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Evaluating the Relationships Between Science Class Success and Math Placement in High School

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Abstract

In order for students to perform well in science, they need opportunities to develop formal reasoning. Teachers in a private school in Latin America noted that students who had not yet completed Algebra I were struggling in a 9th-grade chemistry course more than their classmates who had completed Algebra I. The purpose of this causal, comparative action research was to determine if math placement was key to supporting student success in science. Data on achievement, as indicated by final exam scores in math, science, and English, were used from the cohort of students enrolled in 9th grade in 2015 and in 10th grade in 2016. A repeated measures ANOVA was used to determine if there was a difference in science achievement between students on an accelerated pathway and students on a nonaccelerated pathway. Spearman's rho was used to determine if science achievement was correlated with math and English. It was found that there was a significant difference in science achievement for students on different pathways, as well as significant differences in achievement between the 2015 and 2016 school years. Additionally, it was found that both math and science and English and math had similar correlations. It was concluded that math provides significant opportunities to practice formal reasoning that is important for success in science.

Keywords: cognitive development, algebraic reasoning, self-efficacy, concrete operational reasoning, formal reasoning, logio-mathmatical/scientific reasoning

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Chapter 1: Introduction

Science and math are subjects that challenge many students, but successful completion of science and math correlates positively with future participation in science, technology, engineering, and math (STEM) courses in undergraduate work and beyond (Hansen, 2014). Success as a ninth grader is indicative of future academic success, and early success in science leads to future interest and self-efficacy in science (McDowell, 2013; Palmer, 2004). Given the significance of achievement in math and science, and in particular during the ninth grade, it is important that school leaders provide courses enabling students to achieve accomplishments upon which they can build future success (McCallumore & Sarapani, 2010). Math may be the key to cognitive development for student success in high-level sciences such as chemistry, biology, and physics (Joyce, Hine, & Anderson, 2017).

Students who struggle in Algebra I are required to apply algebraic thinking to their science class, which may compound frustrations and feelings of failure (Larkin, 2016). Success in ninth grade is foundational to future academic success and experiencing competence in math and science also increases a student's interest in STEM fields (Demirci, 2013; McDowell, 2013). When students in science take courses beyond their cognitive ability, they internalize the failure and identify as someone who is bad at science (Demirci, 2013). It is imperative that school leaders create a pathway the gives students every chance to succeed while challenging them appropriately to grow. To create these opportunities, school leaders must understand the factors that influence student success.

The leadership team at a nonprofit college preparatory school in Latin America gathered feedback from teachers, students, and parents and identified that the current science pathway did not provide opportunities for all students to be successful. This school enrolls about 400 students in the high school division. The teaching, counseling, and administrative staff observed that a significant number of students struggle in science and do not participate in science electives in substantial numbers. The graduation requirements for science are chemistry, biology, and physics. The chemistry course is taken by students in ninth grade, with about two-thirds of the students taking it concurrently with Algebra I. Math and science are the two classes in ninth grade with the highest failure rates, which this school defines as a year-long average below 60%. This failure rate raised concern among the stakeholders in the community, and further investigation is needed.

The leadership in the school approached the science department where the teaching staff indicated that students in all three science courses displayed a reverse bell curve, meaning that there was a group of students who did very well, students who struggled to maintain a passing score of 60%, and very few students in between these two groups. Teachers at the school indicated that this phenomenon seemed to correlate with students' math placement. Students who concurrently enrolled in Algebra I and chemistry struggled in chemistry, whereas those who completed Algebra I in eighth grade tended to be more successful in chemistry. Science teachers also reported this phenomenon did not resolve as students moved into biology and then onto physics. While there was no apparent explicit need for Algebra I or geometry to be successful in biology, these students continued to struggle. A lack of participation in advanced placement sciences and science electives also existed. Despite an abundance of science elective courses offered and sufficient flexibility in the schedule for electives, there was not enough student interest in these courses. Participation in these advanced classes would provide a path that leads students to enroll in and complete an undergraduate degree in a STEM-related area. Greater and more successful participation in science courses benefits both the students, who have the potential to enter a rewarding and lucrative career, as well as universities who are looking to add underrepresented groups to their programs (Redmond-Sanogo, Angle, & Davis, 2016). Given that most of the student body at this school in Latin America is Hispanic, improving how the school organizes science instruction and the course sequence could increase the diversity of students entering STEM fields professionally (Redmond-Sanogo et al., 2016). Successfully preparing students to enter STEM disciplines would also enhance the reputation of the school.

Statement of the Problem

Researchers suggested that college-level mathematical thinking allows for cognitive development, enabling student success in the biological sciences (Joyce et al., 2017). Terry, Kontur, and de La Harpe (2016) demonstrated that college-level prerequisite skills developed in math courses correlate with the successful completion of physics courses. Further research exploring the relationships between cognitive development in math and success in science at the high school level is needed.

Given that ninth grade is an indicator of future academic success, it is imperative that school leaders make informed decisions regarding science course placement as soon as students start their high school career (Labby, West, & Voloch, 2015). Placing students in developmentally appropriate coursework will provide students the opportunity to experience success. This can only occur when they take courses according to their cognitive readiness. Analyzing the relationship between students' math placement and success in science is a significant research need so educational leaders can support appropriate pathways for each student, ensuring that all students have opportunities to experience success in science.

Purpose of the Study

The purpose of this action research study was to compare science achievement scores for all students in chemistry, biology, and physics to math placement and math achievement at a private international school in Latin America. This analysis will provide the necessary information for school leaders to organize the science and math curriculum.

Research Questions

Q1. Do students placed on an accelerated math pathway perform better in science classes, biology, and chemistry than students on a nonaccelerated math pathway?

Q2. Does students' science achievement correlate with English and math achievement?

Definition of Key Terms

Algebraic reasoning. Algebraic reasoning is abstract reasoning needed to perform algebraic functions such as solving equations for unknown variables (Susac, Bubic, Vrbanc, & Planinic, 2014).

Cognitive development. Cognitive development is brain development that makes it possible to understand complex processes (Susac et al., 2014).

Concrete operational reasoning. Children in the concrete operational stage observe simple relationships and phenomena directly and repeatedly and predict outcomes for similar phenomena, such as predicting what will happen when a ball is dropped (Fabby & Koening, 2015).

Formal reasoning. Formal reasoning is used when the individual can reason without referring to concrete objects and apply mathematical and logical reasoning to solve a problem (Fabby & Koening, 2015).

Logio-mathematical/scientific reasoning. Reasoning is based in formal reasoning and is necessary for solving complex problems successfully (Fabby & Koenig, 2015).

Self-efficacy. Self-efficacy is the belief that individuals have power over the events of their life and have the ability to control how those events are experienced (Bandura, 2010).

Chapter 2: Literature Review

The aim of this study was to determine if students enrolled in a private school in Latin America demonstrated different levels of achievement in science when compared to their math placement. The purpose of this chapter is to review the history of science in high schools, the reasoning required to do well in science and how that reasoning develops, and the importance of creating a sequence of science courses that support a student's self-efficacy beginning in ninth grade.

In the 1500s, leaders of curriculum and experts in science added science to education requirements in the West, and since then educational leaders have debated what they should include in mandatory science education (Hurd, 1991). To achieve in science, students must be able to apply scientific reasoning. Scientific reasoning is a cognitive ability that develops in students at different ages (Shrager & Siegler, 1998). Students may develop the reasoning ability to understand science in math by eighth or ninth grade, whereas others may develop the ability to reason at that level later (Shrager & Siegler, 1998). While there may be contributing factors to students' achievement in science other than their math placement, based on studies conducted in universities, math may be critical to understanding why students struggle in the sciences required for graduation (Joyce et al., 2017). It is critical for leaders of high schools to understand the key components so that they can make decisions that will allow students to experience success in science, which in turn can support interest, self-efficacy, and meaningful learning in science (Palmer, 2004).

To conduct this literature review, I used the Brown Library at Abilene Christian University (ACU). The OneSearch search engine and the EBSCO database were utilized to find scholarly, peer-reviewed articles. Keyword searches were conducted using key phrases such as formal reasoning in science, cognitive development and science, the correlation between success in science and math, the history of science education, the importance of success in science in ninth grade, and fostering success in STEM education.

History of Required Science Courses in High School

Hurd (1991), an authority on the history of science education, wrote that the idea of including science in Western education started in the 1500s. Science was introduced to Western civilization at this time, and therefore into education. The purpose of learning and practicing science was to improve society; prior to this, science as it is known today did not exist (Hurd, 1991). DeBoer (2000), another renowned scholar in the history of science, reported that in the early 19th century, science became part of school curricula at the urging of scientists. These scientists indicated that there was a need to understand deductive reasoning, which is critical to the scientific method and independent thought. These scientists thought that citizens who were scientifically literate would improve democratic society (DeBoer, 2000). Leaders such as Benjamin Franklin and, later, Thomas Jefferson encouraged science education for improving agriculture and society in general. Jefferson even advocated for writing science textbooks for students starting in the first grade, but his efforts failed (Hurd, 1991).

In the mid- to late 19th century, the leaders of universities such as Harvard and MIT understood that it was necessary to emphasize students taking coursework in science to benefit agricultural and mechanical needs. The courses that were required to enter science tracks at these universities included biology, chemistry, and physics (Hurd, 1991). The aim of these programs was to prepare students to enter agricultural programs in universities (Hurd, 1991).

At the same time, the educational philosopher Spencer (1859) criticized science education as a collection of disparate facts that could not improve society and claimed students would lose the information as soon as they left the classroom. He advocated for an approach that involved more exploration and critical thought about how learning fits into society. His suggestions led to the inclusion of laboratory work into the curriculum, but his ideas of exploration were left behind as the demands for memorization were seen as too rigorous (Hurd, 1991).

By the 1890s, the country was shifting from an agricultural to industrial economy, which led to a reevaluation of school curriculum (Hurd, 1991). In 1893, the Committee of Ten proposed sweeping changes to schools. Their recommendations included a minimum of one physical and one biological science course in high school curricula; it was suggested that biology be taken before physics (Vázquez, 2006). The Industrial Revolution introduced electricity, mechanization, and urbanization, which resulted in a pace of life and invention that were far more rapid than ever before (Stephens & Roderick, 1983). The result of this increased pace was a need for a workforce that had technical skills and the ability to observe problems and recommend solutions (Stephens & Roderick, 1983). The requirements recommended by the Committee of Ten were intended to prepare students for the shift that was occurring as part of the industrial revolution (Hurd, 1991).

The advent of World War II brought about the need for increased scientific and technical knowledge shifting the focus in science education so that engineers and scientists would be available to meet the needs of war (Hurd, 1991). The demands of the war prompted scientific innovation unlike any other war before (Mindell, 2012). These included things like rocketry and early computer technologies that guided ballistic missiles, radar technology that allowed pilots and antiaircraft stations to detect objects that were unseen, and nuclear technology that was developed to create the atomic bomb that ended the war (Mindell, 2012). In addition to technologies created for weapons and defense, technologies were created for mass production that supported the deployed troops. Penicillin was mass-produced to manage the demands of venereal diseases, nutritional science advanced to create high-calorie, nutrient-dense preserved foods, and plastics were created to replace goods that had been diverted to the battlefield (Mindell, 2012).

In the 1950s, Congress established the National Science Foundation (NSF), which was created to promote high-quality science education through an infusion of funds dedicated to the development of new science curricula (Hurd, 1991). The statutory mission of the NSF was "to promote the progress of science; to advance the national health, prosperity and welfare; and to secure the national defense; and for other purposes" (National Science Foundation Act of 1950, 2012, p. 1). During this era, the focus of science education was on understanding scientific thought, inspiring the brightest to enter science and inspiring sympathy and support for science from those who did not typically enter scientific fields (DeBoer, 2000). In the 1960s, the scientific community encouraged greater rigor in high school science classes to prepare a workforce that was technological and a military that was advanced to respond to needs that were perceived in the public due to the Cold War (DeBoer, 2000).

The 1980s through early 2000s brought rapidly advancing technologies as well as fears that American students were falling behind those of other nations as measured on international science achievement assessments (Heckhausen & Krappmann, 1998). As a result of these fears, the leaders at the American Association for the Advancement of Science (AAAS) began Project 2061 (Rutherford, 1990). The book *Science for All Americans* was also written, which called for reform in science education that was standards-based and would ensure that students would be scientifically literate so they would be equipped to make decisions in an increasingly technological world (Rutherford & Ahlgren, 1994).

In 1993, members of the National Research Council added to this call for scientific literacy by publishing the *National Science Education Standards*. These standards laid out specific learning objectives for each grade level that were increasingly complex and aligned from elementary school through high school. The purpose of these national standards was to ensure that all students met the same standards and that mastery would be an indication of scientific literacy (DeBoer, 2000).

Beginning in 2010, the Carnegie Corporation funded the development of new science standards that were intended to better prepare students for success in science in college, making them more competitive on the world's stage (Pruitt, 2014). The result of this was the development of the Next Generation Science Standards (NGSS) completed in 2013 (Bybee, 2013). The NGSS standards include inquiry and engineering design standards in addition to standards related to factual content that all students are expected to know (Pruitt, 2014). Like the *National Science Education Science Standards*, they are aligned from kindergarten through high school by category of content. Those themes are science and engineering practices, disciplinary core ideas, and crosscutting concepts. In kindergarten through eighth grade, physical and life science core ideas are spiraled through each grade, and in high school there are standards for Earth and space science, life science, chemistry, and physics courses (Bybee, 2013). Students are expected to master requirements that emphasize the production of informed citizens and, for some, to provide the necessary preparation to pursue STEM careers (Redmond-Sanogo et al., 2016).

Since the beginning of the inclusion of science in formal educational settings, its purpose was to give students opportunities to become informed citizens and provide a path for students to prepare for current technologies (Hurd, 1991). Given the importance of science education in modern society, it is critical that students have opportunities to experience success to develop an interest in the subject. However, high school and college leaders still identify science as an area with which students often struggle and universities have difficulty retaining students in their STEM programs (Larkin, 2016; Thompson & Bolin, 2011). From the 1500s until today, there has been a growing focus on science education, and due to technological advancements, the demands in the courses have become increasingly more complex. To understand how to teach today's science, it is important to understand how researchers have investigated how cognitive development plays a role in students' achievement in science.

Cognitive Development and Scientific Reasoning

Children develop cognitively by progressing through stages. Jean Piaget (1970) developed the theory of cognitive development. This theory represented a revolutionary way to describe how people learn from infancy to adulthood, and his work continues to influence how educators understand learning (Herman, 2012). Piaget described learning as the creation of personal meaning and that meaning takes on different levels of complexity as individuals grow and add information and understanding about the world in which they exist (Herman, 2012). Researchers find Piaget's ideas have stood the test of time but have been modified as new information has added to researchers' understanding of learning (Herman, 2012).

Piaget (1970) examined an individual's ability to problem-solve and proposed stages of cognitive development corresponding to physical maturation. High school students are adolescents ranging in age from 14 to 18 years old. Adolescence typically corresponds to two of

Piaget's stages: concrete operational (typically 7–10 years old but can extend until 15 years old) and formal operational (typically 11–15 years old but can be as late as 18 years old). Children in the concrete operational stage observe simple relationships and phenomena directly and repeatedly and predict outcomes for similar phenomena, such as predicting what will happen when a ball is dropped (Herman, 2012). Formal reasoning is used when individuals can reason without referring to concrete objects and when they can apply mathematical and logical reasoning to solve a problem. For example, formal reasoning is used when a student solves a problem by using a formula in physics to determine what speed a ball is traveling right before it hits the ground after it is dropped (Herman, 2012). Scientific reasoning is a form of formal reasoning and is necessary for solving complex problems successfully (Fabby & Koenig, 2015).

Fabby and Koening (2015) measured students' scientific reasoning by administering the Lawson Classroom Test of Scientific Reasoning (LCTSR) developed by Lawson (1995). They also measured students' ability to solve physics problems from an introductory physics class for health science majors in college. Based on their performance on the LCTSR, students were divided into high, average, and low groups. Their answers to physics problems were then evaluated and compared (Fabby & Koening, 2015). They found that there was a significant difference in the groups, with the high reasoning group performing the best, indicating that formal reasoning is needed to answer physics problems successfully. Based on the results of this study, the authors concluded that students might struggle in science because they are asked to use scientific reasoning beyond their cognitive development.

While Piaget indicated that high school students should be able to function using formal reasoning, the age at which they can achieve that stage of development is variable (Shrager & Siegler, 1998). Development of formal reasoning, sometimes referred to as scientific reasoning, can continue to develop until adulthood and improves with practice (Shrager & Siegler, 1998). Intentional practice and instruction in schools can improve students' formal reasoning (Bello, 2014).

Bello (2014) randomly selected two schools in Kaduna State, Nigeria, and randomly assigned one to be a control school and one an experimental school. All schools in Kaduna State, both private and public, taught the same standards for biology. He evaluated the biology curriculum and determined that a significant portion of the curriculum required formal reasoning. Both school groups were given the Group Assessment of Logical Thinking (GALT) test prior to this quasi-experimental study. Bello found that 85% of the students were functioning at the concrete level of reasoning. He created two groups for his study: the experimental group, which was taught genetics using the learning cycle, and the control group, which was taught genetics using traditional lectures. The learning cycle is an inquiry-based teaching method developed by Karplus in 1979. This method was created in to build opportunities for students to practice and develop formal reasoning abilities. The other group was taught the same content for 13 weeks using lecture. After the 13 weeks, both groups were given the GALT again. After the treatment, 49% of the experimental group acquired formal reasoning, whereas only 6% did so in the control group (Bello, 2014).

Bello's (2014) results echoed those reported by Fabby and Koenig (2015) when studying college physics students, implying that formal reasoning is needed to perform well in all sciences. To think scientifically in biology, chemistry, or physics, students must be able to use data to support conclusions, identify trends, and make predictions (Herreid, Herreid, & Schiller, 2014). Considering that students arrive at formal reasoning and therefore scientific reasoning at different times and acquire formal reasoning through practice, it is not reasonable to expect that all students will succeed in mastering the core sciences required for graduation on the same path and time (Shrager & Siegler, 1998).

In 1893, the Committee of Ten recommended that students take biology in ninth grade followed by chemistry or physics in later grades, and most schools continue using that sequence to this day (Vázquez, 2006). However, biology courses have changed significantly since 1893 to include many more complex, abstract concepts such as genetics, evolution, and the mechanisms that cause evolution, all of which require complex reasoning to understand (To, Tenenbaum, & Hogh, 2017).

Most schools throughout the United States and worldwide contain large numbers of students who struggle to succeed in biology in ninth grade as well as in alternative courses such as physics (Popkin, 2009). To et al. (2017) conducted a study of high school biology students in England who were learning evolution. A total of 106 students from randomly selected schools aged 12 to 16 were chosen for this study and came from a variety of socioeconomic backgrounds. All schools used the same curriculum mandated by the British government, which held that concepts of evolution were introduced to students in middle school. These students were interviewed and given different scenarios to analyze evolutionary concepts. The researchers found that younger students could learn to apply vocabulary but did so in a colloquial manner. Younger students could not integrate the factors that describe the mechanisms of evolution in a well-reasoned manner that gave evidence of deep understanding and analysis, but the older students were able to do so much more effectively (To et al., 2017).

Students struggle to achieve in the core sciences, biology, chemistry, and physics when the sequence starts in the ninth grade for all students (Popkin, 2017). One solution to this problem included changing the order of the courses, but these attempts did not have satisfactory results (Popkin, 2017). Leaders need to consider other factors such as a student's cognitive readiness before choosing an appropriate science class for ninth grade.

Math as Key to Developing Scientific Reasoning

Math learning may be foundational to success in core sciences including biology, chemistry, and physics because it affords students the opportunity to develop and practice formal reasoning (Joyce et al., 2017). The cognitive development that occurs by developing formal reasoning from practicing math can be transferred to science (Shrager & Siegler, 1998). Logico-mathematical reasoning, which is sometimes also called scientific reasoning, is a form of formal reasoning that applies to math and science (Fabby & Koenig, 2015).

Korkmaz (2012) conducted a study of 45 students in their first year of a computer and instruction technology undergraduate degree in a college of education. These 45 students were taught 5 hours a week for 4 weeks concepts such as conditions, algorithms, constraints, and conditions. Additionally, they were provided models for problem-solving, given problems to solve, and given feedback on those problems. After the course these 45 students were given the California Critical Thinking Disposition Inventory (CCTDI) to measure critical thinking, the Logico-Mathematical Intelligence Self-Perception Sub-Scale to measure logico-mathematical thinking, and a test with four open-ended algorithm questions to test their algorithm design skill.

Then Korkmaz (2012) did a Pearson's correlation analysis on the standardized results of these assessments. He found a positive correlation ($r = 0.48$) between logico-mathematical intelligence, or processing information through logic, and critical thinking. The correlation between logico-mathematical intelligence and algorithm design skill was 0.74. Korkmaz concluded that logico-mathematical reasoning is needed to process information logically. This includes the critical thinking needed to develop algorithms, including pattern recognition, persistence, convergent thinking, and problem-solving, which are all skills necessary to succeed in biology. Students should have opportunities to build both logico-mathematical intelligence and critical thinking skills before applying those skills in other domains.

Al-Balushi and Al-Battashi (2013) randomly selected 102 ninth-grade students in Oman to test spatial ability, working memory capacity, and their relationship to science and mathematics achievement. To measure spatial ability, they gave the students the Water Level Task. To measure working memory, they used the Digit Span Backwards Test, and science and math achievement was measured by the students' end-of-year score. To compare high and low achievers in math and science, *t* tests were used on the results of the special ability and working memory tests. Al-Balushi and Al-Battashi concluded that students who had better spatial ability and working memory capacity performed better in math as well as science.

When students have the opportunity to practice the skills that all fall under the idea of formal reasoning, they improve in science (Shrager & Siegler, 1998). Learning the mathematical concepts included in Algebra I produces a foundation to understand and practice this abstract and symbolic thinking (Hong, 2013). Joyce et al. (2017) demonstrated that undergraduate health science students in Australia who completed high-level math courses such as math 3C3D, which is equivalent to Advanced Placement Calculus AB and BC, performed better in demanding science courses such as biochemistry and anatomy. A total of 218 first-year university students who were studying health sciences were included in the study. At the end of their first year, the grade point averages of students who took high-level math classes in high school were compared to those who did not. They concluded that mathematical thinking allows for cognitive development, enabling student success in the biological sciences.

School leaders in Georgia evaluated the state biology end-of-course exam in ninth grade and became concerned with the low pass rate. McDowell (2013) sampled 200 ninth-grade students in Georgia in 2012. These students took the Georgia Biology End-of-Course Test (EOCT) in 2012 as well the Criterion-Referenced Competency Test (CRCT) in seventh grade. All of the students who took biology were learning the same curriculum throughout the year and took common formative and summative assessments. McDowell then did a bivariate linear regression analysis comparing the two test scores. She found a strong correlation ($r = 0.72$) between the scores on the CRCT and Biology EOCT in ninth grade.

McDowell (2013) also identified a correlation between age or math placement and success in science. She did not establish the cause of the correlation but proposed that the cause could be the cognitive development of the student. The recommendation from this study was made to add flexibility to science pathways, allowing students to take high-level sciences, including biology, when they were cognitively ready. For many students, this readiness occurs after they complete Algebra I (McDowell, 2013).

No causal study could be found that documented the influence of Algebra I on achievement in science in high school. Some high schools in the United States have switched to a physics-first model as an attempt to address failures in biology (Popkin, 2009). However, most schools have reversed this course sequence because of the direct need for algebra skills in physics to solve problems (Popkin, 2009). Taking physics first caused students enrolled in Algebra I concurrently to struggle in physics, and the initiative had a difficult time gaining traction (Popkin, 2009).

Terry et al. (2016) studied students in a general Physics II course at the United States Airforce Academy. These students were taught the same content with the same instructional strategies and given common assessments. The researchers averaged all the exam scores in Physics II as well as scores in their prerequisite math, social studies, and English classes. They determined that prerequisite skills developed in math courses explained 48% of the variance of successful completion of physics. The correlation between math and physics scores was stronger than between physics and English or social studies scores. The researchers concluded that mathematical thinking, rather than general academic skills, are required for success in science courses. This math prerequisite was particularly important for courses such as physics, which rely on algebraic skills.

Korpershoek, Kuyper, van der Werf, and Bosker (2011) analyzed 6,033 Dutch students, 720 of whom focused their final school examination (FSE) on math, chemistry, and physics in their ninth-grade year in high school. This kind of exam is taken by students who want to prepare for a science degree when they attend university. These researchers conducted a regression analysis comparing students' math ability, as measured by an average of seventh-, eighth-, and ninth-grade arithmetic tests, and their performance on the FSE. They reported that students who scored higher on a math ability assessment also scored higher in high-level chemistry and physics classes.

Importance of Success in Ninth Grade

Students' success in ninth grade is predictive of their overall future academic success (McCallumore & Sparapani, 2010). Ninth grade not only is indicative of future academic success but also is a year that is marked by high rates of absenteeism, academic decline, and isolation. In the face of these issues, it is essential that schools offer pathways that support student success (McCallumore & Sparapani, 2010). Given that ninth grade represents such an important academic milestone, it is imperative that school leaders make informed decisions regarding course placement for ninth-grade students.

Many ninth-grade students take Algebra I, and mastering algebraic thinking opens doors to higher math courses, which are predictive of future postsecondary success (Labby et al., 2015). Teacher-researchers in New York examined over 13,000 students and found that Algebra I had the lowest passing rate of all core content. They set out to review the research literature to identify the importance of success in Algebra I as well as best practices for teaching it to a diverse student population. They found that dropping out of college is, at least in part, due to being required to take remedial math courses due to lack of skills that they should have acquired in high school, and traditional methods of remediation were not successful. Additionally, they found that for struggling high school students, extra time spent in high school math courses increased overall academic success rates in college due to opportunities to effectively acquire and apply algebraic concepts that are sequenced with developmental supports. If Algebra I is also key to developing the formal reasoning needed to successfully complete core science courses, requiring ninth graders who struggle in math to apply complex algebraic concepts to science before mastering them in math creates a system that sets many students up for failure (Popkin, 2009).

Opportunities to Develop Self-Efficacy and Interest

Placing students in courses before appropriate cognitive development may induce long-lasting psychological and emotional consequences (Howard, Scott, Romero, & Saddler, 2015). Howard et al. (2015) utilized data from the High School Longitudinal Study of 2009 (HSLS09), which the U.S. Department of Education National Center for Educational Statistics collected from more than 21,000 students enrolled in public schools. This study included questions on algebraic reasoning as well as psychological and motivational constructs. The researchers isolated data on a program that enrolled all students in Algebra I in eighth grade and concluded that doing so was damaging to those students who were not ready. They identified and evaluated a cohort of failing students for Algebra I skills as well as the psychological impacts of being in Algebra I as an eighth grader. The failure resulted from a lack of cognitive readiness for the content in Algebra I. Howard et al. (2015) found that these students gained no algebraic skills from exposure to Algebra I when compared to students who passed eighth-grade math.

Additionally, these researchers found that these students had significantly lower perceptions of self-efficacy in math that did not begin to resolve until their junior year of high school (Howard et al., 2015). Given the established need for formal reasoning to understand and perform complex tasks asked of students in biology and chemistry, it is important that students operate in that stage of development before being enrolled in those courses (Fabby & Koenig, 2015). Enrolling students in science before they are cognitively prepared to learn it may result in similar negative outcomes for developing student self-efficacy to the students enrolled in Algebra I before they were cognitively ready (Howard et al., 2015).

Students who are successful in science have an interest in the subject and report high self-efficacy (Palmer, 2004). Academic self-efficacy leads to positive learning-related emotions (Putwain, Sander, & Larkin, 2013). Putwain et al. (2013) measured learning-related emotions (LREs) and academic self-efficacy in 206 undergraduate students at the end of their second semester. They quantified LREs with scores from the Achievement Emotions Questionnaire and academic self-efficacy with the Academic Behavioral Confidence scale (Putwain et al., 2013). The researchers conducted a correlational analysis of the measures of LREs, self-efficacy, and achievement and found they were correlated. They found that LREs are emotions that promote feelings of achievement and competence, providing psychological characteristics that promote academic achievement even as a course becomes more challenging. Students who experience success are also more likely to perform better academically in the future (Joshua, 2014). For example, students who achieved past academic success performed better on exams that included convergent thinking and problem-solving, such as college entrance exams (Joshua, 2014). Students experience success when they participate in courses that align with their cognitive readiness.

Students who perform better academically, as measured by grade point average (GPA), also possess a greater interest in science and math and perceive science as important for their lives (Demirci, 2013). Interest and success in math and science courses lead students to choose those disciplines as a college major, which can lead to successful and lucrative careers (Demirci, 2013). In a cohort study at a large Texas public university, 3,618 students were followed through their college career, and data such as gender, high school GPA, home town, and ethnicity were collected to determine what, if any, factors contributed to a student's decision to change majors (Thompson & Bolin, 2011). Thompson and Bolin (2011) demonstrated that having a high GPA in high school was correlated with retention in STEM majors in college.

Hansen (2014) used data collected from a longitudinal database in Florida and North Carolina from 2006 to 2009. From the analysis of test scores, he concluded that successful STEM participation in undergraduate majors and beyond is dependent on a student's possession of a strong foundation in advanced math and science in high school. There was a positive association between access to these advanced math and science classes and achievement in STEM fields (Hansen, 2014). Feeling successful in these math and science classes in high school increases feelings of belonging, which in turn increases interest and resilience as challenges become more complex (Gottfried, Estrada, & Sublett, 2015).

Fredricks et al. (2016) sampled 140 black male undergraduate students who were attending historically black colleges and universities. Their purpose was to empirically determine factors that lead to student success in STEM fields. The researchers collected data such as age, family background, and socioeconomic status. They also interviewed and gave the participants the Student Success Questionnaire, a survey that was developed and standardized for this study. They concluded that feeling engaged was also positively correlated with success in STEM fields. Students defined engagement as being emotionally and socially engaged, which grows out of a sense of belonging. Fostering this kind of positive learning environment in high-level math and science classes is dependent on feelings of self-efficacy and interest (Strayhorn, 2015). Analyzing the relationship between math placement and science achievement would provide school leaders with information that will allow them to support appropriate pathways for each student to ensure that they have opportunities to experience self-efficacy in science.

Other Factors That Impact Science Achievement

Science achievement can be impacted by other factors such as poorly written curriculum or course sequences (Larkin, 2016). School leaders are responsible for providing developmentally appropriate pathways and curriculum. For example, some school leaders throughout the United States recognized that large portions of students failed to succeed in core science pathways that start with biology, so they changed the course sequence to physics first (Larkin, 2016). Larkin (2016) conducted a case study on three schools whose leaders chose to put physics first. He found that most schools changed back to requiring biology first due to the need for Algebra I to solve physics problems. Some curriculum leaders supported the idea that a solution to the math readiness problem is teaching science courses at a more conceptual level. The use of conceptual science courses would eliminate the issue of students not being Algebra I ready. This proposed solution also required training for teachers in the new conceptual curriculum, which would ensure that students who are lower in math skills would have access to physics regardless of their lacking skills.

This solution of conceptual physics solves the need for logico-mathematical reasoning, but it raises other issues. For example, one significant problem is that teaching these courses on a conceptual level limits a student's ability to prepare for the corresponding class at the Advanced Placement (AP) or college level (Redmond-Sango et al., 2016). The researchers conducted a research study to identify high school courses that could predict success in college classes critical to the successful completion of a STEM degree. They sampled 893 students over 2 years and collected demographic data, high school grades, college grades, and admission exam scores. After employing a variety of statistical tests, they found that successful completion of high school physics, calculus, and chemistry was the most predictive of the corresponding courses in college, which serve as gatekeeper courses in undergraduate STEM degrees.

Combining Algebra I with physics in one block was a second proposed solution in the physics first pathway to meet the math demands of physics. This approach could potentially be applied to teaching Algebra I simultaneously with chemistry to maintain the current science sequence. This solution requires that math and science be blocked together and team-taught by a math teacher and a science teacher (Larkin, 2016). This is also a problematic solution for logistical reasons such as scheduling and staffing. Additionally, this solution does not acknowledge that flexible math pathways currently exist, and a significant number of students already take Algebra I in eighth grade (Larkin, 2016).

Another possible explanation for failure in science courses is a lack of consistent teaching strategies that effectively engage students. Walker and Warfa (2017) conducted a meta-analysis of 21 primary studies on teaching strategies in chemistry classes. They focused on data demonstrating that effective teaching strategies increase engagement and therefore achievement. Utilizing a protocol such as the Process Oriented Guided Inquiry Learning (POGIL), which was developed for chemistry and expanded to other science disciplines, positively affected achievement. Similarly, Hutto, Kirchoff, and Abrahamson (2015) used a radical enactive embodied view of cognition strategies with computer simulations in math classes, which requires learning to happen. Radical enactive embodied cognition strategies require that the learners interact with their learning physically; in this study the researchers accomplish this through the computer games that require physical interaction. They found that abstract math concepts were more easily understood when students had opportunities to interact in their environment to deduce, rather than memorize, meaning.

Metacognitive awareness has been shown to be correlated to achievement in chemistry (Rahman, Jumani, Chaudry, Chisti, & Abbasi, 2010). The researchers collected data on 900 tenth-grade students in chemistry. They measured metacognitive awareness and correlated it to students' achievement in chemistry as measured by an achievement test developed by the researchers. Metacognition and content were shown to be positively correlated ($r = 0.45$). It was noted that teaching metacognition strategies along with content could improve achievement.

When teachers are intentional about teaching self-regulating learning strategies, such as setting goals, setting up strategies to reach those goals, and reflecting and refining those goals and strategies, student achievement improves (Nagle, Sheckley, & Allen, 2016; Nwafor, Obodo, & Okafor, 2015). The researchers randomly assigned two urban eighth-grade science classes a curriculum that included self-regulated learning (SLR) strategies, and two other classes were assigned conventional teaching strategies. All of the classes covered the same curriculum standards. They then gave each class a common unit test and collected data about on-time homework completion. They found that the groups taught the SLR strategies performed better on the content tests. Traits such as the ability to self-regulate, which is to some degree a personality trait, was correlated with academic success (Eilam, Zeidner, & Aharon, 2009). Improving self-regulation occurred when students had opportunities to practice related skills (Eilam et al., 2009).

Reading comprehension and general language mastery could also be correlated to science achievement (Bayat, Şekercioğlu, & Bakır, 2014). The researchers collected data on 132 eighth-grade students in Turkey. These students were given the Science Items Comprehension Test and the Turkish Reading Comprehension Test. They found that students who performed better on reading comprehension tests also performed better on comprehensive science tests, demonstrating that there are a variety of academic skills that help students achieve in science. Adding teaching strategies designed to increase engagement, understanding, and reading comprehension could increase achievement, but these strategies do not address cognitive readiness. Therefore, determining if math placement is correlated to success in science is a necessary area of research.

Summary

Science education and literacy is a requirement for all students graduating from high school (National Research Council, 2015). However, many students indicate that they struggle in the required sciences in high school (Larkin, 2016). This struggle may be based in part on placing students in courses that require levels of cognitive reasoning that students have not yet developed (Fabby & Koenig, 2015). Successful completion of certain math courses might be key to supporting cognitive development helping students understand and perform in science (Korkmaz, 2012). Analyzing math placement and science achievement data is imperative to determine if these kinds of relationships hold for all sciences when comparing them to math placement.

If Algebra I is a gatekeeper for students to transition from concrete to formal reasoning, then it should be completed before core sciences. If students have opportunities to perform well in science, they will have more opportunities to develop self-efficacy and interest in science which, in turn, leads to even greater achievement (Putwain et al., 2013). It is important for school leaders to understand what would best support science achievement and create pathways for success that begin in ninth grade (McCallumore & Sparapani, 2010). While other factors might impact science achievement, a comparison between students' science achievement on accelerated and nonaccelerated pathways, as well as a correlation between math and science achievement, will give school leaders critical information they need to make decisions on course sequencing and pathways so that students have every reasonable opportunity to achieve in science.

Chapter 3: Research Method

The purpose of this action research study was to compare science achievement scores for all students in chemistry, biology, and physics to math placement and math achievement at a private international school in Latin America. This analysis provides the necessary information for school leaders to organize the science and math curriculum. I intended to answer two questions: (a) Do students placed on an accelerated math pathway perform better in science classes, biology, and chemistry than students on a nonaccelerated math pathway? and (b) does students' science achievement correlate with English and math achievement? This chapter includes the research and design methods, population and samples, instruments, data collection and analyses, assumptions, limitations, and delimitations.

Research Design and Method

Ex post facto, causal-comparative, and correlation designs were used within an action research approach to answer the research questions. Action research was an appropriate choice as I was on the faculty at the school in the science department at a private international school in Latin America with interest in supporting school leaders in decision-making processes regarding the science pathways at the school. Action research is pursued by members of an organization for the purpose of improving the organization (Sagor, 2000). Action research typically involves collaboration, and that was a challenge for me because I am a staff member in an international school (Sagor, 2000). International schools often have high turnover rates in their teaching faculty, which was the case in this school, so finding collaborators who would be available for the action research was a challenge. I used an ex post facto design because the chosen cohort of students had previously completed chemistry and biology at the time of the study. Because the data are historical, no manipulation of the independent variable occurred. There were two groups: accelerated math pathway students and those on the nonaccelerated pathway (Fraenkel, Wallen, & Hyun, 2011).

I applied the causal-comparative component of the research design to determine if students on an accelerated pathway performed better in science than those on the nonaccelerated pathway (see Table 1).

Table 1

Example Data Collection for Causal-Comparative Study

Group	Grade 9	Grade 10
Accelerated math group	Chemistry exam	Biology exam
Nonaccelerated math group	Chemistry exam	Biology exam

The purpose of a causal-comparative design is to determine if there is a difference between two groups that is caused by a preexisting independent variable not manipulated by the researcher (Fraenkel et al., 2011). Due to the nature of causal-comparative studies, the sample could not be randomized, nor could a control be applied, making it difficult to determine causation and to generalize to other groups. Even if there is a significant difference in science achievement between the two math groups, it is possible that math grouping is not the cause of that difference, and other factors such as general low academic skills, motivation, or language skills could explain low achievement. The interpretation of the results must take those limiting factors into consideration (Fraenkel et al., 2011).

To answer the second research question regarding the correlation between students' math and science achievement, a correlation research design was employed. The results of the correlation research design will provide needed information for leaders when making decisions regarding flexible pathways for students in science at the school being investigated. Conducting a correlation study is ideal for this question because I was attempting to determine if there is a relationship between variables, which in this study are math achievement and science achievement as reported on exams. These variables already existed in a database and were not manipulated by me (Fraenkel et al., 2011). A positive correlation, if found in this case, would mean that high scores in math are associated with higher scores in science, whereas a negative correlation would indicate that high math scores would predict low science scores. It is also possible for no correlation to exist, in which case there is no relationship between math achievement and science achievement. Just as with causal-comparative studies, correlation does not necessarily posit causation; results must be interpreted carefully. Caution must be taken when discussing the results because the correlation of variables does not necessarily mean math achievement causes science achievement (Fraenkel et al., 2011).

Population and Sample

The school involved in this study was a private school in a country located in the Caribbean. It enrolled approximately 380 students in the high school division. The majority of students, about 70%, were children of wealthy nationals who desired the opportunity for their children to receive an American-style education and who can afford the tuition. The school also enrolled students whose parents work at the U.S. embassy or for corporations who conduct business in the country but are nationals of either the United States or a Latin American country. The 2015 cohort of ninth graders analyzed in this research was representative of the other cohorts at the school in demographics, socioeconomic status, and number.

The cohort of students in ninth grade in the 2014–2015 school year is the sample that will be used for this study. These students completed all three core science requirements at the time of the study, which made them an ideal sample because achievement in chemistry and biology can be evaluated. These students were placed on math pathways because of criteria they met before middle school. There were 79 students in this cohort, and 70 students were used in this study. Nine students were eliminated because they stopped attending the school or did not fall into these two pathways.

The majority of students in the school were divided into two math pathways. They were placed on an accelerated or nonaccelerated pathway based on MAP Growth scores, grades in math classes, as well as teacher and parent recommendations when they were in fifth grade. MAP Growth scores reflect a student's growth and performance in math, science, language usage, and reading (Northwest Evaluation Association, 2019). The first pathway is an accelerated pathway that includes students who completed Algebra I in eighth grade, geometry in ninth grade, Algebra II in 10th grade, and precalculus in 11th grade. A total of 34 students were on this pathway. The second pathway, nonaccelerated, included students who took Algebra I in ninth grade, geometry in 10th grade, and Algebra II in 11th grade. A total of thirty-six students were on this pathway. The students in the 2015 cohort of freshmen were coded according to their group placement.

To determine the power of this sample, G*Power v. 3.1 software was used to determine the sample size. Thirty-six was the minimum sample size for a repeated-measures ANOVA test given the parameters of an alpha of 0.05 for two groups. Sixty-four was the minimum sample size for a correlation analysis, with an alpha of 0.05 (Faul, Erdfelder, Lang, & Buchner, 2007). Given this analysis, the 2015 cohort of freshmen had a number that was sufficient for the causal-comparative studies and the correlation analysis (Fraenkel et al., 2011).

Descriptive statistics were used to establish the normality of the data including mean, standard deviation, histograms, skewness, and kurtosis for each exam in science and math using

SSPS software v. 25 (Muijs, 2016). The data were graphed and analyzed visually for normal distributions. Additionally, Levene's test was calculated to ensure that the samples in each group had equal variances (Muijs, 2016). The sample size was found to be sufficient, and the data used for the first research question were also sufficiently normally distributed, so parametric tests were used to further analyze the data. However, to answer the second research question, nonparametric correlation analysis (Spearman's rho) was used because the English exam data were not normally distributed (Fraenkel et al., 2011; Neideen & Brasel, 2007). Additionally, the teacher generated tests were validated using AP exams, and those sample sizes were significantly smaller than 74, so they were also correlated using Spearman's rho (Fraenkel et al., 2011).

Instruments

The school utilized the PowerSchool database containing the scheduling and grade data for all students, which were analyzed in this study (PowerSchool, 2018). Preexisting data including AP exam scores, final course exams in PowerSchool, and math placement were collected. Final exams were common among teachers teaching the same subject and were cumulative. A significant proportion (50% or more) of the exams were multiple choice with only one correct answer. This data provided the most unbiased measure of achievement in a course without the inherent differences that come from the grading practices of individual teachers (Abdul & Jisha, 2014).

Archived data found in PowerSchool software were used to conduct this study. The data needed for this research were collected for the purpose of reporting grades for report cards and transcripts. Grades were input into PowerSchool by teachers. Final exams were generated by teachers, aligned to standards taught that semester, and were common between teachers. Multiple versions of the exams may have been given but consisted of scrambling the questions.

Therefore, all students in a given subject took the same exam, at the same time, proctored by a staff member who did not teach the course. The science courses should be aligned to NGSS standards and the exams should reflect that alignment. The math and English courses should be aligned to Common Core math and English standards, and those exams should reflect that alignment as well. Exams were predominately multiple choice with only one correct answer, and the key was common to all teachers giving the same exam. Free response questions in math and science were limited but consisted of problems to solve that would have one correct solution or short written answers that were graded using rubrics that were developed by the teachers. Essays on the English exams were graded by a common rubric. The exams were scored by the teacher of that course. This school has a large foreign hire staff from North America, which is how it is able to offer an American-style education. However, that type of international staffing results in very high turnover. There were no structures in place to archive old exams, and many of the teachers who administered and graded those exams are no longer employed at the school, so raw data on test items was not available. Therefore, this study was dependent on the data stored on PowerSchool, which reflected the overall exam score.

To establish the predictive validity of the exams as a measure of achievement, a Spearman's rho correlation was computed comparing AP scores to those of the corresponding lower-level class (Trochim, 2006). AP exams are standardized exams administered by the College Board. These exams consist of multiple-choice questions and free-response questions, all of which are graded by staff trained by The College Board using answer keys and rubrics (College Board, 2019). If the AP exams are shown to be correlated with the teacher-generated final exams, the local exams are more likely valid measures of standards in that course (Trochim, 2006). Biology exam scores were compared to AP Biology, chemistry to AP Chemistry, and

Algebra I, geometry, and precalculus to AP Calculus AB (Muijs, 2016). Ninth- and 10th-grade English scores were compared to the AP Language scores (Muijs, 2016).

Qualitative Data Collection and Analysis Procedures

Operational definitions of variables. For the purpose of the causal comparative study, the math pathway was the independent variable, and science achievement, as measured by achievement on the final exam in biology and chemistry, was the dependent variable. For the correlational study, math final exam scores in Algebra I, geometry, Algebra II, and precalculus were compared to science final exam scores in biology and chemistry (Fraenkel et al., 2011).

Data collection and analysis. All of the statistical tests in the analysis were conducted using SPSS v. 25.0. To answer the first research question, the mean final exam scores for each group (accelerated or nonaccelerated) in each science course (chemistry or biology) were calculated. A two-by-two repeated measures factorial ANOVA test was conducted to see if there were significant statistical differences across years, between groups, and to test interaction effects (Muijs, 2016).

To answer the second research question, correlation analyses were used. The purpose of this analysis was to examine the relationships between student performance in math and science. For each science course, a Spearman's rho correlation was computed to compare math exam scores to each of the three science exam scores. If there is a correlation between math and science skills, there should be a significant relationship in the exam data (Terry et al., 2016). Additionally, a Spearman's rho correlation was computed to compare English exam scores to science exam scores. If there was a significant correlation between English and science skills, then there would be a significant relationship between the English and science exam scores. Comparing the correlations indicated whether math skills are more fundamental in developing the formal reasoning needed to achieve in science or overall academic skills are needed instead. A similar correlation between the math and science scores would indicate that overall academic skills are needed, whereas a more significant correlation between math and science would indicate that math is the course that needs to be considered by leadership when planning course pathways (Terry et al., 2016).

Researcher's role. I was a staff member of the school in the science department. In my role at the school, the issue of student success in science in relation to math skills became apparent. Discussions with other members of the department revealed the possibility of achievement in science being correlated with math and math placement. I also administered the biology final exams but did so in collaboration with the other staff members teaching biology and with no knowledge that the results would be used in this study. All the data in the study were analyzed using SPSS so that minimal bias would enter into the results because the conclusions were based on statistical analysis (Mujis, 2016).

Ethical Considerations

This study received approval from ACU's Institutional Review Board (IRB) before data collection. The school administrator gave written permission for the data to be used. Data collected from minors were used in this study, but all identifying information was removed before analysis by a member of the high school teaching faculty who was not involved in the research. I am an instructor at the school.

The 2015 cohort of freshmen graduated from the school in 2018, so they are no longer students at the school where the action research occurred and are therefore further protected from risk in this study. The data used were taken from the PowerSchool archives, which were password protected. The data were then given to a staff member of the school who added in AP exam scores, which were stored in a shared Google Drive folder to which all teaching staff had access. Data were deidentified by replacing names with random numbers prior to giving the data to me. I stored this information in a Google Drive folder that was accessible by login and password.

Assumptions

I assumed that the 2015 cohort was representative of all other cohorts at the school. All other cohorts had approximately the same number of students and the same percentage of students in accelerated and nonaccelerated math pathways. The same criteria were used in elementary school for math pathway placement.

Limitations

The results of this research cannot be generalized to other schools. The unique criteria of placing students on math pathways as well as the particular demographic makeup of the school make the results of the study useful for the leaders at this specific school; however, because other schools do not have the same criteria and demographic makeup, the results cannot be generalized to other schools. A second limitation was the assumption that the 2015 freshmen cohort was representative of other cohorts at the school.

Delimitations

One delimitation of the study was focusing only on the school in question. This action research study had the purpose of gathering information that the leaders of the school need in order to make decisions regarding science pathways. Another delimitation was that the data analysis was limited to the 2105 cohort of freshmen students. This cohort was representative of the rest of the student body, so the results from this study should be sufficient to inform leadership.

Summary

The purpose of this study was to provide information to leaders of a private school in Latin America so they can make informed decisions regarding math placement and science course sequence in an effort to support student success in science. Given my role as a faculty member of the science department, this was an action research study. The intent was to use a causal correlational study to determine if a student's math course placement, accelerated or nonaccelerated, was a determinant of ability to achieve in science. Additionally, I aimed to determine if math achievement was correlated with science achievement. Having this information will help leadership understand if Algebra I is critical to support the successful completion of science graduation requirements at the school.

Chapter 4: Results

This ex post facto causal-comparative action research study was conducted on a cohort of students who began high school in 2015 in a private school in Latin America. The purpose of the study was to determine if students on different math pathways, accelerated or nonaccelerated, displayed different levels of science achievement as measured by their final exam performance. Additionally, exam data in English and science were compared to math exam data. The purpose of this correlational component was to determine if math or general academic skills, such as language, were related to science performance. The results of this study will be provided to school leaders to determine if support systems, such as alternative science pathways, should be created.

Descriptive Statistics and Tests of Normality

Before the statistical analysis to answer the research questions was performed, descriptive tests were done to determine the normality of the data. These included, mean, median, and standard deviation. Skewness and kurtosis were also calculated, and histograms were created to determine the normality of the data. To establish the validity of the exams, a correlation between the exam data and AP exams was done.

Data were collected and analyzed by me. The total cohort of students who were in ninth grade in 2015 was 79 students. Seven students did not complete their high school career at this school and were therefore eliminated from the data set. Additionally, 2 students did not follow the traditional pathway or matriculated into the school after ninth grade and were also eliminated from the data set. A total of 70 students remained, which included 34 on the accelerated pathway and 36 on the nonaccelerated pathway. The data were then analyzed using SPSS, and descriptive statistics were calculated. Table 2 shows the mean and standard deviations for the

Table 2

Descriptive Statistics in Math, Science, and English

Course	Accelerated math group exam score		Nonaccelerated math group exam scores	
	M	*SD*	*M*	*SD*
9th-grade chemistry	79.00	11.625	61.83	15.861
9th-grade math exam	76.06	13.013	72.64	12.090
9th-grade English exam	79.68	15.279	67.64	10.905
10th-grade biology exam	83.41	8.931	71.17	11.193
10th-grade math exam	78.85	13.850	66.81	13.765
10th-grade English exam	83.24	11.919	72.94	14.815

Note. $N = 70$. The maximum score on the exam was 100.

accelerated (1) and nonaccelerated (2) pathways in science, math, and English for ninth grade in 2015 and tenth grade in 2016.

Histograms of the exam data were created using SPSS to visually evaluate the normality of the data. The histograms shown in Figures 1, 2, 3, 4, 5, and 6 show the distribution of the exam scores. Chemistry and biology have the accelerated and nonaccelerated pathways separated because those groups were analyzed to answer the first research question. The entire data set for English and math are visualized in the histogram because all exam scores were used to answer the second research question. Skewness and kurtosis were calculated for each data set were calculated in SPSS, and the values are shown in Table 3. Levene's test of variances was also calculated in SPSS, and the values are shown in Table 4.

The data for math and science exams were normally distributed. This was confirmed by the skewness values, most of which were under 0.5, and kurtosis values under 1.0, indicating normally distributed data (Jain, 2018). The 10th-grade biology accelerated group had a skewness value of –0.673 and a kurtosis value of 1.276, which indicated moderate skewness. But the ANOVA is robust enough to manage data that do not depart significantly from normal distribution, and there is no significant risk of Type I errors occurring (Blanca, Alarcón, Arnau,

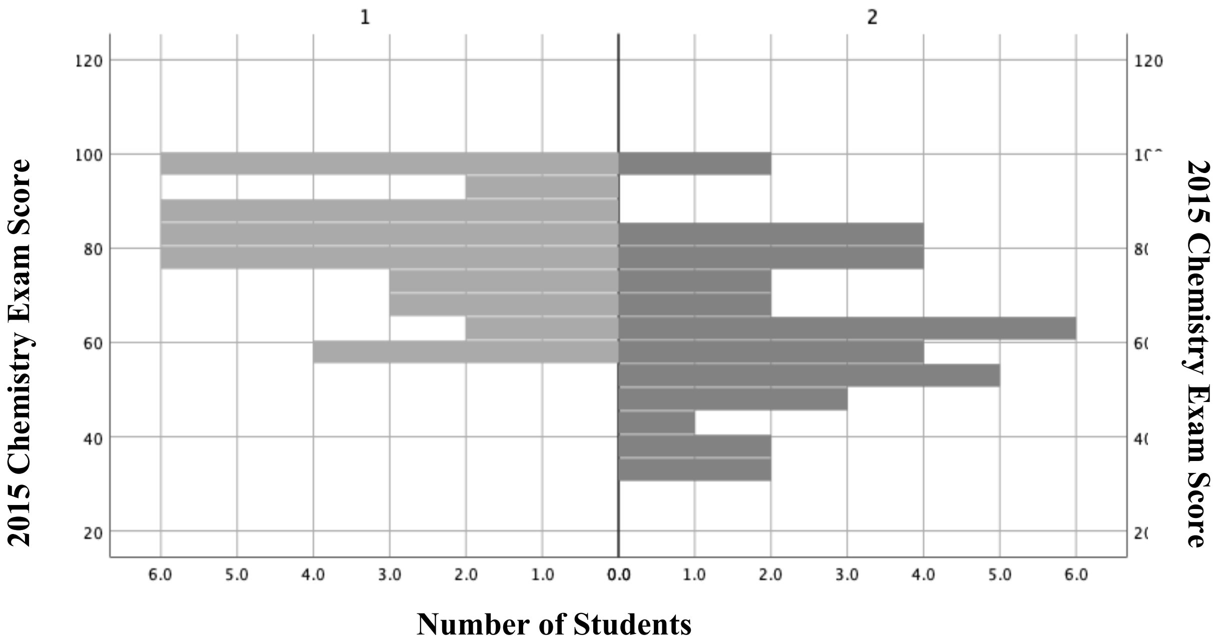

Figure 1. 2015 9th-grade chemistry score histogram of accelerated (1; *n = 34*) and nonaccelerated (2; *n = 36*) groups.

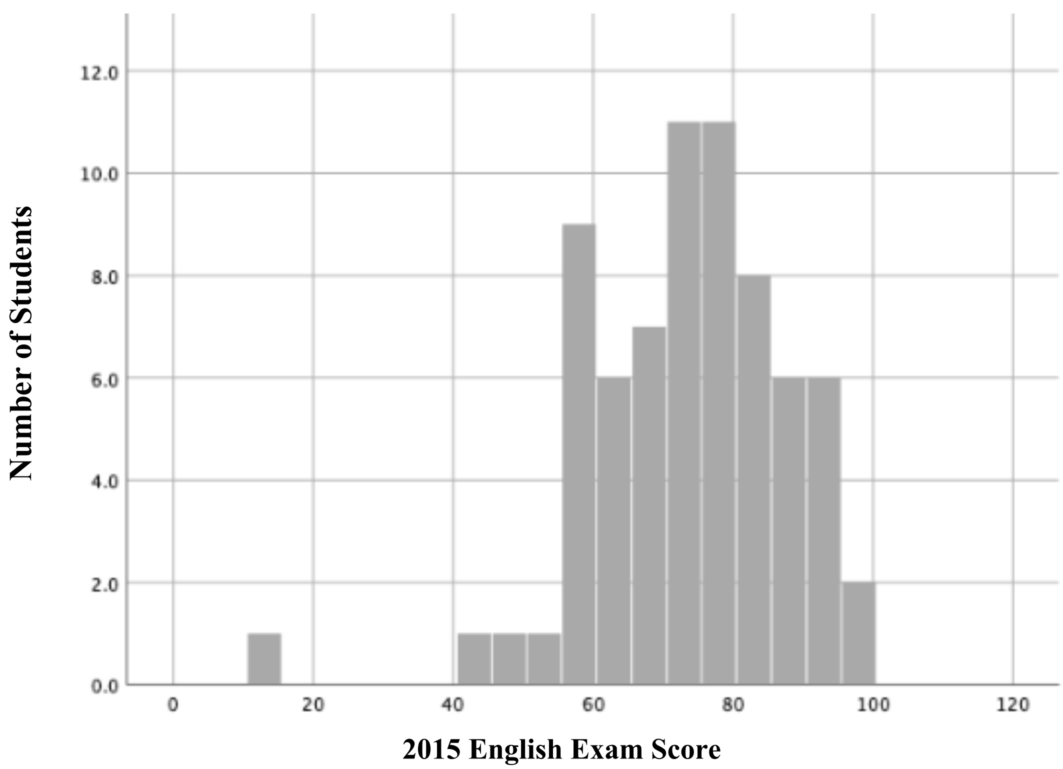

Figure 2. 2015 10th-grade English exam score histogram ($N = 70$).

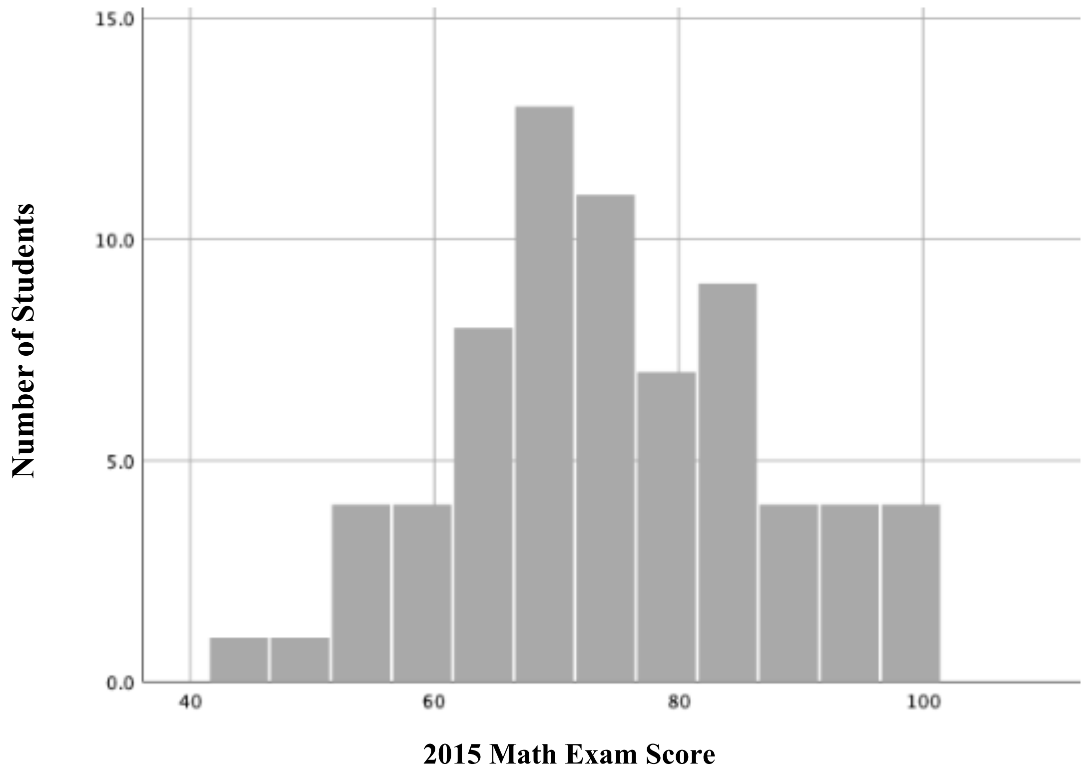

Figure 3. 2015 9th-grade math exam score histogram (N = 70).

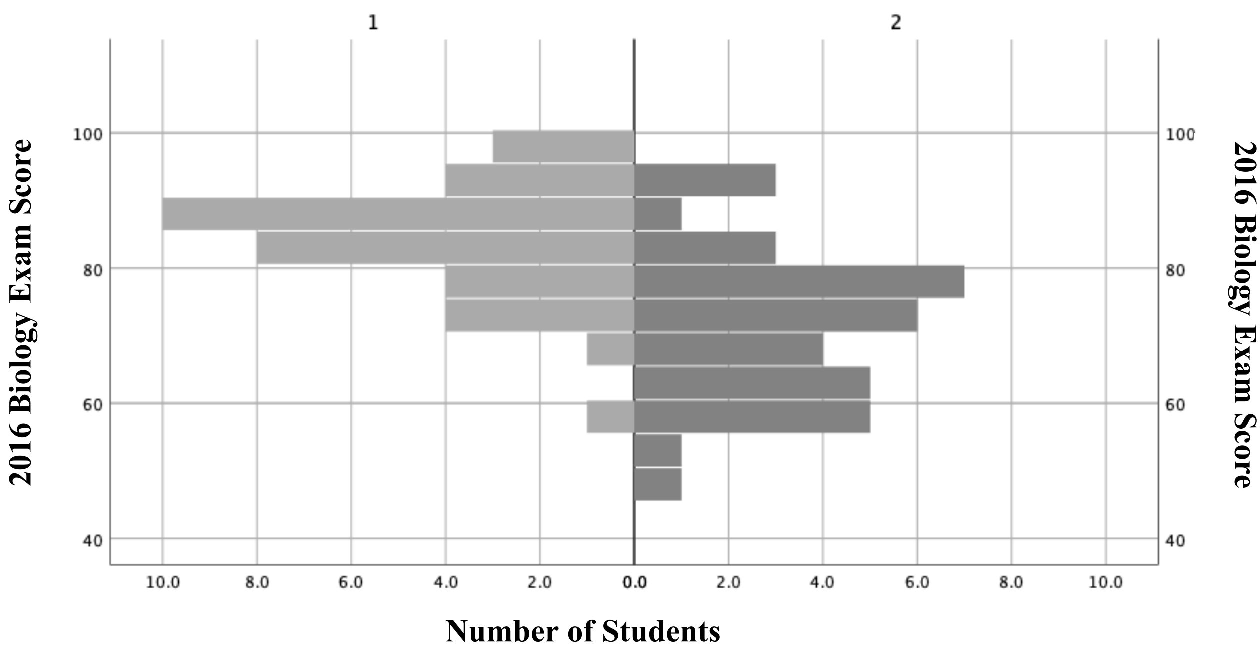

Figure 4. 2016 10th-grade biology exam score histogram of accelerated (1; n = *34*) and nonaccelerated (2; n = *36*) groups.

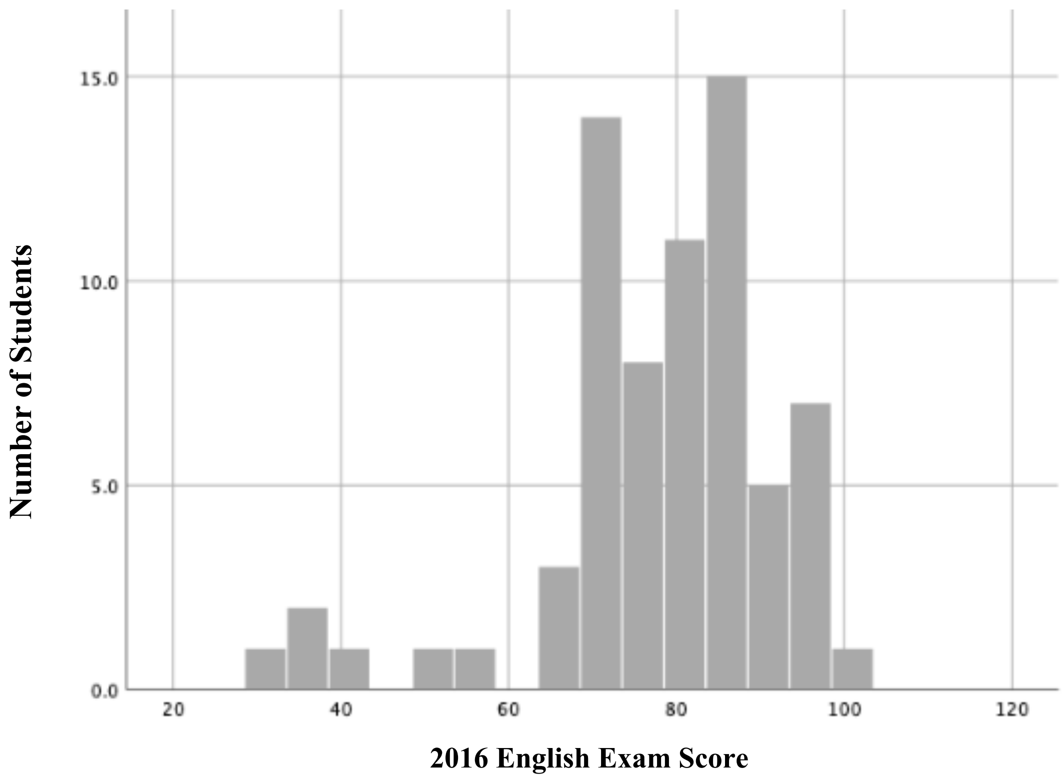

Figure 5. 2015 10th-grade English exam score histogram (*N* = 70*)*.

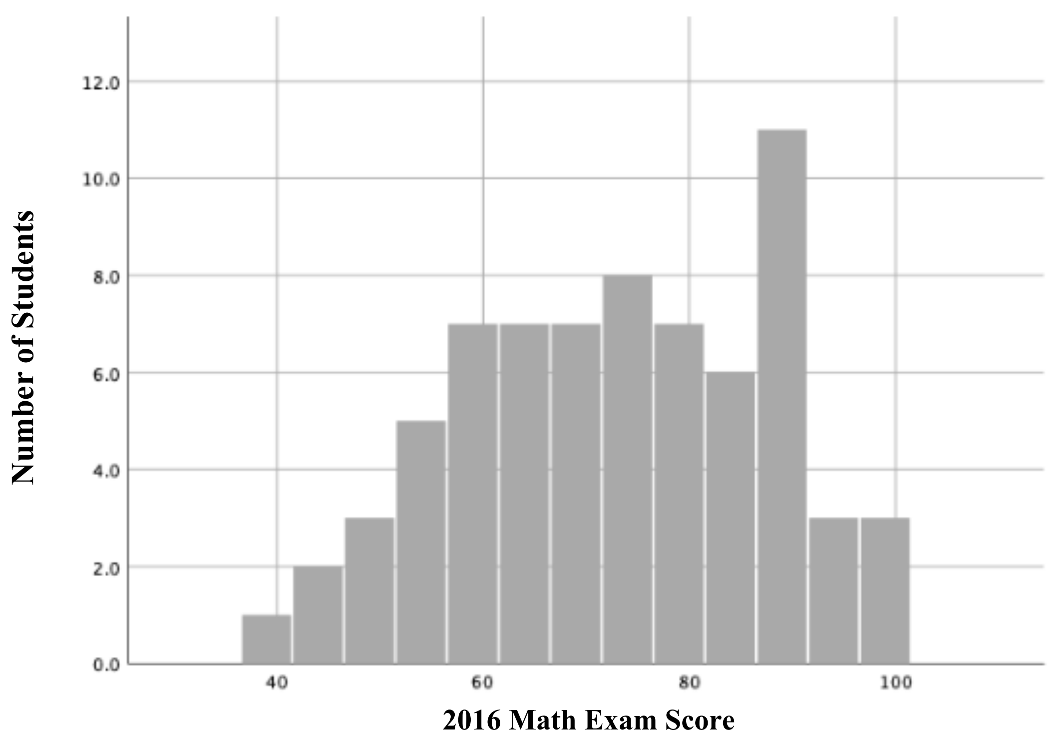

Figure 6. 2016 10th-grade math exam score histogram (*N* = 70).

Table 3

Skewness and Kurtosis Values From Exam Data

Exam	Skewness	Kurtosis
2015 9th-grade chemistry exam accelerated	0.319	–0.680
2015 9th-grade chemistry exam nonaccelerated	0.062	–0.631
2015 9th-grade math exam	0.0119	–0.569
2015 9th-grade English exam	–1.031	2.935
2016 10th-grade biology exam accelerated	–0.673	1.276
2016 10th-grade biology exam nonaccelerated	0.041	–0.514
2016 10th-grade math exam	–0.247	–0.722
2016 10th-grade English exam	–1.352	2.612

Note. $N = 70$. Accelerated ($n = 34$) and nonaccelerated ($n = 36$).

Table 4

Levene's Test of Equality of Error Variance

Course	Levene's statistic	*df1*	*df2*	*Sig.*
Chemistry based on mean	3.534	1	68	.064
Biology based on mean	3.019	1	68	.087

Note. $N = 70$.

Bono, & Bendayan, 2017). Levene's test of variances showed that the variance for the two compared groups are not significantly different. In chemistry, Levene's test of variances indicated that the variance in mean scores was equal ($F = 3.534$, $p = 0.064$). In biology, Levene's test of variance also indicated that the mean scores were equal ($F = 3.109$, $p = 0.087$). These results provided evidence that the data met the assumptions of an ANOVA test (Mujis, 2015).

The histograms for the English scores in 2015 and 2016, shown in Figures 2 and 5, display clusters of data on the lower end of the scale, demonstrating that the data were not normally distributed. This was confirmed by the high kurtosis values for both 2015 and 2016. A kurtosis value of more than 2.0 indicates that there are outliers in the data (Jarin, 2018). Additionally, the English 2015 and 2016 groups had data that were skewed, both having skewness values of greater than 1.0 (Jarin, 2018). Therefore, the nonnormally distributed data in the English exam made the nonparametric Spearman's rho correlation analysis the best choice to answer the second research question (Fraenkel et al., 2011).

Repeated-Measures ANOVA

The first question of this research was, Do students placed on an accelerated math pathway perform better in biology and chemistry than students on a nonaccelerated math pathway? To answer this question a two-by-two repeated-measures ANOVA was used to compare the chemistry and biology exam scores across the accelerated and nonaccelerated groups. The results of this analysis are shown in Table 5. The estimated marginal means of measure was also plotted on the graph shown in Figure 7.

Table 5

Repeated-Measures ANOVA Test Comparing Accelerated and Nonaccelerated Math Students' Performance in Science

Effect	*df*	*SS*	*MS*	*F*	*p*	Partial eta^2
Year	1	1651.768	1651.768	31.809	0.000	0.319
Group	1	7563.025	7563.025	30.702	0.000	0.311
Year*Group	1	211.768	211.768	4.078	0.047	0.057
Error (year)	68	3531.118	51.928			

Note. *N* = 70. Accelerated (*n* = 34) and nonaccelerated (*n* = 36).

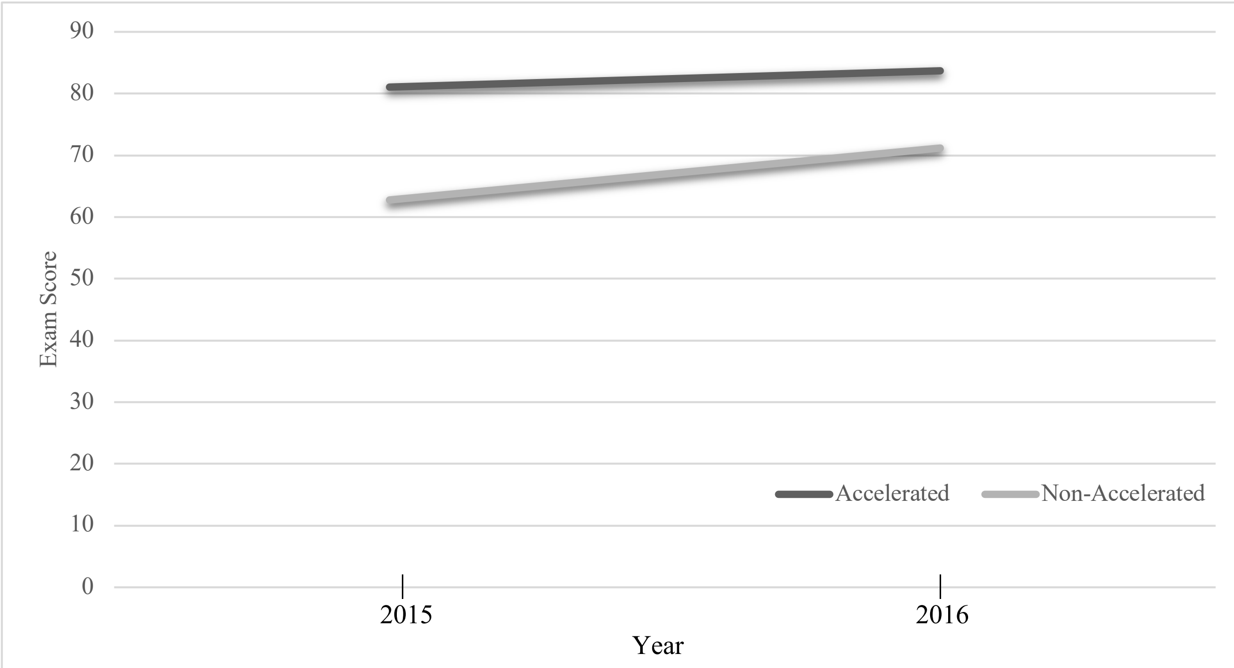

Figure 7. Estimated marginal means of chemistry (2015) and biology (2016) exams on accelerated and nonaccelerated pathways. $N = 70$. Accelerated ($n = 34$) and nonaccelerated ($n = 36$).

A statistically significant difference between scores on the chemistry and biology exams was found, which in Table 5 is indicated by the variable Year, $F(2, 68) = 31.809$, $p = 0.000$, $\eta^2 p = 0.319$. The partial eta squared for this analysis was 0.319, indicating that the effect size was large (Richardson, 2011). This indicated that students performed substantially better on the second year's exam.

Additionally, there was a statistically significant difference between the accelerated and nonaccelerated groups as shown by the variable Group in Table 5, $F(1, 68) = 30.702$, $p = 0.000$, $\eta^2 p = 0.311$). The students in the accelerated group performed better. The partial eta squared for this analysis was 0.311, indicating a large effect size caused by being in different math groups

(Richardson, 2011). This indicates that students on the accelerated math pathway performed substantially better than those on the nonaccelerated pathway.

Finally, there was a statistically significant interaction between year and group, $F(1, 68) = 4.078$, $p = 0.047$, $\eta^2 p = 0.057$. As shown in Figure 7 in the variable Year*Group, the accelerated group did not have as much growth as the nonaccelerated group from 2015 to 2016. The partial eta squared value indicate that the effect size is small (Richardson, 2011).

Correlational Analysis

The second research question in this study was, Does students' science achievement correlate with English and math achievement? To answer this question, Spearman's rho correlations between math, English, and science exams were calculated. The results of these Spearman's rho analyses can be seen in Table 6. All of the exams were compared so the number of subjects for each correlation analysis was 70.

All of the exam scores were correlated and found to be statistically significant, with *p* values of .000 or less. All of the correlations were positive, meaning as one score increases, so does the other. The correlation between English 2015 and math 2015 scores was moderate, $r_s = 0.352$, $n = 70$, $p = 0.000$, and so was the correlation between the chemistry 2015 and math 2015 scores, $r_s = 0.552$, $n = 70$, $p = 0.000$, and the English 2016 and math 2016 scores, $r_s = 0.562$, $n = 70$, $p = 0.000$ (Weir, 2015). The correlation between English 2015 and chemistry 2015 scores was strong, $r_s = 0.680$, $n = 70$, $p = 0.000$, and so was the correlation between biology 2016 and math 2016 scores, $r_s = 0.637$, $n = 70$, $p = 0.000$, as well as between English 2016 and biology 2016 scores, $r_s = 0.637$, $n = 70$, $p = 0.000$ (Weir, 2015). The correlations for each year were higher in the math and science comparison than in the math and English comparison. The correlation between math and science was different in 2015 than 2016. In 2015, the correlation

Table 6

Spearman's Rho Correlation Between Math and English and Math and Science

	English 2015	Chemistry 2015	English 2016	Biology 2016
Math 2015	0.352**	0.554**		
English 2015		0.680**		
Math 2016			0.562**	0.637**
English 2016				0.605**

Note. Only correlations used to compare tests taken in the same year are shown.

**$p < 0.01$, two-tailed.

was stronger between English and chemistry, whereas in 2016, the correlation between math and biology was stronger than between English and biology.

Validity of the Exams

To establish evidence for the validity of the school generated exams, a Spearman's rho correlation analysis was done. Due to the nonnormal distribution of the English exams and a sample size significantly lower than the 64 that the G*power analysis indicated was needed, Spearman's rho was the best statistical test for this analysis (Fraenkel et al., 2011). The results of the analysis can be found in Table 7.

There was a positive correlation for each exam, but the strength of the correlation strength varied. The English 2015 and 2016 exams were weakly correlated with the AP Language exam, $r_s = 0.224$, $n = 8$, $p = 0.592$ (Weir, 2015). The 2015 and 2106 math exams were moderately correlated with the AP Calculus AB exam, $r_s = 0.437$, $n = 14$, $p = 0.118$ and $r_s = 0.473$, $n = 14$, $p = .088$, as was the AP Chemistry and chemistry exams, $r_s = 0.440$, $n = 6$, $p = 0.547$ (Weir, 2015). The biology exam was highly correlated with the AP Biology exam, and

Table 7

Spearman's Rho Correlation Between Campus-Generated and AP Exams

Course	AP Language	AP Calculus AB	AP Chemistry	AP Biology
English 2015	0.225			
English 2016	0.225			
Math 2015		0.437		
Math 2016		0.473		
Chemistry 2015			0.440	
Biology 2016				0.949*

Note. Only correlations used to validate the exams in the study are shown.

*p value < 0.05, two-tailed.

was the only exam found to have a significant correlation, $r_s = 0.949$, $n = 5$, $p = 0.013$ (Weir, 2015).

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this ex post facto action research study was to provide information to the leadership of a private school in Latin America regarding the success of students in science who were on different math pathways, accelerated or nonaccelerated. Currently, the school provides one pathway for science students, and the staff has indicated that their students may be struggling as a result. The two research questions in this study aimed at providing leadership in the school with sufficient information to support students and their success in science.

By asking the first research question, I aimed to determine if there was a significant difference in science achievement for the group of students on the accelerated pathway compared to the students on the nonaccelerated pathway. To answer this question, a two-by-two repeated-measures ANOVA was conducted comparing the science achievement of students on the accelerated pathway to that of the students on the nonaccelerated pathway over a 2-year period. The second research question was aimed at determining if there was a correlation between students' achievement in math and science as well as math and English. The aim of this research question was to identify if general academic skills were contributing to the lower achievement observed in students on the nonaccelerated math pathway. Spearman's rho was used to analyze the exam data to answer this research question.

Discussion of the Findings for Research Question 1

The first research question examined whether students on the accelerated math pathway displayed higher achievement levels than students on the nonaccelerated math pathway. It was analyzed using a two-by-two repeated-measures ANOVA. Based on the literature review, especially the importance of logico-mathematical thinking in science, it was hypothesized that there would be a significant difference (Joyce et al., 2017).

The results of the two-by-two repeated measures ANOVA showed that there was a significant difference in the accelerated and nonaccelerated groups. This difference might be because the math pathway students are on impacts their achievement in science. The strong partial eta squared value indicated that the pathway had a powerful effect explaining this difference (Richardson, 2011). The students on the accelerated math pathway who had already completed Algebra I performed better than those who were on the nonaccelerated pathway and were concurrently enrolled in chemistry and Algebra I. That trend continues as students moved into biology courses.

This finding was in alignment with previous studies. Formal reasoning is necessary to understand many of the abstract concepts in science courses such as identifying trends, using data to support conclusions, and identifying trends (Herreid et al., 2014). The development of formal reasoning develops in individuals at varying rates but improves for all individuals with practice (Bello, 2014). Given that Algebra I provides practice for developing formal reasoning, it is reasonable that those students who are on the accelerated math pathway, having completed Algebra I before beginning chemistry, would perform better.

Additionally, it was found that there was a statistically significant difference between students' performance in chemistry in 2015 and biology 2016. The mean scores on the biology exam were higher for both groups than on the chemistry exam. This difference could be due to a variety of reasons. First of all, the students taking the biology exam had a year of academic growth in which they had opportunities to develop their abstract and symbolic thinking by completing Algebra I for the nonaccelerated group and geometry for the accelerated students (Hong, 2013). Another reason for the difference could be due to the nature of the courses. Chemistry is a course that requires the use of explicit math concepts, which biology does not require. As Terry et al. (2016) showed, prerequisite skills developed in math accounted for 48% of the variance in the successful completion of physics, another science course that explicitly uses math. It stands to reason that chemistry could be similar and that could account for the greater variance in the chemistry exam than the biology exam. The partial eta squared for the difference in performance by year is also large, indicating that the year the student takes the exam had a significant effect on her achievement (Richardson, 2011).

The data in Figure 7 show that while having a year of academic growth improves achievement, there is still a difference in students' achievement on the accelerated and nonaccelerated pathways. Many students struggled with biology when it was traditionally placed in ninth grade (Popkin, 2009). Solutions such as putting physics in ninth grade instead were met with problems due to the algebra skills required in physics, and those same issues may be contributing to the larger difference in the accelerated and nonaccelerated group in this study. Chemistry as a ninth-grade course for all students may not be the best solution (Popkin, 2009). However, given that there was still a statistically significant difference between the accelerated and nonaccelerated group in biology, it is not reasonable to think that moving it to ninth grade would be a solution enabling all students to experience success.

McDowell (2013) noted that when leaders mandate biology in ninth grade, all students are not able to be successful in biology at the same time in their educational career. Additionally, Joyce et al. (2017) found that first-year university students who had taken more rigorous math classes performed better in biological science courses. The analysis in this study provides information to the school's leadership that higher-level math in high school might be the key to success in chemistry and biology, which were courses the high school required for graduation.

Finally, there was a significant interaction when considering both year and group. This is demonstrated clearly in Figure 7, where it can be seen that the lines are separate. However, because the nonaccelerated pathway has a more significant improvement from the chemistry exam in 2015 to the biology exam in 2016, if the data were to be extrapolated, the lines would likely meet, indicating that the difference in achievement in the two groups would no longer be significant. The effect size for this statistical test was small, indicating that there may be many other factors besides the variables of group and year that explain science test scores (Richardson, 2011).

The result from the interaction of year and group is substantiated by researchers who indicated that formal reasoning improves with practice (Bello, 2014). However, placing the students on the same science pathway without regard for their math placement could harm those students by not providing them with opportunities to experience positive self-efficacy, which promotes achievement (Putwain et al., 2013). Additionally, students who have higher achievement in the sciences are more interested in continuing to pursue science and have a greater retention rate in college in STEM-related degrees as a result (Demirci, 2013). Considering that the school leadership designated chemistry a ninth-grade course and given that researchers found that ninth grade success is indictive of future academic success, it is imperative that school leaders create pathways to provide students with success (McCallumore & Sparapani, 2010).

Discussion of the Findings for Research Question 2

The purpose of the second research question was to determine if there was a significant correlation between the students' math exam scores and English exam scores, as well as a correlation between math exam scores and science exam scores, for the 2 years that were evaluated in Research Question 1. The purpose of this question was to produce additional information for use by the leadership of the school for evaluating science pathways. As discussed previously, the difference in the exam scores of the students on the accelerated and nonaccelerated math pathways cannot be conclusively attributed to their math skills (Fraenkel et al., 2011). By evaluating and comparing the correlations, the leadership can determine if math might be a more significant contributor to a student's success in science or if other academic skills need to be addressed. Due to the nonnormally distributed data, Spearman's rho was used to analyze the data (Fraenkel et al., 2011).

In 2015, there was a much stronger correlation between math and science, $r_s = 0.554$, than between math and English, $r_s = 0.352$. The same trend was found in 2016. The math and science correlation was stronger, $r_s = 0.637$, than the math and English correlation, $r_s = 0.562$. There was a positive correlation between English and math, but the correlation between science and math was stronger. This indicated that the skills in math more closely align with those in science than those in English and those in math.

A different trend is seen when comparing English exam scores to science scores. In 2015, there was a stronger correlation between English and chemistry, $r_s = 0.680$, compared to that of math and chemistry, $r_s = 0.554$. In 2016, however, there was a stronger correlation between math and biology, $r_s = 0.637$, than English and biology, $r_s = 0.605$. Terry et al. (2016) found a higher correlation between university students' physics and math scores than between their physics and English scores, which indicated to them that math skills were more significant to success in science than language stills. Given the results of that study, it was expected that the correlation between math and science would be stronger than that between English and science, but the results were mixed. It was interesting that the results indicated a stronger correlation between chemistry and English, because chemistry, like physics, is a course that is reliant on algebraic equations, whereas biology is not as explicitly reliant on algebra. Bayat et al. (2014) found a strong correlation between reading comprehension and science achievement, and as the results of this study were mixed, the realities of language acquisition and comprehension of a mostly English language learning population cannot be discounted. However, the importance of math as a contributing factor to developing skills necessary for success in science also cannot be discounted.

Limitations

The analysis of the two-by-two repeated-measures ANOVA added necessary and new information for leadership to use in its evaluation of the programs. However, there are some limitations that need to be taken into consideration. While there was a significant difference between the accelerated and nonaccelerated pathways, there was no conclusive evidence that the math pathway caused the difference (Fraenkel et al., 2011). Additionally, AP tests were used to validate the teacher-generated exams given in each course. Only the biology and AP Biology exams were strongly correlated, $r_s = 0.949$. All other exams were moderately correlated with $r_s < 0.5$. These weak correlations could be due to the very small number of students taking the AP exams, or to the poor alignment of the exam to standards or between lower-level courses and AP courses.

There were significant limitations in the analysis of the second research question. First, finding a correlation does not mean causation can be determined so the correlations seen in this analysis do not necessarily mean one is causing the results in the other (Fraenkel et al., 2011). Additionally, a possible lack of validity of the teacher-generated tests must be considered. The English exam, which had a weak correlation to the AP Language exam for both the 2015 and

2016 exams, $r_s = 0.224$, was a concern. This correlation was much weaker than the correlation of the other exams in the analysis. This could be due to the low number of students taking the exam, poor alignment between courses, or grading methods against a rubric. Finally, due to the specific characteristics of the school where data were collected, the results cannot be generalized to other schools.

Recommendations

The results of this study provided significant information that the leadership of the school should take into consideration when considering options for pathways in science. Because of significant differences found across year and pathway, the following recommendations are for the leadership of the school to take into consideration for planning purposes. Recommendations for future research are also given.

Recommendations for practical application. Given the conclusion that there is a difference in achievement in science between students who are on the accelerated math pathway and those on the nonaccelerated pathway, a similarly flexible pathway should be given for students in science. Because ninth grade and experiences of self-efficacy are so important in the academic life of a student, it is important that students are given opportunities that provide the best chance of achievement when they start high school (McCallumore & Sparapani, 2010; Putwain et al., 2013).

First of all, resorting the three core science classes, chemistry, biology, and physics, by moving a different course into ninth grade to manage the effects of the lack of formal reasoning has not been successful. Schools around the world have identified that studying biology in ninth grade is not successful for all students (To et al., 2017). Changing to physics in ninth grade has also not been successful (Terry et al., 2016). Based on the results from this study, I concluded that requiring chemistry first has many of the same problems. Instead of shuffling one of the three core sciences into ninth grade with little success, earth and space science should be an option for students who have not yet completed Algebra I. The NGSS created standards for the course to build upon topics in physical and life science standards from middle school and make a bridge to the required physical and life sciences in high school (Bybee, 2013). This course should be offered to ninth-grade students who have not yet completed Algebra I. This offering would enable these students to continue to practice performance expectations and learn standards that will increase their opportunities for success in the other three required sciences (Bybee, 2013).

Secondly, general academic supports should be put into place. Given that the correlations between math and science and math and English were very similar, there are likely other factors besides formal reasoning that are impacting achievement. A significant portion of the population of students at the school learned English as a second language. Additional supports and strategies might help improve reading comprehension and therefore improve science achievement (Bayat et al., 2014).

Finally, curricular alignment between courses from elementary to high school should be evaluated. The weak correlations between the teacher-generated tests and the AP exams provide evidence that these courses are not well aligned. The school in this research study is a school that offers AP courses in all departments. The College Board mandates the curriculum for these courses, and students take an assessment in May based on that curriculum that is administered by the College Board (2019). The school has also adopted Common Core standards for math and English and NGSS standards for science. The College Board has also aligned its courses and exams to Common Core and NGSS, so the courses should be aligned in the curriculum and assessment practices (College Board, 2019).

The weak and moderate correlations between teacher-generated tests and their corresponding AP exams lead me to question the alignment of teacher-generated assessments to the standards that the school has officially adopted. If the teacher-generated tests and the AP exams are both aligned to the same sets of standards, higher correlations would be observed. The leadership of the school should create opportunities and professional development to ensure that the curriculum and teaching strategies are aligned and effective. The time in this professional development should be spent on evaluating the units of study in each class and the assessments that are given to evaluate student achievement in those units of study to ensure that they are aligned to the adopted standards. Adjustments should be made as needed to ensure alignment. It would also be beneficial to provide time for teachers to identify and evaluate released exam questions that have been found to have valid assessment questions and use them as a model for their exams.

An alternative recommendation to increase alignment between lower-level courses and AP course would be to offer pre-AP courses or adopt a new program called Springboard. Springboard is a program that was developed by the College Board for math and English and has curriculum and resources for middle and high school (College Board, 2018). These courses would be more closely aligned to the AP courses so that students who would like to take the corresponding course would be prepared by a foundational course (College Board, 2019).

The leadership of the school should continue to calculate correlations between the scores on the AP exams and their corresponding lower-level course exams to ensure alignment. Additionally, the school leaders could consider a change from requiring all students to take the

SAT, which is the current external test required for graduation, to requiring them to take the ACT. This change would aid leaders in evaluating the validity of their curriculum because the ACT assesses math, science, social studies, reading, and writing (ACT, 2019). This change would provide data to the leadership of the school for all students in all core academic content areas.

The purpose of these recommendations is to increase student achievement in ninth grade in meaningful yet rigorous ways that build feelings of self-efficacy. Laying a foundation in the ninth grade for success in all academics is important for students and their future academic success (Demirci, 2013). Following these recommendations could result in students who are more willing to participate in the science program, as indicated by electives, AP course participation, and majoring in STEM degrees after high school (Demirci, 2013).

Recommendations for future research. While results of this study can be used to support leadership decisions regarding science pathways and general academic supports for ninth graders, questions remain. For the leadership of this school or the leadership of other schools to make the best data-driven decisions for students, further research should be done.

Data should be collected and analyzed from other cohorts of students to validate the results of this study. While demographic makeup of the 2015 cohort of ninth graders is similar to that of others, data from other years should also be analyzed to confirm the conclusions of this study. Additionally, because the correlations between math and science and between math and English were very similar, it is recommended that an additional study should be done to analyze the impact of language skills on science achievement.

It was the original intention of this study to evaluate the data from the physics exam. Due to an exemption policy for 11th graders, the top-performing students did not take the final exam, and an analysis of this data would not have represented the achievement of all students. The study could be repeated with midterm data instead of final exam data because students at this school did not have an opportunity to exempt that exam. This would add significant data points that would add to an understanding of the factors that affect science achievement.

This study should also be repeated at other schools to determine if the trends seen at this school can also be generalized to other schools. If my recommendations are adopted in the school where the study took place, then data on those cohorts of students should be collected to examine future trends. It is my opinion that the difference between the accelerated and nonaccelerated groups may become less significant if students do not begin chemistry before they have completed Algebra I.

Conclusions

The purpose of this study was to determine if there was a significant difference in the achievement of students in science who were on accelerated and nonaccelerated math pathways and if there was a correlation between a student's math and science achievement and between English and science achievement. No current study exists at the high school level demonstrating that Algebra I is a gatekeeper course for science achievement. The results of this study indicated otherwise. To generalize that finding to other students, the study should be replicated in other schools. Additionally, if the pathway changes at the school involved in this study, the leadership of the school should continue to take and analyze data to confirm that a more flexible science pathway increases science achievement.

My analysis demonstrates that math may not be the only factor impacting a student's achievement in science. As a result of this finding, the school leadership should evaluate the curriculum and assessments to ensure that they are supportive of English language learners, engaging, and aligned with standards. Time for professional development should be given to teachers to ensure that these recommendations are implemented with fidelity. Data should be continually analyzed to ensure that teachers utilize best practices effectively so that students have learning opportunities that prepare them for their future high school courses as well as those they will take during postsecondary education.

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Appendix A: IRB Approval Letter

ABILENE CHRISTIAN UNIVERSITY
Educating Students for Christian Service and Leadership Throughout the World

Office of Research and Sponsored Programs
320 Hardin Administration Building, ACU Box 29103, Abilene, Texas 79699-9103
[redacted]

March 11, 2019

Tila Hidalgo

Dear Tila,

On behalf of the Institutional Review Board, I am pleased to inform you that your project titled "Evaluating the Relationships Between Science Class Success and Math Placement in High School:<

(IRB# 19-019)is exempt from review under Federal Policy for the Protection of Human Subjects as:

☐ Non-research, and
☑ Non-human research

Based on:

- Research does not involve interaction or intervention with living individuals, and the information I am collecting is not individually identifiable [45 CFR 46.102(f)(2)] .

If at any time the details of this project change, please resubmit to the IRB so the committee can determine whether or not the exempt status is still applicable.

I wish you well with your work.

Sincerely,

Megan Roth

Megan Roth, Ph.D.
Director of Research and Sponsored Programs