A student can take AP/IB Chemistry in either 11th or 12th grade, so if a student did not enroll in Algebra 1 in 8th grade they could access this course as a senior to meet the mathematics prerequisite of Algebra 2. However, the data showed that most students do enroll in this course in the 11th grade, which supports the strong relationship that those students did enroll in Algebra in 8th grade. AP/IB Physics requires that the student either be concurrently enrolled in Calculus A/B or IB Mathematics HL 2 or have already taken those classes to access this science course. That would require a student to be enrolled in Algebra 1 in 8th grade, at a minimum, or have taken a summer mathematics class so they could meet that mathematics prerequisite. The mathematics and science course sequences could explain this strong relationship as well. The Chi Square values for AP/IB Biology and AP/IB Environmental Science were basically the same, but they were lower than AP/IB Chemistry and AP/IB Physics. Students can access either of those courses in the 11th or 12th grades and they only have a mathematics prerequisite of Algebra 2. Therefore; there is more flexibility when those students access those science courses because they can take them in 12th grade. This raises causality issues around the kind of student tends to take these classes or whether this choice is influenced by something anecdotal, such as which teacher is teaching it in the school, student interest in the subject matter, or that mathematics preparation is not related to enrollment at all.

In question 1, the data revealed which students were taking Algebra 1 in 8th grade in this large district on the East Coast of the United States. Question 2 results revealed the relationship between students having been enrolled in Algebra 1 in 8th grade and the science courses they took while the students were in high school. The Chi Square, however, does not control for any demographic factors, so the data do not define which student populations took the courses. Question three controls for demographic factors while providing data around whether Algebra 1 enrollment in 8th grade could predict which students took which science classes during high school.

Question 3: Controlling for demographic factors, how did taking Algebra 1 by 8th grade predict whether a student took:

a. Honors Biology
b. Honors Chemistry or the first year of IB Chemistry
c. Honors Physics or the first year of IB Physics
d. Any Advanced Placement (AP) Science class or the second year of any International Baccalaureate (IB) Science class

For all of the aspects of question 3, a logistic regression was used to control for demographic variables while estimating the probability of students who enrolled in different science courses and whether they took Algebra 1 by 8th grade in the sample of 19,359 students from a large school district in the mid-Atlantic of the United States. The eleven predictor variables—FRMS, Black, Hispanic, Native American, Asian, Undeclared, Multi-Racial, Gender, ELL status, Special Education Status, and Algebra 1 by 8th grade participation—were used in the analysis.

Honors Biology. As shown in Table 7, the overall predictive model for Honors Biology was statistically significant (likelihood ratio chi square= 6130.82 [11], p <.0001). The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.25.

Free/Reduced Meals, Black students, Hispanic students, Asian students, Gender, ELL status, Special Education status, and if they took Algebra 1 were significant predictors of whether a student would participate in Honors Biology, even when controlling for the other independent variables. Students who were enrolled in Algebra 1 by 8th grade were 727% more likely to enroll in Honors Biology. Thus, whether a student took Algebra 1 by 8th grade, even when demographic factors were controlled for, accurately predicts whether a student would enroll in Honors Biology. Even though Honors Biology lacks a math prerequisite, if students took Algebra 1 by 8th grade strongly predicted whether they would also be enrolled in Honors Biology.

Table 7

How did demographic factors predict if a student enrolled in Honors Biology (3a)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.57	0.69	0.63
Race/Ethnicity					
	Black students	<.0001*	0.57	0.74	0.65
	Hispanic students	<.0001*	0.49	0.60	0.54
	Native American students	0.1503	0.26	1.23	0.56
	Asian students	<.0001*	1.23	1.47	1.34
	Undeclared students	0.9856	0.37	2.62	0.99
	Multi-Racial students	0.8997	0.85	1.15	0.99
Females		0.0003*	1.06	1.21	1.13
English Language Learners		<.0001*	0.04	0.17	0.08
Special Education Status		<.0001*	0.18	0.24	0.21
Algebra 1		<.0001*	7.55	9.07	8.27

*Note: * designates significant statistic*

Several of the control variables also proved to be statistically significant. White students were 53% more likely than Black students and 86% more likely than Hispanic students to participate in Honors Biology. Asian students were 34% more likely than White students to be enrolled in Honors Biology. Students who were not Special education were 381% more likely than those who did receive Special Education services to take Honors Biology. Students who did not receive Free or Reduced Meals were 59% more likely than those who did receive Free or Reduced Meals to be enrolled in Honors Biology. Students who did not receive English

Language services while in high school were 1137% more likely than those who did receive English Language services to participate in Honors Biology.

These results replicate many of the equity issues found in other studies. White students were enrolled in Honors Biology at a significantly higher rate than Hispanic or Black students while Asian students were enrolled at a higher rate than White students. Students who received Special Education services, those who were English Language Learners and those who received Free or Reduced Meals were enrolled in Honors Biology at a significantly lower rate than their peers who did not receive Special Education services, were not English Language Learners and who did not receive Free or Reduced Meals. For example, if a student was an English Language Learner, s/he enrolled in Honors Biology .08% of the time.

Honors Chemistry. As shown in Table 8, the overall predictive model for Honors Chemistry was statistically significant (likelihood ratio chi square= 7260.63 [11], $p <.0001$). Free and Reduced Meals, Black students, Hispanic students, Asian students, ELL, Gender, Special Education status and Algebra 1 were significant predictors of whether a student would participate in Honors Chemistry. Similar to the findings for Honors Biology, students who were enrolled in Algebra 1 in 8th grade were 2812% more likely to take Honors Chemistry. White students were 36% more likely than Black students and 76% more likely than Hispanic students to participate in Honors Chemistry. Asian students were 80% more likely than White students, and Girls were 11% more likely than Boys to be enrolled in Honors Chemistry. Students who took Algebra 1 by 8th grade were 2812% more likely to enroll in Honors Chemistry than those students who did not take Algebra 1 by 8th grade. Students who did not receive Special education services were 449% more likely to take Honors Chemistry than those who did receive these services. Students who did not receive Free or Reduced Meals were 83% more likely than those who did receive Free or Reduced Meals to be enrolled in Honors Chemistry. Students who did not receive English Language services while in high school were 567% more likely to participate in Honors Chemistry than those who did receive English Language services. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.06.

Table 8

How did demographic factors predict if a student enrolled in Honors Chemistry or IB Chemistry 1 (3b)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.49	0.61	0.55
Race/Ethnicity					
	Black students	<.0001*	0.64	0.84	0.74
	Hispanic students	<.0001*	0.51	0.64	0.57
	Native American students	0.2667	0.68	3.93	1.64
	Asian students	<.0001*	1.64	1.97	1.80
	Undeclared students	0.5979	0.48	3.58	1.31
	Multi-Racial students	0.1018	0.97	1.34	1.14
Females		0.0026*	1.04	1.19	1.11
English Language Learners		<.0001*			0.15
Special Education Status		<.0001*	0.15	0.22	0.18
Algebra 1		<.0001*	24.74	34.28	29.12

*Note: * designates significant statistic*

Even when demographic factors were controlled for, taking Algebra 1 by 8th grade was a significant predictor of which groups would take Honors Chemistry. Students who were in Algebra 1 by 8th grade were 2812% more likely to enroll in Honors Chemistry. The Algebra 2 math requirement for this course offers the most likely reason for the strength of this relationship. Due to the nature of both the math and the science course sequences, chemistry is taken in 10th grade and Algebra 2 is the third course in the high school math sequence. White students were enrolled in Honors Chemistry at a significantly higher rate than Hispanic or Black students, while Asian students were enrolled at a higher rate than White students. Gender was significant in that Girls were more likely to enroll in Honors Chemistry than Boys. Similarly to Honors Biology, students who received Special Education services, who were English Language Learners and who received Free or Reduced Meals were enrolled in Honors Chemistry at a significantly lower rate when compared to their peers who did not receive Special Education services, were not English Language Learners and who did not receive Free or Reduced Meals. For example, if a student was a Special Education student, s/he enrolled in Honors Chemistry 0.18% of the time.

Honors Physics. As shown in Table 9, the overall predictive model was statistically significant (likelihood ratio chi square= 982.70 [11], p <.0001). Free and Reduced Meals, Hispanic students, Asian students, Multi-Racial students, Gender, Special Education status and Algebra 1 by 8th grade were significant predictors of whether a student would participate in Honors Physics. Students who were enrolled in Algebra 1 by 8th grade were 112% more likely to enroll in this course than students who did not take Algebra 1 in 8th grade. White students were 15% more likely than Hispanic students to participate in Honors Physics.   But Asian students were 30% more likely than White students, and Boys were 19% more likely than Girls to be enrolled in Honors Physics. Multi-Racial students were 17% more likely than White students to enroll in Honors Physics. Students who did not receive Special education services were 26% more likely to take Honors Physics than those who did receive Special Education services, and students who did not receive Free or Reduced Meals were 28% more likely to be enrolled in Honors Physics than those who did receive Free or Reduced Meals. Students who were enrolled in Algebra 1 by 8th grade were 112% more likely to be enrolled in Honors Physics than students who did not take Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.04.

Table 9

How did demographic factors predict if a student enrolled in Honors Physics or IB Physics 1 (3c)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.72	0.85	0.78
Race/Ethnicity					
	Black students	0.9095	0.90	1.13	1.01
	Hispanic students	0.0030*	0.79	0.95	0.87
	Native American students	0.0565	0.28	1.02	0.53
	Asian students	<.0001*	1.19	1.42	1.30
	Undeclared students	0.4408	0.54	4.19	1.49
	Multi-Racial students	0.0389*	1.01	1.36	1.17
Females		<.0001*	0.79	0.89	0.84
English Language Learners		0.7618	0.81	1.17	0.97
Special Education Status		<.0001*	0.72	0.87	0.79
Algebra 1		<.0001*	1.98	2.28	2.12

*Note: * designates significant statistic*

When demographic factors were controlled for, whether a student took Algebra 1 by 8th grade was a significant predictor of whether they would participate in Honors Physics. While less so than for Honors Biology and Honors Chemistry, taking Algebra 1 by 8th grade was still a significant predictor of a student’s enrollment in Honors Physics. This could be explained by either the science sequence or summer math classes. Honors Physics can be taken in 11^{th} or 12^{th} grade in this district, so students taking the course in 12^{th} grade would have met the math co-requisites by then. Taking a summer math class to "catch up" would also allow a student to meet the math prerequisites. The data show Black students or ELL students were not significant predictors of whether a student would enroll in Honors Physics. However, unlike previous questions where White students were enrolled in higher-level science classes at a higher rate than Black students, Black race was not a significant predictor of enrollment for Honors Physics. White students were enrolled at a higher rate than Hispanic students, while Asian students were enrolled at a higher rate than White students. Gender was significant again, but this time Boys were more likely to enroll in Honors Physics than Girls. Students who received Special Education services and those who received Free or Reduced Meals were enrolled in Honors Physics at a lower rate when compared to the rate of their peers who did not receive these services. The ELL student demographic was not a predictor, which could be explained by the fact that this was such a small group of students; only 0.62% of the sample (or 85 students) were enrolled in Algebra 1 by the 8^{th} grade and only 8.58% (or 484 students) were not enrolled in Algebra 1 by 8th grade.

AP/IB Biology 2. As shown in Table 10, the overall predictive model was statistically significant (likelihood ratio chi square= 2173.25 [11], p <.0001). Free and Reduced Meals, Black students, Hispanic students, Asian students, Gender, ELL students, Special Education status and Algebra 1 by 8th grade were significant predictors of whether a student would participate in AP/IB Biology2. Students who were enrolled in Algebra 1 by 8th grade were 274% more likely to be enrolled in AP/IB Biology 2. Black students were 18% more likely than White students to participate in AP/IB Biology2, but Asian students were 142% more likely than White students to participate in AP/IB Biology2. Girls were 138% more likely than Boys to be enrolled in AP/IB Biology 2, which is different than Honors Physics but similar to Honors Biology and Honors Chemistry. Students who did not receive Special education services were 350% more likely to take AP/IB Biology 2 than those who did receive these services. Students who did not receive Free or Reduced Meals were 32% more likely to be enrolled in AP/IB Biology 2 than those who did receive Free or Reduced Meals. A student who was not an English Language Learner, was 421% more likely than those who were English Language Learners to be enrolled in AP/IB Biology 2. If a student took Algebra 1 by 8th grade they were 274% more likely to be enrolled in AP/IB Biology 2. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.12.

Table 10

How did demographic factors predict if a student enrolled in AP/IB Biology 2 (3d1)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.67	0.85	0.75
Race/Ethnicity					
	Black students	0.0366*	1.01	1.39	1.08
	Hispanic students	0.0044*	0.71	0.94	0.81
	Native American students	0.5088	0.20	2.23	0.67
	Asian students	<.0001*	2.20	2.66	2.42
	Undeclared students	0.9569	0.29	3.65	1.04
	Multi-Racial students	0.0507	1.00	1.45	1.20
Females		<.0001*	2.18	2.58	2.38
English Language Learners		0.0003*	0.08	0.47	0.19
Special Education Status		<.0001*	0.17	0.30	0.22
Algebra 1		<.0001*	3.26	4.29	3.74

*Note: * designates significant statistic*

When demographic factors were controlled for, whether a student took Algebra 1 by 8th grade was a significant predictor of whether a student would enroll in AP/IB Biology 2. Algebra 1 by 8th grade was only slightly more predictive of whether a student would take Honors Physics but still significantly less than Honors Biology and Honors Chemistry. There were also significant differences in which groups of students enrolled in AP/IB Biology 2. Unlike previous questions where White students were enrolled in these classes at a higher rate than Black students, for AP/IB Biology 2, Black students were enrolled at a higher rate. But like previous questions White students were enrolled in AP/IB Biology at a higher rate than Hispanic students but less than Asian students. Gender was significant again, but this time Girls were enrolled in AP/IB Biology 2 at a significantly higher rate than Boys. Similarly to many other questions, students who received Special Education services, were English Language Learners or received Free or Reduced Meals were enrolled in AP/IB Biology 2 at a significantly lower rate when compared to that of their peers who did not receive Special Education services, were not English Language Learners and did not receive Free or Reduced Meals.

AP/IB Chemistry 2. As shown in Table 11, the overall predictive model was statistically significant (likelihood ratio chi square= 1763.9 [11], p <.0001). Free and Reduced Meals, Hispanic students, Asian students, Multi-Racial students, ELL, Gender, Special Education status and Algebra 1 by 8th grade were significant predictors whether a student would participate in AP/IB Chemistry 2. Students who were enrolled in Algebra 1 by 8^{th} grade were 783% more likely to be enrolled in AP/IB Chemistry 2 than students who were not enrolled in Algebra 1 by 8^{th} grade. White students were 41% more likely than Hispanic students to participate in AP/IB Chemistry 2. Multi-Racial students were 27% more likely than White students and Asian students were 179% more likely than White students to participate in AP/IB Chemistry 2. Girls were 26% more likely than Boys to be enrolled in AP/IB Chemistry 2. Students who were not Special education were 387% more likely to take AP/IB Chemistry 2 than those who did receive Special Education services. Students who did not receive Free or Reduced Meals were 79% more likely to be enrolled in AP/IB Chemistry 2 than those who did receive Free or Reduced Meals, and a student who was not an English Language Learner was 940% more likely to be enrolled in AP/IB Chemistry 2 than those who were English Language Learners. A student enrolled in Algebra 1 by 8^{th} grade was 782% more likely to enroll in AP/IB Chemistry 2 than a student not enrolled in Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.13.

Table 11

How did demographic factors predict if a student enrolled in AP/IB Chemistry 2 (3d2)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*			0.46
Race/Ethnicity					
	Black students	0.1389	0.67	1.06	0.84
	Hispanic students	0.0004*	0.59	0.86	0.71
	Native American students	0.7144	0.37	4.25	1.26
	Asian students	<.0001*	2.50	3.10	2.78
	Undeclared students	0.9027	0.25	4.85	1.10
	Multi-Racial students	0.0341*	1.02	1.57	1.27
Females		<.0001*	1.14	1.38	1.26
English Language Learners		0.0204*	0.01	0.70	0.10
Special Education Status		<.0001*	0.13	0.32	0.20
Algebra 1		<.0001*	6.84	11.39	8.83

*Note: * designates significant statistic*

When demographic factors were controlled for, whether a student took Algebra 1 by 8th grade was a significant predictor of whether a student would enroll in AP/IB Chemistry 2. The course sequence could play a role with this aspect of question 3, because many students take AP/IB Chemistry 2 in their junior year since it follows directly after taking Honors Chemistry which is taken in 10th grade. This would mean that it would be very hard for a student to take this course without taking Algebra 1 by 8th grade in order to meet the math corequisite for the Chemistry course. In the division as well, academic advising does not recommend a student take this course unless they are either concurrently enrolled in Pre-Calculus or have already taken Pre-Calculus. There were also significant differences in which groups of students enrolled in AP/IB Chemistry 2 as well. However, unlike previous questions where White students were enrolled in the classes at a higher rate than Black students, for AP/IB Chemistry 2, Black race was not a significant predictor. White students were enrolled at a higher rate than Hispanic students, while Asian students were enrolled at a higher rate than White students. Multi-Racial students were enrolled in AP/IB Chemistry 2 at a higher rate than White students. Gender was significant again, but this time Girls enrolled in AP/IB Chemistry 2 at a higher rate than Boys. Similarly to many other questions, students who received Special Education services, were English Language Learners or received Free or Reduced Meals enrolled in AP/IB Chemistry 2 at a lower rate when compared to their peers who did not receive Special Education services, were not English Language Learners and did not receive Free or Reduced Meals. Whether a student was enrolled in Algebra 1 by 8th grade was a very strong predictor of whether a student would be enrolled in AP/IB Chemistry 2.

AP/IB Physics 2. As shown in Table 12, the overall predictive model was statistically significant (likelihood ratio chi square= 1167.97 [11], p <.0001). Free and Reduced Meals, Black students, Hispanic students, Asian students, Gender, Special Education status and Algebra 1 by 8th grade were significant predictors of whether a student would participate in AP/IB Physics 2. Students who were enrolled in Algebra 1 by 8^{th} grade were 1748% more likely to be enrolled in AP/IB Physics 2 than students who were not enrolled in Algebra 1 by 8^{th} grade. White students were 50% more likely than Hispanic students and 54% more likely than Black students to participate in AP/IB Physics 2. Asian students were 49% more likely than White students, and Boys were 218% more likely than Girls to be enrolled in AP/IB Physics 2. Students who were not Special education were 214% more likely to take AP/IB Physics 2 than those who did receive Special Education services, and students who did not receive Free or Reduced Meals were 81% more likely to be enrolled in AP/IB Physics 2 than those who did receive Free or Reduced Meals. Students who were enrolled in Algebra 1 by 8th grade were 1748% more likely to be enrolled in AP/IB Physics 2. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.14.

Table 12

How did demographic factors predict if a student enrolled in AP/IB Physics 2 (3d3)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.46	0.67	0.56
Race/Ethnicity					
	Black students	0.0013*	0.50	0.84	0.65
	Hispanic students	<.0001*	0.54	0.82	0.66
	Native American students	0.7176	0.17	3.43	0.76
	Asian students	<.0001*	1.31	1.68	1.49
	Undeclared students	0.9841	0	0	0
	Multi-Racial students	0.1467	0.94	1.49	1.19
Females		<.0001*	0.28	0.35	0.31
English Language Learners		0.1438	0.13	1.34	0.42
Special Education Status		<.0001*	0.22	0.45	0.32
Algebra 1		<.0001*	12.56	27.19	18.48

*Note: * designates significant statistic*

When demographic factors were controlled for, whether a student took Algebra 1 by 8th grade was a significant predictor of whether a student would enroll in AP/IB Physics 2. The Odds Ratio of Algebra 1 by 8th grade being so high for this course could be solely attributed to the mathematics sequence in this division. For a student to enroll in AP/IB Physics 2, the student must either be concurrently enrolled in Calculus AB or BC or IB Higher Mathematics 2, which a student can only take if they have taken Algebra 1 by 8th grade. There were also significant differences in which groups of students enrolled in AP/IB Physics 2. White students were more likely to be enrolled in AP/IB Physics 2 than Hispanic or Black students, but they were enrolled at a lower rate than Asian students. Gender was a significant predictor with Boys enrolling at a much higher rate than Girls. However, students enrolled in Special Education and those who received Free or Reduced Meals were much less likely to participate in AP/IB Physics 2 when compared to the rate of their peers who did not receive these services.

AP/IB Environmental Science. As shown in Table 13, the overall predictive model was statistically significant (likelihood ratio chi square= 1179.90 [11], p <.0001). Free and Reduced Meals, Hispanic students, Black students, Multi-Racial students, Gender, ELL students, Special Education status and Algebra 1 by 8th grade were significant predictors of whether a student would participate in AP/IB Environmental Science. Students who were enrolled in Algebra 1 by 8^{th} grade were 85% more likely to be enrolled in AP/IB Environmental Science than students who were not enrolled in Algebra 1 by 8^{th} grade. White students were 74% more likely than Hispanic students and 109% more likely than Black students to participate in AP/IB Environmental Science. Girls were 38% more likely than Boys to be enrolled in AP/IB Environmental Science, and students who were not Special education were 323% more likely to take AP/IB Environmental Science than those who did receive these services. Students who did not receive Free or Reduced Meals were 58% more likely than those who did receive Free or Reduced Meals to be enrolled in AP/IB Environmental Science. Students who took Algebra 1 by 8th grade were 85% more likely to be enrolled in AP/IB Environmental Science. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.02.

Table 13

How did demographic factors predict if a student enrolled in AP/IB Environmental Science (3d4)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.56	0.72	0.63
Race/Ethnicity					
	Black students	<.0001*	0.40	0.57	0.48
	Hispanic students	<.0001*	0.50	0.66	0.57
	Native American students	0.9140	0.45	2.41	1.05
	Asian students	0.8581	0.89	1.14	1.01
	Undeclared students	0.7884	0.84	1.14	0.97
	Multi-Racial students	0.0274*	0.68	0.98	0.82
Females		<.0001*	1.28	1.49	1.38
English Language Learners		0.0027*	0.23	0.73	0.41
Special Education Status		<.0001*	0.19	0.30	0.24
Algebra 1		<.0001*	1.66	2.07	1.85

*Note: * designates significant statistic*

When demographic factors were controlled for, whether a student took Algebra 1 by 8th grade was a significant predictor of whether a student would enroll in AP/IB Environmental Science. Taking Algebra 1 by 8th grade was a good predictor of whether a student would be enrolled in AP/IB Environmental Science but not nearly to the degree that any of the other science classes. There were also significant differences in which groups of students enrolled in AP/IB Environmental Science as well. White students were more likely to be enrolled in AP/IB Environmental Science than Hispanic, Black and Multi-Racial students, and for the first time, Asian race was not a predictor of enrollment in AP/IB Environmental Science. Girls were enrolled at a higher rate than Boys in AP/IB Environmental Science. Like many previous questions, students enrolled in Special Education and those who received Free or Reduced Meals were much less likely to participate in AP/IB Environmental Science when compared to the rate of their peers who did not receive these services.

Question 3 summary. The data revealed that whether a student was enrolled in Algebra 1 by 8th grade, while demographic factors were controlled for, was a good predictor of the science classes students would access while in high school in this large division on the East Coast of the United States. It was a very strong predictor for Honors Biology, Honors Chemistry, IB/AP Chemistry 2, AP/IB Biology 2 and AP/IB Physics 2 and less strong for Honors Physics and AP/IB Environmental Science. The results for research question 3 show inequities related to the demographic characteristics of students and whether Algebra 1 was a good predictor of science course enrollment. These inequities could affect students who took Algebra 1 by the 8th grade, students who took Algebra 1 after the 8th grade, or both. Question 4 was set up to investigate this issue more closely. The whole sample of students was split into two groups based on when students took Algebra 1. The relationship between demographic variables and course-taking pattern for each of the two groups was then examined. Research Question 4 examines these issues for the students who took Algebra 1 by 8th grade. Question 5 does the same for the students who took Algebra 1 after 8th grade.

Question 4: For students who took Algebra 1 before high school, how did demographic factors predict whether they took:

a. Honors Biology
b. Honors Chemistry
c. Honors Physics
d. Any AP Science class or the second year of any IB Science class

For all of the aspects of question 4, a logistic regression was used to estimate the probability of students who enrolled in different science courses and who also took Algebra 1 by 8th grade while controlling for demographic factors in the sample of 19,359 students from a large school district in the mid-Atlantic of the United States. The ten predictor variables: FRMS, Black, Hispanic, Native American, Asian, Undeclared, Multi-Racial, Gender, ELL and Special Education Status were used in the analysis.

Honors Biology. As shown in Table 14, the overall predictive model was statistically significant (likelihood ratio chi square= 932.17 [10], p <.0001). Free/Reduced Meals, Free and Reduced Meals, Black students, Hispanic students, Asian students, ELL and Special Education status were significant predictors of whether a student would participate in Honors Biology. White students were 47% more likely than Black students and 85% more likely than Hispanic students to participate in Honors Biology if they had taken Algebra 1 by 8th grade. Asian students were 41% more likely than White students to be enrolled in Honors Biology if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 353% more likely than those who did receive these services to take Honors Biology if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 70%

more likely than those who did receive Free or Reduced Meals to be enrolled in Honors Biology if they had taken Algebra 1 by 8th grade. Students who did not receive English Language services while in high school were 1256% more likely than those who did receive English Language services to participate in Honors Biology if they had taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.25.

Table 14

How did demographic factors predict if a student enrolled in Honors Biology (4a)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.53	0.65	0.59
Race/Ethnicity					
	Black students	<.0001*	0.59	0.78	0.68
	Hispanic students	<.0001*	0.48	0.61	0.54
	Native American students	0.4724	0.28	1.80	0.71
	Asian students	<.0001*	1.28	1.55	1.41
	Undeclared students	0.7066	0.41	3.62	1.23
	Multi-Racial students	0.9746	0.84	1.19	1.00
Females		0.0003*	1.06	1.23	1.14
English Language Learners		<.0001*	0.03	0.19	0.07
Special Education Status		<.0001*	0.18	0.27	0.22

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in Honors Biology. Again, White students were enrolled in Honors Biology at a significantly higher rate than Hispanic or Black students, while Asian students were enrolled at a higher rate than White students. Similarly to question 1, students who received Special Education services, were English Language Learners or received Free or Reduced Meals were enrolled in Honors Biology at a significantly lower rate when compared to the rate of their peers who did not receive Special Education services, were not English Language Learners and did not receive Free or Reduced Meals. For example, if a student was an English Language Learner, s/he enrolled in Honors Biology .07% of the time.

Honors Chemistry. As shown in Table 15, the overall predictive model was statistically significant (likelihood ratio chi square= 1093.8 [10], p <.0001). Free and Reduced Meals, Black students, Hispanic students, Asian students, ELL, Gender and Special Education status were significant predictors of whether a student would participate in Honors Chemistry, if they had taken Algebra 1 by 8th grade. White students were 37% more likely than Black students and 76% more likely than Hispanic students to participate in Honors Biology if they had taken Algebra 1 by 8th grade. Asian students were 84% more likely than White students, and Girls were 11% more likely than Boys to be enrolled in Honors Chemistry if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 421% % more likely than those who did receive these services to take Honors Chemistry if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 86% more likely than those who did receive Free or Reduced Meals to be enrolled in Honors Chemistry if they had taken Algebra 1 by 8th grade. Students who did not receive English Language services while in high school were 577% more likely than those who did receive English Language services to participate in Honors Chemistry if they had taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.06.

Table 15

How did demographic factors predict if a student enrolled in Honors Chemistry or IB Chemistry 1 (4b)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.48	0.60	0.54
Race/Ethnicity					
	Black students	<.0001*	0.63	0.84	0.73
	Hispanic students	<.0001*	0.51	0.64	0.57
	Native American students	0.2890	0.64	4.58	1.71
	Asian students	<.0001*	1.68	2.02	1.84
	Undeclared students	0.5305	0.49	3.93	1.39
	Multi-Racial students	0.0522	1.00	1.38	1.00
Females		0.0044*	1.03	1.19	1.11
English Language Learners		<.0001*	0.07	0.33	0.15
Special Education Status		<.0001*	0.16	0.24	0.19

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in Honors Chemistry. Again, White students were enrolled in Honors Chemistry at a significantly higher rate than Hispanic or Black students while Asian students were enrolled at a higher rate than White students. Unlike Honors Biology, gender was significant in that Girls were more likely to enroll in Honors Chemistry than Boys. Similarly to the Honors Biology, students who received Special Education services, were English Language Learners or received Free or Reduced Meals enrolled in Honors Chemistry at a significantly lower rate when compared to the rate of their peers who did not receive Special Education services, were not English Language

Learners and did not receive Free or Reduced Meals. For example, if a student was a Special Education student, s/he enrolled in Honors Chemistry 0.19% of the time.

Honors Physics. As shown in Table 16, the overall predictive model was statistically significant (likelihood ratio chi square= 275.66 [10], $p < .0001$). Free and Reduced Meals, Hispanic students, Asian students, Multi-Racial students, Gender, ELL and Special Education status were significant predictors of whether a student would participate in Honors Physics if they had taken Algebra 1 by 8th grade. White students were 21% more likely than Hispanic students to participate in Honors Physics if they had taken Algebra 1 by 8th grade. Asian students were 38% more likely than White students and Boys were 27% more likely than Girls to be enrolled in Honors Physics if they had taken Algebra 1 by 8th grade. Multi-Racial students were 28% more likely than White students to enroll in Honors Physics if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 90% more likely than those who did receive these services to take Honors Physics if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 48% more likely than those who did receive Free or Reduced Meals to be enrolled in Honors Physics if they had taken Algebra 1 by 8th grade. Students who did not receive English Language services were 68% more likely than students who did receive these services to be in Honors Physics if they had taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.02.

Table 16

How did demographic factors predict if a student enrolled in Honors Physics or IB Physics 1 (4c)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.60	0.75	0.67
Race/Ethnicity					
	Black students	0.2578	0.79	1.07	0.92
	Hispanic students	0.0019*	0.73	0.93	0.83
	Native American students	0.0740	0.18	1.08	0.44
	Asian students	<.0001*	1.25	1.53	1.38
	Undeclared students	0.8668	0.31	2.65	0.91
	Multi-Racial students	0.0065*	1.07	1.55	1.29
Females		<.0001*	0.73	0.85	0.79
English Language Learners		0.0233*	0.38	0.93	0.60
Special Education Status		<.0001*	0.44	0.62	0.53

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in Honors Physics. However, unlike previous questions where White students were enrolled in the classes at a higher rate than Black students, for Honors Physics Black race was not significant. White students were enrolled at a higher rate than Hispanic students, while Asian students were enrolled at a higher rate than White students. Gender was significant again but this time, Boys were more likely to enroll in Honors Physics than Girls. Similarly to Honors Biology and Honors Chemistry, students who received Special Education services, were English Language learners or received Free or Reduced Meals were enrolled in Honors Physics at a lower rate when compared to the rate of their peers who did not receive Special Education services, did not receive English Language services and did not receive Free or Reduced Meals.

AP/IB Biology 2. As shown in Table 17, the overall predictive model was statistically significant (likelihood ratio chi square= 927.36 [10], p <.0001). Free and Reduced Meals, Black students, Asian students, ELL, Gender and Special Education status were significant predictors of whether a student would participate in AP/IB Biology2, if they had taken Algebra 1 by 8th grade. Black students were 32% more likely than White students to participate in AP/IB Biology2, if they had taken Algebra 1 by 8th grade. Asian students were 147% more likely than White students and Girls were 135% more likely than Boys to be enrolled in AP/IB Biology 2 if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 308% more likely than those who did receive these services to take AP/IB Biology 2 if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 33% more likely than those who did receive Free or Reduced Meals to be enrolled in AP/IB Biology 2 if they had taken Algebra 1 by 8th grade. A student who was not an English Language Learner and had taken Algebra 1 by 8th grade was 247% more likely than those who were English Language Learners to be enrolled in AP/IB Biology 2. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.06.

Table 17

How did demographic factors predict if a student enrolled in AP/IB Biology 2 (4d1)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.66	0.86	0.75
Race/Ethnicity					
	Black students	0.0017*	1.11	1.56	1.32
	Hispanic students	0.0995	0.76	1.02	0.88
	Native American students	0.4614	0.13	2.52	0.57
	Asian students	<.0001*	2.24	2.73	2.47
	Undeclared students	0.8163	0.32	4.18	1.16
	Multi-Racial students	0.1239	0.96	1.42	1.16
Females		<.0001*	2.16	2.57	2.36
English Language Learners		0.0182*	0.10	0.81	0.29
Special Education Status		<.0001*	0.17	0.35	0.24

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in AP/IB Biology 2. However, unlike previous questions where White students were enrolled in the classes at a higher rate than Black students, for AP/IB Biology 2, Black students enrolled at a higher rate. Also notable was the fact that being Hispanic was not a significant predictor of whether a student would enroll in AP/IB Biology2. Like the other aspects of the questions, Asian students were enrolled at a higher rate than White students in AP/IB Biology 2. Gender was significant again, but this time Girls were enrolled in AP/IB Biology 2 at a significantly higher rate than Boys. Similarly to many other questions, students who received Special

Education services, were English Language Learners or received Free or Reduced Meals were enrolled in AP/IB Biology 2 at a remarkably lower rate when compared to the rate of their peers who did not receive Special Education services, were not English Language Learners and did not receive Free or Reduced Meals.

AP/IB Chemistry 2. As shown in Table 18, the overall predictive model was statistically significant (likelihood ratio chi square= 1242.22 [10], p <.0001). Free and Reduced Meals, Black students, Hispanic students, Asian students, ELL, Gender and Special Education status were significant predictors of whether a student would participate in AP/IB Chemistry 2 if they had taken Algebra 1 by 8th grade. White students were 75% more likely than Hispanic students and 47% more likely than Black students to participate in AP/IB Chemistry 2 if they had taken Algebra 1 by 8th grade. Asian students were 190% more likely than White students and Girls were 27% more likely than Boys to be enrolled in AP/IB Chemistry 2 if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 890% more likely than those who did receive these services to take AP/IB Chemistry 2 if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 116% more likely than those who did receive Free or Reduced Meals to be enrolled in AP/IB Chemistry 2 if they had taken Algebra 1 by 8th grade. A student who was not an English Language Learner and had taken Algebra 1 by 8th grade was 1912% more likely than those who were English Language Learners to be enrolled in AP/IB Chemistry 2. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.09.

Table 18

How did demographic factors predict if a student enrolled in AP/IB Chemistry 2 (4d2)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.66	0.86	0.57
Race/Ethnicity					
	Black students	0.0006*	0.55	0.85	0.67
	Hispanic students	<.0001*	0.47	0.69	0.57
	Native American students	0.8033	0.26	2.82	0.86
	Asian students	<.0001*	2.61	3.22	2.90
	Undeclared students	0.9094	0.25	4.76	1.09
	Multi-Racial students	0.0617	0.99	1,52	1.23
Females		<.0001*	1.16	1.40	1.27
English Language Learners		0.0028*	0.01	0.36	0.05
Special Education Status		<.0001*	0.07	0.15	0.10

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in AP/IB Chemistry 2. Like many of the previous questions, White students were enrolled at a higher rate than Hispanic and Black students, while Asian students were enrolled at a higher rate than White students. Gender was significant again with Girls enrolling in AP/IB Chemistry 2 at a higher rate than Boys. Similarly to many other questions, students who received Special Education services, were English Language Learners or received Free or Reduced Meals enrolled in AP/IB Chemistry 2 at a lower rate when compared to the rate of their peers who did not receive Special Education services, were not English Language Learners and did not receive Free or Reduced Meals.

AP/IB Physics 2. As shown in Table 19, the overall predictive model was statistically significant (likelihood ratio chi square= 1050.82 [10], p <.0001). Free and Reduced Meals, Hispanic students, Asian students, Black students, Gender, ELL status and Special Education status were significant predictors of whether a student would participate in AP/IB Physics 2 if they had taken Algebra 1 by 8th grade. White students were 92% more likely than Hispanic students and were 99% more likely than Black students to participate in AP/IB Physics 2 if they had taken Algebra 1 by 8th grade. Asian students were 55% more likely than White students and Boys were 208% more likely than Girls to be enrolled in AP/IB Physics 2 if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 573% more likely than those who did receive these services to take AP/IB Physics 2 if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 122% more likely than those who did receive Free or Reduced Meals to be enrolled in AP/IB Physics 2 if they had taken Algebra 1 by 8th grade. And students who were not English Language Learners were 473% more likely than those who did receive English Language services while in high school to be enrolled in AP/IB Physics 2 if they had taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.09.

Table 19

How did demographic factors predict if a student enrolled in AP/IB Physics 2 (4d3)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.37	0.54	0.45
Race/Ethnicity					
	Black students	<.0001*	0.39	0.65	0.50
	Hispanic students	<.0001*	0.43	0.64	0.52
	Native American students	0.4105	0.13	2.31	0.55
	Asian students	<.0001*	1.38	1.76	1.56
	Undeclared students	0.9845	0	0	0
	Multi-Racial students	0.2436	0.91	1.43	1.14
Females		<.0001*	0.29	0.36	0.33
English Language Learners		0.0029*	0.006	0.55	0.17
Special Education Status		<.0001*	0.10	0.21	0.15

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in AP/IB Physics 2. White students were more likely to be enrolled in AP/IB Physics 2 than Hispanic or Black students, but they were enrolled at a lower rate than Asian students. Gender was significant again but this time because Boys enrolled at a much higher rate than Girls. However, Special Education students, English Language Learners and those who received Free or Reduced Meals were much less likely to participate in AP/IB Physics 2 when compared to the rate of their peers who did not receive Special Education or English Language services or did not receive Free or Reduced Meals.

AP/IB Environmental Science. As shown in Table 20, the overall predictive model was statistically significant (likelihood ratio chi square= 1050.60 [10], p <.0001). Free and Reduced Meals, Hispanic students, Black students, Gender, ELL status and Special Education status were significant predictors of whether a student would participate in AP/IB Environmental Science if they had taken Algebra 1 by 8th grade. White students were 91% more likely than Hispanic students and 128% more likely than Black students to participate in AP/IB Environmental Science if they had taken Algebra 1 by 8th grade. Girls were 38% more likely than Boys to be enrolled in AP/IB Environmental Science if they had taken Algebra 1 by 8th grade. Students who did not receive Special education services were 446% more likely than those who did receive Special Education services to take AP/IB Environmental Science if they had taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 73% more likely than those who did receive Free or Reduced Meals to be enrolled in AP/IB Environmental Science if they had taken Algebra 1 by 8th grade. And students who were not English Language Learners were 199% more likely to enroll in AP/IB Environmental Science if they had taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.06.

Table 20

How did demographic factors predict if a student enrolled in AP/IB Environmental Science (4d4)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		<.0001*	0.51	0.65	0.58
Race/Ethnicity					
	Black students	<.0001*	0.37	0.52	0.44
	Hispanic students	<.0001*	0.46	0.60	0.52
	Native American students	0.7973	0.39	2.06	0.90
	Asian students	0.5053	0.94	1.14	1.03
	Undeclared students	0.2807	0.64	4.56	1.71
	Multi-Racial students	0.0209*	0.68	0.97	0.81
Females		<.0001*	1.28	1.49	1.38
English Language Learners		0.0002*	0.19	0.60	0.33
Special Education Status		<.0001*	0.15	0.23	0.18

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in AP/IB Environmental Science. White students were more likely to be enrolled in AP/IB Environmental Science than Hispanic or Black students, and for the first time, Asian race was not a predictor of enrollment in AP/IB Environmental Science. Girls were enrolled at a higher rate than Boys in AP/IB Environmental Science. Like many previous questions, Special Education students, English Language Learners and those who received Free or Reduced Meals were much less likely to participate in AP/IB Environmental Science when compared to the rate of their peers who did not receive Special Education services or who did not receive Free or Reduced Meals.

Question 4 summary. This question examined the relationship between demographic variables and science course-taking patterns for the group of students in the sample who did take Algebra 1 by 8^{th} grade. Students who received Free or Reduced Meals, were English Language Learners or received Special Education services did not enroll in higher-level science classes at the same rate as their peers who did not receive Free or Reduced Meals, English Language services or special education services. In almost all the questions, Asian students were enrolled at a higher rate than White students who were enrolled at a higher rate than Hispanic or Black students. The exception to this was for AP/IB Environmental science where Asian race was not a predictor of enrollment. It is also significant to note that for AP/IB Biology 2, being Hispanic was not a significant predictor of that course's enrollment, and Black students enrolled at a higher rate than White students. Notably, girls enrolled in all the honors and AP/IB science classes at a higher rate than boys except for Honors Physics and AP/IB Physics 2.

The following research question, Question 5, examined whether students who did not take Algebra 1 by 8^{th} grade accessed the highest science courses they could where the mathematics prerequisite was not above Algebra 2.

Question 5: For students who did not take Algebra 1 before high school, how did demographic factors predict whether a student took:

e. Honors Biology
f. AP Biology or the second year of IB Biology or IB Environmental Systems

Honors Biology. As shown in Table 21, the overall predictive model was statistically significant (likelihood ratio chi square= 365.83 [10], $p < .0001$). Free and Reduced Meals, Hispanic students, Black students, ELL and Special Education status were significant predictors of whether a student would participate in Honors Biology if they had not taken Algebra 1 by 8th grade. White students were 93% more likely than Hispanic students and 79% more likely than Black students to participate Honors Biology in if they had not taken Algebra 1 by 8th grade. Students who did not receive Special education services were 456% more likely than those who did receive these services to take Honors Biology if they had not taken Algebra 1 by 8th grade. Students who did not receive Free or Reduced Meals were 23% more likely than those who did receive Free or Reduced Meals to be enrolled in Honors Biology if they had not taken Algebra 1 by 8th grade. Students who were not English Language learners were 958% more likely to take Honors Biology if they had not taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.09.

Table 21

How did demographic factors predict if a student enrolled in HN Biology (5a)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		0.0414*	0.66	0.99	0.81
Race/Ethnicity					
	Black students	<.0001*	0.42	0.73	0.56
	Hispanic students	<.0001*	0.14	0.66	0.52
	Native American students	0.1717	0.03	1.85	0.24
	Asian students	0.9562	0.71	1.38	0.99
	Undeclared students	0.9888	0.66	1.56	1.01
	Multi-Racial students	0.6794	0.63	1.36	0.92
Females		0.5455	0.89	1.24	1.05
English Language Learners		<.0001*	0.03	0.30	0.09
Special Education Status		<.0001*	0.13	0.24	0.18

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did not take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in Honors Biology. White students were more likely to be enrolled in Honors Biology than Hispanic or Black students. Similarly to many previous questions, Special Education students, those who received Free or Reduced Meals and ELL students were much less likely to participate in Honors Biology when compared to the rate of their peers who did not receive Special Education services or who did not receive Free or Reduced Meals.

AP/IB Biology 2. As shown in Table 22, the overall predictive model was statistically significant (likelihood ratio chi square= 223.71 [10], p <.0001). Gender, Hispanic students, Black students, Asian students, ELL students and Special Education status were significant predictors of whether a student would participate in AP/IB Biology 2, if they had not taken Algebra 1 by 8th grade. Girls were 152% more likely than boys to participate in AP/IB Biology 2 if they had not taken Algebra 1 by 8th grade. White students were 60% more likely than Black students and 106% more likely than Hispanic students to participate AP/IB Biology 2 in if they had not taken Algebra 1 by 8th grade. Asian students were 89% more likely than White students to participate in AP/IB Biology 2 if they had not taken Algebra 1 by 8th grade. Students who did not receive Special education services were 433% more likely than those who did receive these services to take AP/IB Biology 2 if they had not taken Algebra 1 by 8th grade. Students who were not English Language learners were 903% more likely to take AP/IB Biology 2 if they had not taken Algebra 1 by 8th grade. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.10.

Table 22

How did demographic factors predict if a student enrolled in AP/IB Biology 2 (5b)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		0.2236	0.66	0.99	0.81
Race/Ethnicity					
	Black students	0.0341*	0.40	0.97	0.62
	Hispanic students	0.0002*	0.33	0.71	0.49
	Native American students	0.8046	0.10	5.95	0.77
	Asian students	0.0003*	1.34	2.66	1.89
	Undeclared students	0.9896	0	0	0
	Multi-Racial students	0.1717	0.85	2.46	1.44
Females		<.0001*	1.92	3.31	2.52
English Language Learners		0.0210*	0.01	0.70	0.10
Special Education Status		<.0001*	0.11	0.31	0.19

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did not take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in AP/IB Biology 2. White students were more likely to be enrolled in AP/IB Biology 2 than Hispanic or Black students but at a lesser rate than Asian students. Girls enrolled in AP/IB Biology 2 at a higher rate than boys when they had not taken Algebra 1 by 8th grade. And like many previous questions, students enrolled in Special Education or who were English Language Learners were much less likely to participate in AP/IB Biology 2 when compared to the rate of their peers who did not receive Special Education services or were not English Language learners.

AP/IB Environmental Science. As shown in Table 23, the overall predictive model was statistically significant (likelihood ratio chi square= 309.73 [10], p <.0001). Gender, Hispanic students, Black students, Multi-Racial students, ELL students and Special Education status were significant predictors if a student would participate in AP/IB Environmental Science, if they had not taken Algebra 1 by 8th grade. Girls were 39% more likely than boys to participate in AP/IB Environmental Science if they had not taken Algebra 1 by 8th grade. White students were 211% more likely than Black students, 125% more likely than Hispanic students and 68% more likely than Multi-Racial students to participate in AP/IB Environmental Science if they had not taken Algebra 1 by 8th grade. Students who did not receive Special education services were 381% more likely than those who did receive these services to take AP/IB Environmental Science if they had not taken Algebra 1 by 8th grade. Students who were not English Language learners were 118% more likely to take AP/IB Environmental Science if they had not taken Algebra 1 by 8th grade. And students who did not receive Free or Reduced Meals were 80% more likely to enroll in AP/IB Environmental Science than their peers who did receive Free or Reduced Meals. The overall effect size was small with the Likelihood Ratio Index R^2 value of 0.10.

Table 23

How did demographic factors predict if a student enrolled in AP/IB Environmental Science (5c)?

Demographic Factors (Predictors)		p value	Lower 95% CI	Upper 95% CI	Odds Ratio
Overall Significance of the model		<.0001*			
Free/Reduced Meals		0.2236	0.66	0.99	0.81
Race/Ethnicity					
	Black students	<.0001*	0.22	0.48	0.32
	Hispanic students	<.0001*	0.33	0.59	0.45
	Native American students	0.3110	0.05	2.66	0.35
	Asian students	0.3147	0.87	1.52	1.15
	Undeclared students	0.5258	0.20	22.9	2.15
	Multi-Racial students	0.0451*	0.36	0.99	0.60
Females		0.0010*	1.14	1.70	1.39
English Language Learners		0.0356*	0.22	0.95	0.46
Special Education Status		<.0001*	0.15	0.29	0.21

*Note: * designates significant statistic*

When demographic factors were controlled for, of those students who did not take Algebra 1 by 8th grade, there were still significant differences in which groups of students enrolled in AP/IB Environmental Science. White students were more likely to be enrolled in AP/IB Environmental Science than Hispanic, Black or Multi Racial students if they had not taken Algebra 1 by 8th grade. Girls were also enrolled in AP/IB Environmental Science at a higher rate than boys that had not taken Algebra 1 by 8th grade. And similar to many previous questions, Special Education students, and those who were English Language Learners and those who received Free or Reduced Meals were much less likely to participate in AP/IB Environmental Science when compared to the rate of their peers who did not receive Special

Education services, were not English Language learners or did not receive Free or Reduced Meals.

Question 5 summary. Question 5 examined if students who did not take Algebra 1 by 8^{th} grade accessed the highest science classes they could where the mathematics prerequisite did not exceed Algebra 2. Like many other questions, students who received Special Education or who were English Language Learners did not access AP/IB Biology 2, Honors Biology or AP/IB Environmental Science at the same rate as their peers who did not receive Special Education services or were not English Language Learners. However, the data revealed that students who received Free or Reduced Meals were not significant for enrollment in AP/IB Environmental Science and AP/IB Biology 2. In Question 3, girls accessed all the upper level science classes except Honors Physics and AP/IB Physics 2 more than boys. For Question 5, the data reveal that again girls do access the AP/IB science options they have more than boys, except for Honors Biology.

Research Question Results Summary

The data showed significant differences between which students were enrolled in Algebra 1 by 8th grade. White and Asian students were enrolled about 80% of the time but only about 50% of Hispanic and Black students were enrolled in Algebra 1 by 8th grade. Additionally, Special Education students, ELL students and students who received Free or Reduced Meals were enrolled in Algebra 1 by 8th grade at significantly lower rates than their peers who did not receive Special Education services, were English Language Learners or did not receive Free or Reduced Meals.

When students were enrolled in Algebra 1 by 8th grade, the data showed not only do those students enroll in Honors and AP/IB science classes at a much higher rate than students who did not participate in Algebra 1 by 8th grade, but that just taking Algebra 1 by 8th grade is a strong predictor of Honors and AP/IB science course enrollment throughout their high school career. However, there are significant differences in which groups participated in those Honors or AP/IB classes. In almost every question, students who were enrolled in Special Education, who were English Language Learners and students who received Free or Reduced Meals, even if they were enrolled in Algebra 1 by 8th grade, participated at much lower rates than their peers who were not members of these demographics. Race and Gender were significant predictors of enrollment in different courses as well in that Black and Hispanic students participated at a lower rate than their peers who were White. Asian students were more likely to participate in almost every AP/IB science course except AP/IB Environmental Science more than their White peers. Gender was an interesting predictor because it was significant for many courses but not in others, and in several of the questions it was differently significant than this researcher's personal experience in schools.

When students did not take Algebra 1 by 8th grade, those same trends were seen; Students enrolled in Special Education, those who were English Language Learners and students who received Free or Reduced Meals, participated in Honors Biology and AP/IB Biology 2 and AP/IB Environmental science classes at a much lower rates than their peers who were not Special Education students, English Language learners or Free and Reduced Meal students. However, Gender was less indicative of those specific course enrollments if a student had not taken Algebra 1 by 8th grade.

In the following chapter each question will be discussed and will include more context and implications of the data, surprises that were uncovered, how the data compares to previous literature and recommendations for further research.

Chapter 5- Discussion

The purpose of this study was to examine the impact of students accessing Algebra 1 in the 8th grade on their science course-taking patterns in high school in a large district in the Mid-Atlantic region of the United States. This chapter includes a discussion of the major findings as related to the previous literature, the interdependent relationship between science and mathematics and which students have had access to Algebra 1 by 8th grade. Also included is a discussion about the surprises the data showed and possible implications for action. This chapter concludes with a discussion about areas for further research and a brief summary.

The research questions that guided this study:

1. What were the significant differences in student characteristics of those who took Algebra 1 by 8th grade versus those who did not, based on:
    a. SES/FRM
    b. Race Ethnicity
    c. Gender
    d. ESOL level
    e. SPED/504
2. What were the differences in science course-taking patterns for students who took Algebra 1 by 8th grade versus students who did not take Algebra 1 by 8th grade?
3. Controlling for demographic factors how did taking Algebra 1 by 8th grade predict whether a student will take:
    a. Honors Biology
    b. Honors Chemistry
    c. Honors Physics

    d. Any AP Science class or a 2nd year of an IB Science class

4. For students who took Algebra 1 before high school, how did demographic factors predict whether a student will take:
    a. Honors Biology
    b. Honors Chemistry
    c. Honors Physics
    d. Any AP Science class or a 2nd year of an IB Science class
5. For students who did not take Algebra 1 before high school, how did demographic factors predict whether a student took:
    a. Honors Biology
    b. AP or 2nd year of IB Biology or IBESS

The data showed significant differences between which students were enrolled in Algebra 1 by 8th grade. White and Asian students were enrolled about 80% of the time, but only about 50% of Hispanic and Black students were enrolled in Algebra 1 by 8th grade. Additionally, Special Education students, ELL students and those who received Free or Reduced Meals were enrolled in Algebra 1 by 8th grade at much lower rates than their peers who were not Special Education students, English Learners or who do not receive Free or Reduced Meals.

When students were enrolled in Algebra 1 by 8th grade, the data showed that not only do those students enroll in Honors and AP/IB science classes at a much higher rate than students who did not participate in Algebra 1 in 8th grade, but that just taking Algebra 1 by 8th grade was a strong predictor of Honors and AP/IB science course enrollment throughout their high school career. However, there were significant differences in which groups participated in those Honors or AP/IB classes. In almost every question, students enrolled in Special Education, students who were English Language Learners and students who received Free or Reduced Meals, even if they were enrolled in Algebra 1 by 8th grade, participated at much lower rates than their peers who were not Special Education students, English Language learners or Free and Reduced Meal students.

Race and Gender were significant predictors of enrollment in different courses as well. Black and Hispanic students participated at lower rates than their peers who were White. Asian students were more likely to participate in almost every AP/IB science course except AP/IB Environmental Science than their White peers. Gender was an interesting predictor, because it was significant for some courses but not others. In several of the questions, it was also differently significant than the researcher's experience in schools. As a science teacher, the researcher's experience was that teachers were always trying to develop and recruit female students to upper level science classes, because the conventional wisdom said that girls were not accessing those classes. Data from this study suggests a very different picture.

When students did not take Algebra 1 by 8th grade, similar trends were seen. Students enrolled in Special Education, who were English Language Learners and students who received Free or Reduced Meals, participated in Honors Biology and AP/IB Biology 2 and AP/IB Environmental science classes at much lower rates than their peers who were not Special Education students, English Language learners or Free and Reduced Meal students. However, Gender was less indicative of those specific course enrollments if a student had not taken Algebra 1 by 8th grade.

Interpretation of the Findings

Algebra 1 is the keystone prerequisite course for both science and mathematics course sequences in high school. Participation in Algebra 1 by 8th grade allows students access to the highest level of mathematics and science courses (AP/IB) throughout their high school career. Which students access Algebra 1 by 8th grade and what science courses they participate in during their high school career as a result is described in the following sections.

Role of the Algebra Class in Course Sequences

The study's conclusion that students who not take Algebra 1 by 8th grade do not access high-level science classes at the same rate as those who do participate in Algebra 1 by 8th grade, supports previous literature that science course opportunities are dependent on mathematics opportunities and preparation in American high schools (Xin Ma, 2009). If students were not enrolled in Algebra 1 by 8th grade, they realistically could not access certain science courses in their four-year high school career. One of the most striking instances of this were the findings of students who took Honors Chemistry. Out of 19,359 students in the study, only 160 students who did not take Algebra 1 by 8th grade enrolled in this course. The school district's prerequisite that a student must have already taken Algebra 2 or be concurrently enrolled in the course to participate in Honors Chemistry due to the nature of the mathematics used in the Chemistry course effectively bars students who take Algebra 1 in 9th grade from taking the Honors Chemistry course.

Additionally, odds ratios were quite high that Algebra 1 by 8th grade significantly predicted all the upper level science courses. In fact, for AP/IB Physics 2, the odds a student had Algebra 1 by 8th grade is 18.48 times more likely than a student who did not enroll in Algebra 1 by 8th grade. Table 24 shows all the odds ratios for Algebra 1 by 8th grade as a predictor for each of the upper science courses.

Table 24

The odds ratios of a student having taken Algebra 1 by 8th grade

Courses	Odds Ratio
Honors Biology	8.27
Honors Chemistry	9.12
Honors Physics	2.12
AP/IB Biology 2	3.74
AP/IB Chemistry 2	8.83
AP/IB Physics 2	18.48
AP/IB Envi. Sci	1.85

Note: Both the models and Gender were significant in each question.

The findings also support previous literature suggesting that, even when students access Algebra 1 by 8th grade, many will not take advanced science courses in high school. (Ma, 2000; Spielhagen, 2006). For example, there were 13,719 students in the sample who could have taken AP/IB Chemistry 2 during their high school career, because they had the mathematics background to access the course, but only 7851, or 57.23% did so. So, if only 57.23% of the students who could have taken that course did so, how many other students "dropped off" the advanced science track? The data showed that 6,110 students took less than three advanced science classes (0,1 or 2 advanced science classes in their high school career). This was 44.54% of the 13,719 students who took Algebra 1 by 8th grade. Which means only 6,285 students, or 45.81% of the 13,719 prepared students took three or four advanced science classes during their high school career. The district lost just under half of the prepared students from the advance science track. It would have been expected that students who were prepared for advanced science classes would have enrolled in at least four of them if not more. However, only 1,324 students, or 9.65% took five or more advanced science classes in their high school career. While this study was not designed to determine if all students who had access to the courses did or did not take an upper level science class, this example just illuminates the significant number of students who had access to a course but chose not to participate.

Who is Taking Algebra in Middle School?

Lastly, the findings make obvious which groups of students did not participate in Algebra 1 by 8th grade: students with disabilities, English Language Learners, students who receive Free or Reduced Meals, Black students and Hispanic students. This is in line with many previous studies about which groups have access to this course, but this study highlights one large Mid-Atlantic school division where the students had access to the same opportunities and policies. Eighth grade algebra enrollment is lower among Black and Hispanic students, according to several studies (Cogan, Schmidt, & Wiley, 2001; Gamoran & Hannigan, 2000; Walston & McCarroll, 2010). Students who live at a lower SES are also not enrolled in Algebra in 8th grade at the same rate as their peers who live at a higher SES (Filer & Chang, 2008; Gamoran & Hannigan, 2000; Walston & McCarroll, 2010). Previous literature is mixed about the participation rates of girls in Algebra 1 by 8th grade. The findings from this study show that gender is not a significant predictor of enrollment in Algebra 1 by 8th grade.

Surprises in the Findings

There are many data points that were surprising, including the strong relationship between Honors Biology and Algebra 1 by 8th grade, which science classes were preferentially accessed by girls and boys and which classes did not demonstrate ethnicity as a predictor for participation.

Honors Biology. One of the most surprising themes that emerged from the data was that Honors Biology had such a high participation rate by students who had taken Algebra 1 by 8th grade. Honors Biology does not have a mathematics prerequisite however, 64.47% of the sample of students in the study took Honors Biology and took Algebra 1 by 8th grade. When the Honors Biology participation rate is compared to that of Honors Chemistry, where enrollment requires students to have taken Algebra 1 by 8th grade, Honors Biology is enrolled at a rate 5.68% higher than the Honors Chemistry with students who took Algebra 1 by 8th grade. This raises questions related to causality: does taking Algebra 1 in 8th grade help students see themselves taking Honors Science in 9th grade, or is it the type of student who takes Algebra 1 in 8th grade who also tends to be the type to challenge themselves with an Honors science class?

Science courses girls and boys participated in. The odds that a girl would be enrolled in specific science courses was not addressed in the literature review save for the enrollment rate in Algebra 1 by 8th grade. However, the data from this study reveal some surprising findings for girls enrolling in specific science classes. Table 25, below, outlines the odds ratios that a girl would be enrolled in a specific course, which demonstrates which science courses girls did or did not participate in.

Table 25

The odds ratios of girls' participation in specific science classes

Courses	Odds Ratio
Honors Biology	1.14
Honors Chemistry	1.11
Honors Physics	0.79
AP/IB Biology 2	2.36
AP/IB Chemistry 2	1.25
AP/IB Physics 2	0.32
AP/IB Envi. Sci	1.38

Note: Both the models and Gender were significant in each model for each question.

It is very clear that girls avoid both Honors Physics and AP/IB Physics 2, even when they have access to those courses, and that girls are far more likely to enroll in AP/IB Biology 2, AP/IB Environmental Science and AP/IB Chemistry 2 than boys. It is critical to note that, save for Honors Physics and AP/IB Physics 2, boys did not participate at the same rate as girls did in all other science classes. This is surprising because of society's push to attract and increase female participation in STEM courses and STEM fields. In this attempt to increase girls' participation, are schools starting to leave boys behind in STEM courses? Similarly, despite participating at higher rates in most science course, why did girls participate at lower rates in Physics courses?

Which science courses race/ethnicity is not a predictor for. The data showed that in general for most upper level science classes, Black and Hispanic students did not enroll at the same rate as their White or Asian peers. However, the data also showed that the enrollment rates of Black or Hispanic students who had taken Algebra 1 by 8th grade enrolled in certain classes at similar rates as their White peers. For example, Black student enrollment did not differ significantly from White students in Honors Physics. While Hispanic student enrollment did not differ significantly from White students in AP/IB Biology 2 if students had taken Algebra 1 by 8th grade. In addition, Black students were 18% more likely than their White peers to be enrolled in AP/IB Biology 2 as shown in Table 10.

Possible Implications for Action

There were significant differences in which groups of students take Algebra 1 by 8th grade, which had a significant impact on which science courses students enrolled in during their high school career. There were significant differences in which science classes girls did or did not take, even when they had participated in Algebra 1 by 8th grade, as well as which science classes Black and Hispanic students did not take at the same rate as their White peers. This data calls for actions that can be taken to close the enrollment gap in Algebra 1 by 8th grade, increase the enrollment of girls in upper level Physics classes, attract boys to all other upper level science classes other than upper level Physics classes and use academic advising to increase participation in upper level science classes by Black and Hispanic students.

Closing the enrollment gap in Algebra 1 by 8th grade. Steps must be taken to increase enrollment in this keystone class of Black and Hispanic students, so those groups of students have a greater chance of graduating from high school, finishing college in four to five years and graduate from high school college ready (Evan, Gray, & Olchefske, 2006, p.2, Adelman, 2006). This is also a critical action step for a specific subgroup: Black males. With each year of increased mathematics, there was a significant impact on their lifetime earnings (Goodman et al., 2009). The literature described subjective factors that prevented students from being able to access this course, and it was argued that an almost wholly objective process is needed to identify students who are ready to take Algebra 1 by 8th grade.

The division studied does have a somewhat objective process (an IOWA test score and a high pass on the state End-of-Course exam while the students are in upper elementary school) but there is a subjective aspect rolled into the process where teachers have input on which students can enroll in Algebra 1 in 8th grade if the student's scores are borderline. The literature clearly noted that when there is teacher input, even for students who are mathematically ready to take the course, Black students are not recommended for Algebra 1 (Faulkner, V., Still, P. Marshall et al., 2014). Another layer of complexity for this issue in this district is that a student must be recommended into the advanced math class in their elementary school in order to have access to the mathematics readiness process. This is an even more significant checkpoint where teacher input could have a greater impact and prevent students from accessing the advanced math class. The advanced math class compresses two years of elementary mathematics into one, which allows those students to progress through the course sequence faster and be able to "get to" Algebra 1 by 8th grade. In this district, students can "skip" a year of mathematics in middle school to get to Algebra 1 during 8th grade, if they did not take the advanced mathematics class in elementary school. There is not school support for this, however, and it is not clear if those students meet with success in the Algebra 1 class in 8th grade or if they make progress in the mathematics sequence in high school.

The literature is filled with studies that show that "putting everyone into Algebra 1 in 8th grade", or districts having a Universal Algebra 1 Policy does not work either (Allensworth, Nomi, Montgomery, & Lee, 2009), based on achievement test scores, course completion and success in further mathematics classes. However, it is possible to use professional development and training to help upper elementary teachers unlink student behavior or student maturity from mathematical readiness. It is also possible to add into the advanced mathematics evaluation process a blind student analysis of student level data to prevent the impact of teacher recommendations on student access to the necessary advanced mathematics in upper elementary school.

Another simple idea is to put a science course ahead of the normal sequence (before 9th grade Biology) which could allow more students to access Honors Chemistry even if they did not take Algebra 1 by 8th grade. It would not necessarily allow those students to access AP/IB Physics 2, but it could allow more students to also access Honors Physics in 12th grade. The state in which this school division is recently allowed an Environmental Science course ahead of Biology in the science course sequence, which might allow more students to "catch up" in their math sequence and could increase enrollment in Honors Chemistry and other higher level science courses.

Increase the enrollment of girls in upper level Physics classes and boys in all other upper level science classes. The data clearly showed that girls are much less likely to enroll in upper level physics classes whether they took Algebra 1 by 8th grade or not. Additionally, the data revealed that boys are enrolled in all upper level science classes, other than Honors or AP/IB Physics, at a lower rate than girls. As a result, actions are required to encourage more girls to enroll in upper level Physics courses and more boys to enroll in any of the other upper level science classes. It is important to note that girls are taking upper level science classes, just not upper level Physics classes. Schools and districts must work to increase enrollment of girls in these classes who are mathematically prepared for the rigors of the science course, and they must attract boys to the other upper level science classes. The literature was clear in the lessons learned when the United States lost the space race and from *A Nation at Risk* (The National Commission on Excellence in Education, 1983), education reform must be viewed through a long term lens, and education reform must include all students.

Academic advising could be a powerful tool to close enrollment gaps. A theme apparent in the literature revolved around who has access to Algebra in 8th grade and the role of academic advising (Rickles, 2013; Schiller & Muller, 2003; Stein, Kaufman, Sherman, & Hillen, 2011). Fewer students of color, fewer lower SES students, and fewer students whose parents have less education are enrolled in Algebra in 8th grade. There is also a selection bias of the students accessing algebra in 8th grade as part of academic advising in course selection (Dorn et al., 2014; Loveless, 2013; Walston & McCarroll, 2010; Rickles, 2013; Schiller & Muller, 2003; Stein, Kaufman, Sherman, & Hillen, 2011). The data from this study clearly mirror the literature, which means there is an opportunity to reflect on the current academic advising practices. What systems can be developed to help close the enrollment gap among all students in Algebra 1, among girls in upper level Physics classes and to among Hispanic and Black student in upper level science courses? There could be a mixture of increased messaging to families about the importance of Algebra 1 through school community events. That same idea of community messaging could include graphics that encourage all students who took Algebra 1 by 8th grade to enroll in the science classes they have access to and to help parents see the value in those courses for their children. School counselors and other trusted adults could make it a priority to encourage girls to participate in upper level physics classes and suggest that boys consider science classes other than Honors or AP/IB Physics. School counselors could also be asked to prioritize conversations with Hispanic and Black students, English Language Learners, students who receive Free and Reduced Meals, Special Education students, and all their families, to enroll in upper level science courses if they took Algebra 1 by 8th grade. This increased messaging can be compared to the idea that if a teacher holds high expectations for all his/her students, the students will rise to the challenge. If schools and divisions were more inclusive and encouraging to the students who have met the prerequisites, more of them would take these courses. This could lead to an overall increased participation by more subgroups of students in AP/IB classes which would be something to celebrate.

Further Research

The surprises that became apparent in this study raise interesting ideas for further research. For example, girls who had access to upper level Physics classes chose not to enroll in them. It could be interesting to investigate why they chose not to enroll in those classes. Also, Asian students are hundreds of times more likely to take Honors Physics, AP/IB Biology 2, AP/IB Chemistry 2 and AP/IB Physics 2 than their peers and it would be very interesting to determine what motivates them to take these classes but not enroll in AP/IB Environmental Science. Additionally, this researcher is now very interested in understanding why other groups of students who took prerequisite mathematics classes and had access to upper level science classes did not take as many upper level science classes. And lastly, this researcher is drawn to understanding more about what occurs in the classrooms of the science classes that students shy away from, to see if it is possible to figure out how to increase enrollment in those classes.

Another area of research could be to replicate this study with other districts to see if the data would be similar. Another idea would be to do this study after the implementation of the state's new class in the science sequence, because higher-level science classes would be more available to more students later in their high school careers. Another area that could be studied that is related to this topic is how elementary and middle schools prepare the students in mathematics.

Conclusions

This quantitative study was conducted on a large school division in the Mid-Atlantic where two cohorts of students (n=19,359) were subject to the same opportunities and policies to determine if there were significant differences between groups of students who took Algebra 1 by 8th grade and the impact that had on their science course enrollment throughout their high school career. The major findings were that there were significant differences between which students were enrolled in Algebra 1 by 8th grade. White and Asian students were enrolled about 80% of the time, but only about 50% of Hispanic and Black students were enrolled in Algebra 1 by 8th grade. Additionally, Special Education students, ELL students and students who received Free or Reduced Meals were enrolled in Algebra 1 by 8th grade at significantly lower rates than their peers who were not among these demographics.

When students were enrolled in Algebra 1 by 8th grade, the data showed that not only do those students enroll in Honors and AP/IB science classes at a much higher rate than students who did not participate in Algebra 1 by 8th grade, but that just taking Algebra 1 by 8th grade is a strong predictor of Honors and AP/IB science course enrollment throughout their high school career. However, there are significant differences in which groups participated in those Honors or AP/IB classes. In almost every question, students enrolled in Special Education, who were English Language Learners and students who received Free or Reduced Meals, even if they were enrolled in Algebra 1 by 8th grade, participated at much lower rates than their peers who were not among these demographics. Race and Gender were significant predictors of enrollment in different courses, and Black and Hispanic students participated at a lower rate than their peers who were White and Asian. Asian students were more likely than their White peers to participate in almost every AP/IB science course except AP/IB Environmental Science. Gender was an interesting predictor, because it was significant for many courses but not others, and it was differently significant than this researcher's experience in schools.

When students did not take Algebra 1 by 8th grade, those same trends were seen: Students enrolled in Special Education, those who were English Language Learners and who received Free or Reduced Meals, participated in Honors Biology and AP/IB Biology 2 and AP/IB Environmental science classes at a much lower rates than their peers. However, Gender was less indicative of those specific course enrollments if a student had not taken Algebra 1 by 8th grade.

There were many surprises in the data from the study, specifically the fact that girls who had met the mathematics prerequisites shied away from Honors and AP/IB Physics 2, the strength of the relationship between Honors Biology and participation in Algebra 1 by 8th grade and the variability of race and ethnicity as predictors for the majority of science classes.

Not surprising but equally as powerful was how strong a predictor participation in Algebra 1 by 8th grade was for all the upper level science classes. The odds ratio for AP/IB Physics 2 was 18.48, more than double the next highest odds ratio that predicted participation in Algebra 1 by 8th grade.

There are specific action steps this division and all large school divisions could take to increase participation in Algebra 1 by Black, Hispanic, students who receive Free or Reduced Meals, students enrolled in Special Education and students who are English Language Learners. These steps include increased messaging to all families earlier in a student's academic career about the importance of Algebra 1 by 8th grade, differentiated academic advising and a more wholly objective process to determine mathematical readiness when students are in upper Elementary school.

Reflection

This dissertation process truly was an amazing learning experience, because it provided me the opportunity to show myself that "I can do it." At the same time, it was a very humbling experience. As our courses proceeded and we started writing our dissertations it became apparent that our whole cohort was becoming experts in the topics we were researching. At the same time, however, with every step we took on our dissertation journeys, we had no idea how to take on the next part. Looking back, I cannot believe I belabored some of the issues I obsessed over and am shocked when I think how undaunted I was by some of the stages that should have been overwhelming. Ultimately, when I stepped into this unknown, I was reminded of all the other times in my life when I took a leap of faith. This time, I was supported by Doctor Glenn and my cohort, but I took a leap of faith in myself—and, I did it! Some people challenge themselves to run marathons or climb Mount Everest. I challenged myself to get a doctorate. I could not have spent the time writing or doing course work or editing or meeting with Doctor Glenn without the support of my husband. So as much as I did meet this lifelong challenge for myself to be a Doctor, I am fully aware I had his help, love and unwavering support, which is so humbling it takes my breath away. Lastly, on the other side of this epic experience this study will arm me to inspire others so they can help the next generation change the world.

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