AP Physics Course Enrollments: The Impact of Middle School Algebra and Physics First

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AP PHYSICS COURSE ENROLLMENTS: THE IMPACT OF MIDDLE SCHOOL ALGEBRA AND PHYSICS FIRST

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A Dissertation submitted to the Faculty of the Graduate School,
Marquette University,
in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy

Milwaukee, Wisconsin

May 2022

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The position of the United States in the global STEM economy is being challenged by other countries. There is national concern that the STEM pipeline be strengthened to ensure more students pursue STEM degrees and join the STEM workforce. Although it is important to inspire youth in STEM programs, it is also important to provide all students access to the STEM gatekeeper courses of calculus, chemistry, and physics.

This study determined if taking algebra in middle school and Physics First impacted AP Physics enrollments in a suburban high school. Taking physics in ninth grade, or Physics First, is part of a course sequence known as PCB, or physics-chemistry-biology. This study focused on Physics First without a PCB sequence. Eight years of AP Physics enrollment data was used in this quantitative observational study to look for associations between middle school algebra, Physics First, and AP Physics enrollment, particularly for women. Pearson's Chi-square tests for independence were used to determine if the strength of the association between two variables was statistically significant. Effect size was also determined.

Findings showed a significant association between middle school algebra and AP Physics enrollment during the first four years of data but not the last four years of data. There was a significant association between Physics First and AP Physics enrollment with a medium to large effect size. Taking Physics First benefitted women as increasing numbers enrolled in AP Physics over the eight-year period.

Schools should examine math and science course pathways to ensure that all students have access to STEM gatekeeper courses in preparation for STEM degrees and careers. It is important for students to be algebra ready by eighth grade to access calculus in high school. Physics First provides an initial physics experience with access to AP Physics as a capstone course earning college credit. The conceptual understanding of physics and greater understanding of science and engineering practices developed in Physics First will help students be critical thinkers and problem solvers.

ACKNOWLEDGMENTS

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My sincere appreciation to Dr. Jill Birren for her support and direction in writing this document, Dr. Leigh van den Kieboom for her guidance on algebra education trends, Dr. Meera Chandrasekhar for her Physics First knowledge and expertise, Dr. Fred Sutkiewicz for the initial idea of this dissertation and for supporting me in the statistical analysis of the data, and Dr. Doris Walker-Dalhouse for advising me over the years.

Thank you to the teachers in the science department at this school for bringing Physics First to life and making a difference in the lives of many students. Working with this department was a joy!

A personal note of gratitude goes to my husband, Dr. Paul Luepke, for his encouragement throughout the dissertation process. Thank you to David, Mari, and John for inspiring me to make schools the best they can be for all children. I hope that the findings of this dissertation inspire school leaders to do the same.

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Introduction to the Problem

One ninth-grade student begins high school placed in their first algebra course and biology. Another ninth-grade student begins high school placed in geometry and physics. Which student has the better opportunity to successfully take AP Physics as a capstone high school course and potentially pursue a STEM degree in college? Most people would predict that the student enrolling in geometry and physics has the better opportunity. Yet, in our nation's schools, only 24% of all high school students take algebra prior to ninth grade (U.S. Department of Education, 2018) to be placed in geometry as high school freshmen. Approximately 6% of all high school students take ninth-grade physics or Physics First (White & Tesfaye, 2014). Why is this so? It is because of how algebra and physics are traditionally placed in the curriculum.

Taking physics in ninth grade, or Physics First, is part of a course sequence known as PCB, or physics-chemistry-biology. The point of this sequence is to teach science subjects in the order in which they conceptually build on one another (Lederman,1998). Not all high schools offer a PCB sequence with Physics First. This is important to recognize as most studies focus on the impact of Physics First as part of the PCB sequence; however, this study focused on Physics First without a PCB sequence. It looked at Physics First and middle school algebra in the context of taking AP Physics.

This quantitative observational study examined the impact of algebra and physics course placement on AP Physics enrollments. Eight years of AP Physics enrollment data from a high school offering both Physics First and traditional junior year physics was obtained. Statistically significant associations between taking middle school algebra, Physics First, and AP Physics were determined. The statistical analysis of the archived data provided course placement insights.

These course placement insights may be helpful to students, families, and counselors as they map out course pathways through middle school and high school. Students interested in pursuing STEM degrees need to align pre-college science and mathematics courses to support STEM course success in college. Chemistry, calculus, and physics are considered STEM gatekeeper courses (Redmond-Sanogo, 2016). Course placement decisions in middle school may have an impact on a student's STEM degree options in college. For example, in many school districts, a student must take algebra in middle school to reach calculus in high school in preparation for college. Math and science curriculum leaders need to evaluate course-taking pathways to ensure that all students have access to STEM gatekeeper courses.

Background, Context, and Theoretical Framework

Algebra has traditionally been taught to college prep students for the first time in ninth grade. Many educators believe that students are cognitively ready for algebra as they move from concrete to abstract thinking in the teen years. Students need prerequisite skills from middle school mathematics to be successful in algebra. Most students should be ready for algebra in ninth grade. Contrary to that belief, other educators believe that students should take their first algebra course in eighth grade as a gateway course to more advanced mathematics courses, like calculus, in high school. By introducing algebraic thinking as early as elementary school, many students may have the algebra readiness needed to be successful learners in eighth grade (Silver, 1995; Edwards, 2000; Carraher et al., 2006; Kieran et al., 2016; Schifter et al., 2009; Brizuela et al., 2013).

Physics has traditionally been taught to high school juniors. Many educators believe in teaching physics traditionally which requires advanced mathematics for understanding. Most high school science programs are sequenced this way. Other educators, particularly Nobel laureate Dr. Leon Lederman, have been proponents for teaching physics first in the high school science sequence (Lederman, 1998). The change in sequence accounts for algebra being taught in eighth grade, although Physics First is often taught conceptually, with less emphasis on mathematical problem solving. Ninth-grade physics provides a physics experience for more students, particularly those in underrepresented groups like women. Through this pathway, students may develop the self-efficacy, or belief in their abilities, to succeed in advanced coursework in physics.

The placement of algebra and physics in a student's course sequence from middle school to high school is important because it impacts future school and career opportunities for students. When students take middle school algebra and Physics First, they have greater access to AP Physics as a capstone high school course to potentially pursue a STEM degree in college. STEM degrees are needed in the global economy and lead to higher socioeconomic status which all students should have the opportunity to pursue in the United States. Even if these students do not take AP Physics, their conceptual understanding of physics and greater understanding of science and engineering practices developed in Physics First will help them be flexible thinkers and workers.

Although important, the implications of the placement of algebra and physics in a student's course sequence has not been a topic often studied. A review of the literature found no peer-reviewed studies that looked at the impact of middle school algebra and Physics First on AP Physics course enrollments. Although there are qualitative studies that discuss implementation and characteristics of Physics First programs, quantitative studies of Physics First programs are scarce. Many educators in the field have called for more quantitative studies (Bybee & Gardner, 2006; Goodman & Etkina, 2008; Pasero, 2003).

Quantitative published works found examined Physics First as part of a PCB sequence and looked for associations with higher standardized test scores. For example, Glasser (2012) found a statistically strong association between physics in ninth grade and improved test scores on the mathematics portion of the PSAT. Bouma (2013) found there was a significant impact of teaching PCB on SAT math scores. Meyers (2014) found that Missouri's Biology End of Course assessment was not influenced by the PCB sequence. Gaubatz (2013) found no significant growth gains for PCB students on standardized tests, specifically from the EXPLORE to the ACT science.

However, the Gaubatz (2013) article also reported that offering Physics First in a PCB sequence was associated with increases in honors and AP science course enrollments at a suburban school. The enrollment in AP Physics C doubled during the two years of available data. Although teachers thought there would be fewer AP Physics C enrollments due to the two-year gap between learning concepts in Physics First and AP Physics C, the opposite effect was observed. Goodman (2006) found that enrollment in the total number of students taking AP Physics B and AP Physics C increased over four times during four years of available data.

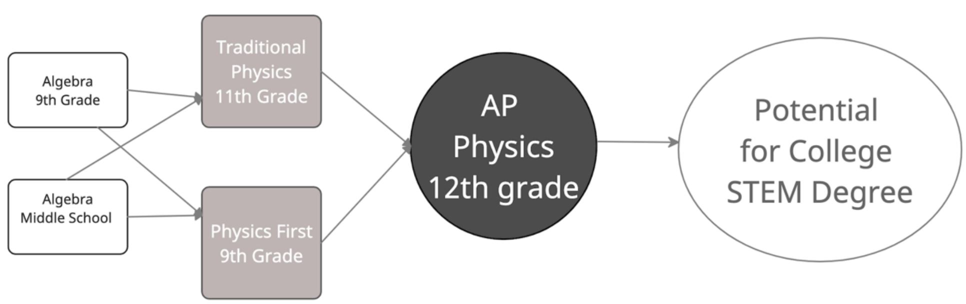
This quantitative research is unique because it traces eight years of AP Physics enrollment data in a suburban high school back to the algebra and physics courses taken by students to look for enrollment patterns. Statistically significant associations between taking AP Physics and middle school algebra or Physics First are explored using a positivist or scientific approach. The positivist approach asserts that scientific knowledge gathered through observational, empirical, and measurable evidence is authentic (Ayiro, 2012). According to Neuman (2014), causal laws can be discovered and used to predict patterns of human activity; in this case, enrolling in AP Physics.

Figure 1 is a conceptual model of this study which is based on Physics First. Physics First is a curricular approach supported by constructivist learning theory. This theory of learning is attributed to the contributions of Dewey, Piaget, and Montessori (Ultanir, 2012). Students actively experience learning as they construct new knowledge from their prior knowledge. Dr. Leon Lederman is credited for introducing Physics First in *ARISE: American Renaissance in Science Education.* He proposed that physics be taught first in high school as an understanding of physics is foundational to chemistry and biology. He wrote, "[learning] is a process of constructing meaning from patterns created from multiple representations of knowledge" (Lederman, 1998). Students use related knowledge and experiences from physics to construct meaning about new concepts in chemistry and biology (Johnson, 2019).

In the model, students who enrolled in traditional physics were in the control group. Students who enrolled in Physics First were in the experimental group. An exception was made in a research question only about algebra. In that case, students who enrolled in 9th grade algebra were in the control group and those in middle school algebra were in the experimental group. The independent variables were the timing of algebra and physics enrollment and the dependent variable was enrollment in AP Physics. Gender was also used as an independent variable in one of the research questions. Enrollment in AP Physics is important as a STEM gatekeeper course leads to a potential to obtain a college STEM degree. Chi-square tests for independence were used to look for statistically significant associations among the variables in the control and experimental groups. Data-based decision making in schools is largely dependent on such analyses.

Figure 1

Conceptual Model of Study



With regards to the future of the Physics First movement, Popkin (2009) quotes Lederman as saying, “the momentum is picking up,” but “we need more physics teachers and lots more data…It will take another decade to get our educational ‘system’ into the 21st century.” The data I have collected in this novel study will hopefully add to the studies described above to better inform the movement.

Statement of the Problem

At the macroscopic level, the United States has been a world leader in science and engineering for decades. With the rise in technology and globalization, that position is threatened by global competition. To compete in the global economy, the perspectives of a diverse STEM workforce are needed. Currently about 20% of the STEM workforce is foreign-born because the U.S. is not producing enough STEM workers (National Science Board, 2022). Within this decade, STEM occupations in the U.S. are expected to grow by 8.0 percent compared to 3.9 percent for all other occupations (Zilberman & Ice, 2021).

To meet this growth, leading scientists and engineers are working to promote STEM career opportunities and access for all. Professional organizations and government entities have structured programs and policies that support the inclusion of people from a wider range of backgrounds and experiences in STEM. Accessibility to STEM by working to reduce the inequities in schools and offering STEM experiences to students historically underrepresented are also being addressed (Ochoa & McCrary, 2021).

Although these efforts are helpful, at the microscopic level, math and science course pathways and opportunities for advanced coursework in the STEM gatekeeper courses should be considered. It is not known how or to what extent a student's decision to enroll in AP Physics is associated with the student taking middle school algebra and Physics First. Having this information may inspire school decision makers to consider new ways of sequencing courses, reimagining teaching methods, and providing supports that will help all students reach their STEM career potential.

Purpose of the Study

The purpose of this study is to provide data to help math and science curriculum leaders make informed decisions on course sequencing that give all students access to STEM gatekeeper courses, specifically AP Physics. The most recent national data shows that most students do not have access to algebra before ninth grade and/or Physics First (U.S. Department of Education, 2018; White & Tesfaye, 2014). Even if a school does not have the resources to offer these courses face-to-face in a school, virtual versions of these courses could be considered as offerings.

This quantitative research traces eight years of AP Physics enrollment data from a suburban high school back to the algebra and physics courses taken by students. Statistically significant associations between taking AP Physics and middle school algebra or Physics First are explored using a positivist or scientific approach. This study includes a control group, students taking physics traditionally as juniors, and an experimental group, students taking Physics First. In a question regarding algebra placement, students taking 9^{th} grade algebra were in the control group and those taking middle school algebra were in the experimental group. Three research questions and null and alternative hypotheses were identified. The independent variables for the questions were enrollment in middle school algebra, enrollment in Physics First, and gender. The dependent variable for all questions was AP Physics course enrollment. The hypotheses were tested using Chi-square analyses and effect sizes. Data-based decision making in schools is largely dependent on such analyses; however, there are few studies with data spanning beyond four years.

Research Questions and Hypotheses

It is not known how or to what extent a student's decision to enroll in AP Physics is associated with the student taking middle school algebra and Physics First. Knowing this information will be helpful to schools considering middle school algebra or Physics First programs. These curricular programs may provide more students the opportunity to access STEM gatekeeper courses and STEM college majors and careers. The U.S. need for a diverse STEM career workforce is a national concern.

The following research questions, null hypotheses, and alternative hypotheses guided this quantitative study:

RQ1: What is the impact of middle school algebra on AP Physics course enrollments?

$H1_0$: Taking middle school algebra was not associated with higher AP Physics course enrollments than taking algebra with Physics First.

H1a: Taking middle school algebra was associated with higher AP Physics course enrollments than taking algebra with Physics First.

RQ2: What is the impact of Physics First on AP physics course enrollments?

$H2_0$: Taking Physics First was not associated with higher AP Physics course enrollments than taking physics as a junior.

H2a: Taking Physics First was associated with higher AP Physics course enrollments than taking physics as a junior.

RQ3: What is the impact of Physics First on the enrollment of women in AP physics courses?

$H3_0$: Taking Physics First was not associated with higher AP Physics course enrollments for women than taking physics as a junior.

H3a: Taking Physics First was associated with higher AP Physics course enrollments for women than taking physics as a junior.

SPSS (Statistical Package for the Social Sciences by IBM) retrospective causal comparative quantitative research methods were used to answer the research questions by looking for relationships between the independent variable (middle school algebra, Physics First, or gender) and the dependent variable, AP Physics enrollment. The questions were answered with the use of cross-tabulation tables, as both variables were categorical (Pallant, 2020, p. 225). Pearson's Chi-square tests for independence were used to determine if the strength of the association between two variables was statistically significant, meaning it was unlikely to have occurred by chance alone. Larger Chi-square values indicate greater association. Non-parametric tests, such as Chi-square tests for two categorical variables, have the potential to be less powerful than parametric tests with continuous variables (Pallant, 2020, p. 215). For that reason, continuity correction values for Chi-square values were reported.

The strength of the association was determined by calculating the effect size. The cross-tabulation tables were small, and so a phi coefficient was used for effect size. The phi coefficient ranges from 0 to 1, with higher values pointing to a greater effect. According to Cohen's criteria for effect size, a small effect is .1, medium effect is .3, and large effect is .5 (Pallant, 2020, p. 228).

Rationale, Relevance, and Significance of the Study

The research questions addressed how or to what extent a student's decision to enroll in AP Physics was associated with the student taking middle school algebra and

Physics First. The association between AP Physics enrollment and taking middle school algebra was compared to the association between AP Physics enrollment and taking Physics First. The association between AP Physics enrollment and gender was also compared to find out if taking Physics First increased the number of women pursuing AP Physics. The researcher had hoped to study the AP Physics enrollments of other subgroups, but the number of cases was too small ($n<5$) for the school studied.

Middle school algebra and Physics First challenge traditional course sequences. Yet they may increase high school opportunities for all students to reach the STEM gatekeeper courses, identified by Redmond-Sanogo (2016), as calculus, chemistry, and physics. As a result, more students could successfully pursue STEM college majors and careers to benefit the United States science and engineering fields. STEM jobs are higher paying jobs which benefit individuals and their families in the economy. Even if a student decides not to pursue a STEM career, there are many benefits to taking physics in high school. Students learn how physics applies to modern life and technology in addition to developing analytical problem-solving skills (Tom, 2011).

For schools offering Physics First, knowing the algebraic thinking that best supports success in Physics First could inform changes in math instruction and course sequencing in grades 6-12. Related to algebraic thinking is the concept of early algebra. Early algebra is a relatively new approach to teaching and learning mathematics even before middle school. It challenges elementary school teachers to incorporate algebraic thinking, such as mathematical relationships, into arithmetic as it is taught. As more students find success in their first physics course, more students may enroll in AP Physics to prepare for STEM careers.

For schools not offering Physics First, knowing the influence that algebra course placement and Physics First can have on AP Physics course enrollments could lead to different course sequencing in math and science from middle school through high school. This could result in a greater percentage of students taking algebra before ninth grade, Physics First, and AP physics. Additionally, students from underrepresented groups may also have greater access to college STEM majors and high paying jobs in the STEM sector of the global economy.

School leaders need data from research on Physics First programs to make changes to curriculum sequences. Existing data has looked at associations between taking Physics First and attaining higher scores on standardized assessments. Although higher standardized test scores are important, choosing to enroll in a rigorous second year of physics indicates the interest, engagement, and commitment to pre-college preparation for STEM degrees. Data reflective of enrollment in a second physics course indicates the potential of students to successfully pursue STEM careers. The second course may be an AP Physics course, IB (International Baccalaureate) Physics course, Advanced Physics course developed by teachers, or a dual enrollment course with a local college. This study is focused on AP Physics enrollment available at the site of the study.

Nature of the Study

The high school in this study implemented a Physics First program in 2007. Based on science department notes, the number of students experiencing physics before graduating increased from 55% to 100% as all students were expected to take physics as either freshmen or juniors. Most students chose to try the new Physics First course as freshmen; however, some opted to take physics as juniors which was the timing most familiar to the community.

Using AP Physics enrollment data from the school student information system over an eight-year period, students were placed in a control group if they took physics during their junior year or in an experimental group if they took Physics First. In the question regarding algebra enrollment, students were placed in a control group if they took 9th grade algebra or in the experimental group if they took middle school algebra. After loading the data into the SPSS software program, Pearson's Chi-square tests for independence (Pallant, 2020, p. 225) were used to determine if the strength of the association between two variables was statistically significant, meaning it was unlikely to have occurred by chance alone. Research questions were answered accordingly.

Definition of Abbreviations for Terms

Throughout the study, some abbreviations for terms were commonly used. They include:

AAPT: The American Association of Physics Teachers, founded in 1930 as the first association to improve the teaching of physics.

ANAR: *A Nation at Risk,* a 1983 report from the United States National Commission on Excellence in Education that is seen as a landmark event in the history of education.

AP: Advanced placement or college level courses taken in high school for college credit through the College Board.

CCSSM: Common Core State Standards for Mathematics released in 2010 and used by most states.

NAEP: The National Assessment of Educational Progress, a standardized assessment given throughout the U.S. covering different grades and subject areas.

NCTM: The National Council of Teachers of Mathematics, founded in 1920 to improve the teaching of mathematics.

NGSS: The Next Generation Science Standards released in 2013 and used by many states.

PCB: A course sequence of physics-chemistry-biology which builds scientific concepts in a logical order.

Physics First: The teaching of physics in ninth grade which often includes a PCB sequence.

SPSS**:** Statistical Package for the Social Sciences by IBM was used for the study.

STEM: A grouping of the academic disciplines of science, technology, engineering, mathematics commonly used in education.

TIMSS: Trends in International Mathematics and Science Study is an assessment given to compare mathematics and science achievement in students from many countries.

Assumptions, Limitations, and Delimitations

There are many assumptions, limitations, and delimitations present in this observational study of archived enrollment data. The following assumptions were present in this study:

1. It is assumed that students enrolled in AP Physics based upon a positive experience in math and physics. Students with a positive experience developed the self-efficacy, interest, and engagement to take a second year of physics.

2. It is assumed that students were in the same school environment for four years and exposed to the same STEM influences, such as school events, which may have impacted their course enrollment decisions.

The following limitations/delimitations were present in this study:

1. The researcher was the science department chair at the school during the time this data was collected; however, the data was analyzed after the researcher left the school due to retirement.
2. There was no measure of student self-efficacy, interest, and engagement in physics as this was an observational study based on archival data.
3. The influence of teachers was not quantified as this was an observational study based on archival data.
4. The study was limited by a small number of cases so that some Chi-square tests could not be run.

Summary and Organization of the Remainder of the Study

This chapter has introduced the problem of a lack of STEM majors coming through the STEM pipeline, possibly due to the timing of algebra and physics in the course sequences of middle school and high school. The STEM gatekeeper course of AP Physics is directly impacted. This quantitative observational study of archival enrollment data from an eight-year period provided insights into this issue. It is hoped that this information will provide the data needed to help math and science curriculum leaders make decisions to help give all students the potential to enter the STEM pipeline successfully, attaining STEM careers and higher socioeconomic status while helping the United States lead the world in scientific discoveries and innovations.

Chapter 2 reviews the literature on the debate of when to offer algebra and physics in the curriculum. AP Physics course enrollments are also discussed along with their significance to the STEM pipeline, particularly for women. Chapter 3 explains the methodology used in researching the impact of middle school algebra and Physics First on AP course enrollments. Chapter 4 presents the results of the study. Chapter 5 discusses those results, makes recommendations, and concludes the study.

CHAPTER 2: REVIEW OF LITERATURE

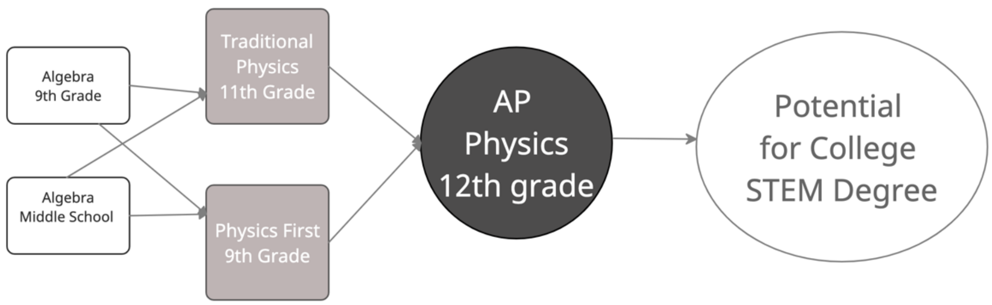
Introduction

Only 24% of all high school students take their first algebra course prior to ninth grade (U.S. Department of Education, 2018) to be placed in geometry as high school freshmen. Approximately 6% of all high school students take Physics First (White & Tesfaye, 2014). Physics First is a curricular approach in which physics is taught in ninth grade instead of the more traditional eleventh grade (Lederman, 1998). Students who take middle school algebra have the math background useful in Physics First; however, the physics course can be taught conceptually to support students who take algebra concurrently. If all students could take their first algebra course before ninth grade and take Physics First in high school, they would have greater access to AP Physics as a capstone high school course, potentially pursuing a STEM degree in college. This is important for school leaders to know because there is a high demand for STEM degrees in the United States to compete in the global economy. STEM careers can lead to higher paying jobs and greater socioeconomic status, which all students should have the opportunity to pursue.

The conceptual model of this study is based on Physics First. Physics First is a curricular approach supported by constructivist learning theory (Lederman, 1998). Students in AP Physics in the same high school over an eight-year period followed one of four pathways: middle school algebra and traditional physics, middle school algebra and Physics First, ninth grade algebra and traditional physics, or ninth grade algebra and Physics First. Students in the traditional physics pathway were in the control group, and students in the Physics First pathway were in the experimental group. In a question about algebra enrollment, students who took 9th grade algebra were in the control group and those who took middle school algebra were in the experimental group. The taking of AP Physics has been associated with greater STEM career interest (Sadler et al., 2014). Figure 1 is a conceptual model of the study.

Figure 1

Conceptual Model of Study



Historically, the placement of algebra and physics in the curriculum has been contentiously debated. The purpose of this review of literature is to examine the arguments supporting different timing of the course placements for algebra and physics, independent variables in this study, in the curriculum sequence. The first part of the review addresses the placement of algebra in the math curriculum; the second part of the review addresses the placement of physics in the science curriculum. The third part of the review examines AP physics course enrollments, the dependent variable in this study, relative to the pursuit of STEM degrees, particularly for women, an additional independent variable. The different AP physics courses offered, reasons that students enroll in the courses, and the significance of taking physics in the pursuit of STEM majors and careers, particularly for women, are explored.

Algebra Placement in the Math Curriculum

Educators have been split on their opinions as to when to offer the first algebra course in the math curriculum. In the past, algebra was taught in ninth grade to college-prep students while others took a general mathematics course. In 1983, *ANAR* initiated educational reforms, including a requirement that algebra skills should be taught to all students in grades K-12 (United States National Commission on Excellence in Education, 1983). Eventually leaders argued that more students should be taught algebra in eighth grade to provide access to advanced math courses which prepare students for rigorous math and science courses needed for STEM degrees in college (National Mathematics Advisory Panel, 2008). Additionally, engaging all students in algebra before high school would diminish the role of algebra as a sorter of students. Taking algebra before high school allows students to take calculus before college, providing access to STEM degrees, such as those in the field of engineering.

Algebra After Eighth Grade

Kilpatrick & Izsak (2008) provide a history of algebra in the school curriculum. Historically, algebra has first been taught in ninth grade. Algebra became part of the high school math curriculum during the nineteenth century as colleges were increasingly requiring algebra for admission. In 1892, the Committee of Ten was appointed by the National Education Association to articulate courses, methods, and content between the high school and college. The subcommittee on mathematics recommended that introductory work in algebra come earlier. After the 1920s, a general mathematics course developed that became a popular alternative to algebra. Two curriculum tracks emerged in ninth grade for math: algebra for the college bound or general math for everyone else.

After World War II, the Commission on Post-War Plans of the NCTM recommended that some students take algebra in ninth grade but that the majority should take general mathematics. The algebra curriculum was modified from the mid 1950s to the mid 1970s to prepare capable students for college.

A great concern in the placement of the first algebra course is developmental readiness. Cognitively, adolescent students are in the process of moving from concrete to abstract reasoning (Ausebel, 1964). Although some students may have the abstract thinking skills to take algebra before ninth grade, others may not. Susac et al. (2014) did a quantitative study involving 331 students in Croatia from the ages of 13-17. Using computerized testing of algebra tasks, it was determined that transitioning from concrete to abstract reasoning requires a lot of time. Simzar et al. (2016) found that while previously high-achieving students may benefit motivationally from eighth grade algebra placement, placing previously average- and low-performing students in algebra can potentially compromise their motivation for mathematics. It is crucial that students have the prerequisite skills needed for algebra before being placed into the class.

In summary, algebra was historically taught in ninth grade to students planning to attend college. Educators argue that more ninth grade than eighth grade students are cognitively ready for algebra as they move from concrete to abstract thinking. Students need prerequisite skills for algebra to be successful, otherwise their motivation may be compromised.

Algebra in Eighth Grade

ANAR (United States. National Commission on Excellence in Education, 1983) was the impetus for the NCTM to begin a standards-based reform of algebra in the later part of the twentieth century along with promoting the need to make algebra available to all students. Algebra was recognized as a gatekeeper course to college (Edwards, 2000; Silver, 1997). Approaches to engage middle and high school student interest in the content were developed. In December of 1993, the U.S. Department of Education's Office of Educational Research and Improvement sponsored a conference on reform in algebra, the Algebra Initiative Colloquium. Fifty-one participants worked in groups to address issues related to algebra, including creating an algebra experience for all students in K-12, educating teachers, reshaping the algebra curriculum, and renewing algebra at the college level (Lacampagne, 1995).

One of the recommendations that came from the Algebra Initiative Colloquium was that all students should have a year of algebra before the end of eighth grade (Schoenfeld, 1995). Several arguments supported this recommendation. First, algebra was recognized as a passport to the job market and a matter of equity. Second, engaging all students in algebra before high school would additionally diminish the role of algebra as a sorter of students. Finally, having taken algebra in middle school, all students would have access to the advanced math courses in high school needed for college preparation and success.

Data on who enrolls in algebra and when they enroll supports greater access to advanced math. Stein et al. (2011) analyzed data sets from the Early Childhood Longitudinal Study, the High School Transcript Study, NAEP, NAEP Long-Term Trends, and the TIMSS to determine who enrolls in algebra. They measured approximately 30% of the nation's eighth graders enrolled in algebra in 2009, as ninth grader enrollment in algebra slightly decreased. The U.S. Department of Education

(2018) analyzed data from the 2015-16 Civil Rights Data Collection (CRDC) and found that only 24% of all eighth graders were enrolled in their first algebra course. Female students (25%) enrolled at a slightly higher rate than male students (22%). Schmidt and McKnight (2012) reviewed several studies to reveal that the educational background of the parents and where they live is related to the opportunities a student has to access algebra. Students living in communities where parents are college-educated and affluent have greater access to algebra in eighth grade than those living in communities of low socioeconomic status.

Dr. Frances Spielhagen studied the impact of access to eighth grade algebra on students and found that students had little, or no advantage being held back from algebra in eighth grade (Spielhagen, 2006a). Spielhagen (2006b) also found that students who complete algebra in the eighth grade stay in the mathematics pipeline longer by taking advanced coursework. They attend college at a greater rate than those who do not. The stronger the preparation for algebra prior to eighth grade, the greater the chances a student has for success. Incorporating algebraic thinking and skills in pre-K-12 is what the NCTM encourages for all students (NCTM, 2014). As students gain familiarity with numbers and operations and work through real-life applications, they start to develop their abstract reasoning. This enhances the algebraic thinking skills needed for the first course in algebra. The importance of algebraic thinking and algebra before high school has been recognized at the federal level.

In 2006, President George W. Bush established the National Mathematics Advisory Panel within the Department of Education to strengthen mathematics education in the United States. The Advisory Panel released *Foundations for Success* in 2008. This report encouraged that every school district prepare all students to take algebra by eighth grade (National Mathematics Advisory Panel, 2008). The report detailed the benchmarks for students in PreK-8 necessary for preparation for algebra. These benchmarks were informed by the curricula of other countries who performed better on the TIMSS. Middle school math curricula in many countries includes algebra and geometry because the foundation for these courses is laid earlier (Schmidt & McKnight, 2012). Although TIMSS scores for Grade 8 improved in 2011 and 2015, the average scaled scores of countries including Singapore, Korea, China, Hong Kong, Russia, Kazakhstan, Canada, and Ireland were higher (Mullis et al., 2016). However, it is important to note that all countries do not test all students. Students from countries who perform better on standardized tests are the next generation of STEM professionals who may outperform the United States in the world economy. Therefore, schools need to consider earlier placement and integrate algebra skills throughout the curriculum.

The 2017 Hanover Research report, *Best Practices in Math Course Sequencing and Integrated Math*, discussed the challenge of knowing when and how to integrate algebra into the math course sequence to prepare students for advanced mathematics courses in high school. Students who take their first algebra course before high school can experience calculus before college; for that reason, algebra is often viewed as a gatekeeper course. In their study of algebra interventions, Hott and Dibbs (2020) found that access to, and completion of, a quality algebra course by eighth grade is positively linked with success in higher-level mathematics courses, admission to college, and entry into STEM majors. Schmidt and McKnight (2012) write about this in *Inequality for All: The Challenge of Unequal Opportunity in American Schools.* They discuss tracking in middle schools and how it negatively influences high school course selection. They point out the importance of the algebra decision in middle school and how it impacts access to math courses sequentially in high school and college.

The NCTM issued a position statement in 2014 that states,

> "All students should have access to algebra in a pre-K-12 mathematics curriculum, including opportunities to generalize, model, and analyze situations that are purely mathematical and ones that arise in real-world phenomena. Algebraic ideas need to evolve across grades as a way of thinking and valuing structure with integrated sets of concepts, procedures, and applications."

This vision of incorporating algebraic thinking and skills in grades pre-K-12 is thought to prepare students for success in their first algebra course. The idea of bringing algebraic thinking into middle school prior to an algebra course has been supported by advocates such as Silver and Edwards. Silver (1995) emphasizes thinking, reasoning, communication, and problem solving in the middle grades in preparation for algebra. Edwards (2000) is a proponent of informally introducing the "big ideas" of algebra in the early middle school grades in preparation for the first course.

Related to algebraic thinking is the concept of early algebra. Early algebra is a relatively new approach to teaching and learning mathematics even before middle school. It challenges elementary school teachers to incorporate algebraic thinking, such as mathematical relationships, into arithmetic as it is taught. This is different than teaching arithmetic until middle school and then adding in algebraic reasoning. Early algebra and algebraic thinking could prepare all students for algebra earlier than ninth grade, as longitudinal research has revealed (Carraher et al., 2006). Early algebra includes developing an understanding of mathematical relations, patterns, and structures presented in an engaging way to young students (Kieran et al., 2016). For example, elementary school teachers found that when patterns are observed and generalizations are emphasized, a wide range of learners develop foundational knowledge (Schifter et al., 2009). Brizuela et al. (2013) reported statistically significant positive impacts of early algebra for students who experienced it compared to those who did not. The same study reported that other researchers had found early algebra promoted improvement in later algebra and math learning.

In summary, all students should take algebra in eighth grade as a gateway course to more advanced mathematics courses in preparation for college and a career. The earlier a student takes their first algebra course, the greater the number of advanced mathematics courses to which the student will have access, particularly calculus. Yet students taking algebra in eighth grade need to be algebra ready, having learned key ideas and problem-solving over the course of their education. The NCTM has supported this initiative through its position statement. It is hoped that algebraic thinking and early algebra will better prepare all students for algebra in the future, whenever they take their first course. Such preparation is aligned with taking physics in ninth grade.

Physics Placement in the Science Curriculum

There are two main arguments for when physics should be taught in the science curriculum; many argue that physics should be taught to high school juniors, while others argue that it should be taught to high school freshmen. As high schools became more diverse in the early part of the twentieth century, a smaller percentage of the student body planned to attend college (Sheppard & Robbins, 2003). The need for physics as a college preparatory course diminished, resulting in a nationwide decline in physics enrollments (U.S. Bureau of the Census, 1975). Historical events including the evolution of modern physics around the time of World War II, the launch of Sputnik, the release of *ANAR* and the TIMSS results led Dr. Leon Lederman, physicist, and Nobel laureate, to propose that physics be taught first in the high school science sequence.

Physics After Ninth Grade

The historical debate of when to teach physics resulted in physics being taught to juniors. Most students took a biology-chemistry-physics sequence during the nineteenth century; however, the Committee of Ten called for physics to be taught before chemistry as it was foundational to many sciences (DeBoer, 1991; Sheppard & Robbins, 2003; Sheppard & Robbins, 2009). Much of the discussion centered on two concerns: 1) which course logically supported the other and 2) whether students had the math skills needed for success in physics. By 1918, high school enrollments increased, and it was recognized that not all students planned to attend college. The Commission on the Reorganization of High School Curriculum met that year to propose a differentiated curriculum to educate all students. The Commission changed physics to include laboratory instruction focused on problems or projects in 1920. Offering physics last in the sequence gave students more preparation in mathematics before taking the course (National Education Association of the United States, 1920). Thus, most high schools offered a biology-chemistry-physics sequence from then on.

Many physics teachers argue that physics should be taught to juniors using advanced mathematics including trigonometry. These teachers are more comfortable with the traditional approach to teaching physics rather than the conceptual approach.

Learning to teach physics conceptually would require staff development, time, and effort. It is also challenging to find the school leadership capable of effectively implementing a move to ninth-grade physics; therefore, continuing to teach physics to juniors makes sense to many. An example of a school district that did not successfully implement Physics First is San Diego. An article in the San Diego Union-Tribune discussed that millions of dollars were spent on new textbooks and staff development to engage more students in physics and yet achievement remained low (Gao, 2006). Students who struggled with algebra found the course difficult. Additionally, 40 science teachers needed to earn credentials to teach physics to cover all classes. Content, pedagogy, student learning, and implementation of *Active Physics* were delivered through summer institutes, monthly meetings, content courses for out-of-discipline teachers, common planning periods, and site-based science administrators (Taylor, Powell, et al., 2005). Despite staff development, time, and effort, the move to ninth-grade physics was unsuccessful.

In summary, teaching physics to juniors is what most schools and teachers have done for years as it is easiest for schools to accommodate. It supports the traditional method of teaching physics in which advanced mathematics are used to understand physics. High school juniors are more likely to have the math and science skills for success in physics due to their prior coursework.

Physics in Ninth Grade

ANAR and the TIMSS results kept policymakers focused on improving education through the standards and accountability movement. Students from the United States were outperformed by other countries so Dr. Leon Lederman, physicist, and director of

Fermi National Accelerator Laboratory, stepped forward to improve science education. In 1998, Dr. Leon Lederman released *ARISE: American Renaissance in Science Education* and referenced *ANAR*. He wrote, “The sequence is inappropriate and does not respect developments in the disciplines over the past century, nor does it respect changes in mathematics teaching, with algebra now introduced as early as eighth grade” (Lederman, 1998, p.5). Dr. Lederman proposed making physics the first course in the high school science curriculum.

Dr. Lederman’s proposal to teach physics first in the high school science course sequence provides more students access to physics. According to the American Association of Physics Teachers Statement on Physics First, “Physics First”—has the potential to advance more substantially the AAPT’s goal of Physics for All, as well as to lay the foundation for more advanced high school courses in chemistry, biology, or physics (AAPT, 2002). The AAPT supported the development of Physics First programs, and the AAPT High School Committee released a pamphlet that was reprinted in 2009. It highlights that only 30% of U.S. high school students complete a physics course and exposing students to physics in ninth grade provides the foundation for understanding engineering concepts and provides real-world connections to mathematical concepts (AAPT, 2009).

The goal of Physics for All was significant in providing diverse student groups access to physics. In *Broadening the Base: High School Physics Education at the Turn of a New Century*, the results of a nationwide survey of high school physics programs and teachers, conducted regularly by the American Institute of Physics, was examined by Neuschatz and McFarling (2003). They found that historically, women and minorities have been underrepresented in high school physics. In the 2001 survey, women made up about half of the enrollment in introductory physics classes. In 1990, 41% of women took physics and in 2001, 46% of women took physics. The move from a mathematical to conceptual approach for teaching physics has increased the number of students enrolling in first year physics. Non-traditional students have been more willing to take the course.

One of the earliest narratives on teaching physics to ninth graders came from Paul Hickman (1990) at Cold Spring Harbor High School in New York. He reported advantages which included that algebra was fresh in the minds of students, students were eager to succeed and felt a sense of accomplishment. Assessments showed that ninth graders performed as well as upperclassmen in physics. Math teachers noticed that students were more interested in math. The school increased offerings in AP science and enrollment in science senior year increased. Students overall were less fearful of physics, particularly young women.

Accounts of schools from the Northeast that used Physics First reported positive impacts for students. Livanis (2006), at Stuyvesant High School in New York, found that ninth grade physics students outperformed students two years older in the same course of study as indicated by the physics Regents exam scores at the mastery level. They also outperformed their classmates on the chemistry Regents exam at the mastery level, tended to study more in the physical sciences, and many took upper-level physics courses later. O'Brien and Thompson (2009) surveyed students in seven Maine high schools to compare content understanding, gains, attitudes, and expectations of students taking physics in ninth grade as compared to those taking it in twelfth grade. They found that a student-centered instructional approach benefitted students more than a traditional lecture-based approach. Ninth grade students showed growth, particularly those in honors-level courses.

Staffing Physics First classrooms is a challenge, and an effective approach to professional development for teachers was described by Rebello et al. (2011). *A TIME for Physics First* was a National Science Foundation Math and Science Partnership that included a leadership component to develop high school ninth grade physics teachers into teacher-leaders for the Physics First reform. Leadership activities were based on a model developed by the Missouri Center for Math and Science Teacher Education, funded by the U.S. Department of Education. Seven core districts participated in the three-year program that included both face-to-face and online components (Hanuscin et al., 2012). The National Science Foundation grant funded the program from 2009-2015. Over 60 teacher-leaders learned to teach Physics First through a curriculum based on inquiry and modeling called *A TIME for Physics First.* This initiative reached about 18% of Missouri's high school students (Bergin et al., 2015). According to the project results, freshmen students who participated in *A TIME for Physics First* reported greater motivation and in-class engagement than comparison students. However, years later as seniors in high school and university students, *A TIME for Physics First* participants did not report greater motivation or science course-taking than comparison students (Bergin et al., 2015).

A textbook commonly used in ninth-grade physics is *Conceptual Physics* by Paul Hewitt. Hewitt believes that students are less intimidated by physics when they focus on using math to understand the relationships between concepts instead of to manipulate algebraic equations (Hewitt, 1990). Dreon (2006) surveyed schools in Pennsylvania and found that of the thirteen schools that responded, ten used *Conceptual Physics* as the textbook because of its basic approach to mathematics. Tesfaye and White (2014) looked at the textbooks used in physics classrooms in a nationwide survey of public and private high schools across the United States. These researchers collected data specifically on textbook use in Physics First classes, defining Physics First as a type of conceptual physics class in which physics is offered first in the sequence of high school science courses. Out of 93 teachers of Physics First in 2009, 74% used *Conceptual Physics;* in 2013, the percentage was 53%. The conceptual approach is more commonly used in ninth grade physics classrooms according to reported textbook use.

Two studies, one qualitative and one quantitative, provide insights on differences between the two teaching approaches. The qualitative study of two groups of Australian physics teachers, traditional and conceptual, found that traditional teachers see physics as mathematical and abstract. They value mathematical problem solving, laboratory work, and lecturing. Conceptual teachers see physics as difficult because the ideas are difficult to understand. They value students constructing their own learning of concepts and sharing ideas in discussions before solving problems both qualitatively and quantitatively (Mulhall & Gunstone, 2012). In a quantitative study, Tashdere and Eryilmaz (2009) looked at two groups of students taught traditionally, and two groups of students taught conceptually in English in Turkey for three weeks. Using an achievement test and an attitude assessment, they found that the students taught conceptually had a better understanding and more positive feeling of physics than those taught traditionally. The conceptual approach to teaching and learning physics worked for a wider range of students than the traditional approach.

The standards movement has also supported the potential for students to be successful in Physics First. In 2010, the CCSSM (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) were released which include a domain for operations and algebraic thinking that spans kindergarten through grade 5. Algebraic thinking extends into the following grades as students learn about algebraic expressions and use them to solve real-life problems. The NGSS (NGSS Lead States, 2013) were released in 2013 and include connections to the CCSSM for each standard. Each standard also includes science and engineering practices, including math and computational thinking as applicable.

The synergy between the mathematics and science standards working in tandem across the grades benefits students with greater preparation for success as they advance through their schooling. For example, the speed of a wave equals its frequency multiplied by its wavelength. This pattern is noted in middle school science and supported by the concept of ratios which is used to recognize and represent proportional relationships between speed, frequency, and wavelength. In high school, an expression is written and rearranged to solve for quantities of interest. The science and math standards are cross-referenced in the NGSS document to show the interconnectedness of the disciplines across the grade levels. Appendix A is a table showing the NGSS and Common Core Math Standard Connections.

In summary, teaching physics to high school freshmen provides a physics experience to more students, particularly those in traditionally underrepresented groups.

The eagerness that freshmen bring into the classroom can result in greater interest in physics then and as a future capstone class. Effective staff development and the use of a conceptual teaching approach support Physics First. The alignment between the CCSSM and NGSS provides a pathway for students to prepare for and access Physics First.

AP Physics Course Enrollments and STEM

One of the ways to measure the success of an introductory course in physics, like Physics First, is to see how many students enroll in an advanced physics course later in high school (Pasero, 2003). Enrolling in a second course indicates that students felt successful in the first course and found it interesting enough to return for advanced content. Advanced physics courses often are AP physics courses but also include IB (International Baccalaureate) Physics, advanced physics, and dual credit physics offered with a local college. Quantitative studies have shown that students with a physics background may pursue STEM majors after high school and attain jobs in STEM fields that support the global economy (Bottia et al., 2015; Redmond-Sanogo et al., 2014; Sadler et al., 2014).

Students are attracted to AP physics courses because they provide college credit for physics and benefits those seeking STEM-related majors in college. Having the prerequisite coursework to take AP physics is challenging. Students need a first course in physics as well as a strong math background. Many schools do not offer AP physics because they do not have enough students with the preparation and interest to fill classes. About 41% of high schools across the United States do not offer any type of physics (U.S. Department of Education, 2018). This section looks at the different AP physics courses offered, reasons that students enroll in the courses, and the significance of taking physics in the pursuit of STEM majors and careers, particularly for women.

AP Course Offerings

According to Physics First teacher Bob Bessin, “There should be a later physics option for those who want to go further and deeper and use more mathematics, but to say that physics can only be taught as a math-based course is elitist, because it denies to all but the mathematically qualified the breadth of what physics can offer” (Bessin, 2007, p. 134). AP physics is the later physics option for many students nationwide. Students have several options from which to choose. Up until 2014, the College Board offered AP Physics B and AP Physics C, which includes one semester of mechanics and one semester of electricity and magnetism, as second-year physics courses. The 2012-2013 Nationwide Survey of High School Physics Teachers (White & Tesfaye, 2014) found that 63% of AP Physics B students took that course as their first physics course as compared to 27% of AP Physics C students. At that time, the College Board changed the curriculum so that AP Physics B was replaced by two courses, AP Physics 1 & 2, with AP Physics 1 being the first-year course, and AP Physics 2 being the second-year course (College Board). AP Physics B, AP Physics 1, and AP Physics 2 are algebra-based whereas AP Physics C is calculus-based.

Reasons to Enroll in AP Physics

Students take AP physics courses to learn college level introductory material while earning college credit. Students may progress to sophomore college classes with credit for freshman college classes from scoring high on an AP physics exam (Pushkin, 1995). For students planning to enter engineering, AP Physics C is the course to take. For students planning to enter any STEM career, AP Physics B, AP Physics 1, and AP Physics 2 are great preparation for college. The appearance of these rigorous courses on a high school transcript are beneficial for college admission and scholarship competitions, even if a student chooses not to take the AP exam.

The number of students who have taken AP physics exams since 2000 has increased overall; however, the number of students who took AP Physics 1 and AP Physics 2 exams decreased (College Board, 2021). This provides a look at nationwide course enrollment trends, although not everyone who takes the courses will take the exams due to interest, cost, and colleges to which one has been accepted. Given that the purpose of this study is to determine the impact of Physics First on AP physics course enrollments, it is important to know the national enrollment trends as a comparison.

Although college credit for physics is an important consideration when enrolling in AP Physics, Maltese and Tai (2011) analyzed school factors to show that students who pursue STEM in college have a growing interest in math and science that moves them forward. A growing interest in math and science as the result of strong self-efficacy, the personal belief that oneself has the skills and knowledge necessary to be successful, may also influence the decision to enroll. In other words, self-efficacy leads to the interest (Lent et al., 2008), although not all researchers agree (Maltese & Tai, 2011).

Physics Course Taking and STEM

Several studies have looked at high school course taking and STEM majors. Bottia et al. (2015) analyzed quantitative data from students in North Carolina’s 2004 high school graduating class who also matriculated into the University of North Carolina system. They found there was a positive significant relationship between students' intent to major in STEM and having taken physics in high school. Redmond-Sanogo et al. (2014) found that high school student success in precalculus/trigonometry, calculus, chemistry, and physics was predictive of college success in the STEM gatekeeper courses of calculus, chemistry, and physics. This finding held true regardless of gender or ethnicity. Students who took physics in high school tended to do better in introductory college physics than students who did not take physics in high school. Similarly, Sadler et al. (2014) found that when high school students take calculus, a second year of chemistry, or one or two years of physics, their interest in STEM careers increased. Sadler and Tai (2000) did an extensive study to prove this point while considering factors impacting success.

White and Tesfaye (2011) studied enrollment patterns of women in high school physics. Although women enrolled in a first year of physics, they did not enroll in a second year of physics at the same rate as men. They found that mathematical rigor was not a factor impacting AP Physics course enrollment. A study by VanLeuvan (2004) found that there was a statistically significant decrease in interest in math and science careers among women between seventh grade and high school graduation. This may suggest that a lack of interest in physics is what drives the lower enrollment. The reasons for women not taking AP Physics are unclear.

The industries that drive the United States economy are largely STEM-related as they include energy, healthcare, transportation, agriculture, and information. When there are not enough college graduates to fill STEM jobs, there is a cause for concern. Xue and Larson (2015) conducted an extensive study to determine if there are enough STEM graduates and made several conclusions. The demand depends upon how and where you look; however, there are shortages in areas such as defense because of the need for U.S. citizenship for security clearance. About 20% of the present STEM workforce is comprised of foreign-born workers (National Science Board, 2022).

Within this decade, STEM occupations in the United States are expected to grow by 8.0 percent compared to 3.9 percent for all other occupations (Zilberman & Ice, 2021). To meet this growth, leading scientists and engineers are working to promote STEM career opportunities and access for all. Professional organizations and government entities have structured programs and policies that support the inclusion of people from a wider range of backgrounds and experiences. These programs and policies work to reduce inequities in schools by offering STEM experiences to students historically underrepresented (Ochoa & McCrary, 2021).

Women have historically been underrepresented in many STEM fields. In the latest report from the National Center for Science and Engineering Statistics (2021), the number of women receiving bachelor's and master's degrees in science and engineering has decreased slightly since 2008 while the number of women receiving doctorate degrees has increased slightly. Women earn about half of all bachelor's degrees in science and engineering, 44.7% of all master's degrees, and 41.2 percent of all doctorate degrees. These degrees are more prevalent in the fields of psychology, biological sciences, and agricultural science. Fewer degrees are earned in computer science and engineering.

The United States Census Bureau (2021) reported that women make up half of all workers but only 27% of STEM workers. They made up 47% of all math workers and

45% of all biological and physical science workers. However, they made up about 25% of computer workers and 15% of those in engineering fields. There is a gender gap in earnings.

Researchers have tried to understand the underrepresentation of women in the STEM fields which are more math intensive. Wang and Degol (2016) reviewed over 30 years of research in psychology, economics, sociology, and education to determine that many factors interact within each individual, so the problem is complex. They include absolute ability differences, relative ability strengths, career preferences, lifestyle preferences, field-specific ability beliefs, and gender stereotypes and bias.

Monica Plisch, the associate director of education and diversity at the American Physical Society wrote, “Physics is often seen as an elite discipline that requires a lot of math and is only for college-bound students. This view is not only outdated, but it also risks underestimating students’ abilities and cutting off their future opportunities in STEM” (Heitin, 2016). Providing students with a strong background in math that culminates in calculus and providing students with a science course sequence including chemistry, physics, and the option to take a second year of either or both is essential in building a STEM pipeline to fill the need for workers in STEM careers. It is also important to encourage and support all students, including women and minorities, as they take these challenging courses in high school.

In summary, the economic future of our country depends on STEM majors, and that driving force impacts the number of students pursuing AP physics courses in high school for college credit and advancement. Not only is the foundational knowledge important from these courses, but also the interest and engagement students find early in these subjects. When students take Physics First, they may find the self-efficacy to enroll AP Physics. Physics First can serve as that first physics course that leads to an AP course, particularly for the algebra-based AP Physics 1, AP Physics 2, and the calculus-based AP Physics C.

Summary

It is interesting to note the similar historic patterns in the curricular shifts leading to both eighth grade algebra and Physics First. Early in the twentieth century, algebra and physics were reserved for only college prep students. After recognizing the deficits in math and science education following World War II and the launch of Sputnik, reforms brought about new ways of teaching these subjects. *ANAR* and the standards movement challenged educators to make algebra and physics accessible to all students. Thus, algebraic thinking in pre-K-12, early algebra, and eighth grade algebra developed to support algebra for all. The NGSS science and engineering practices and conceptual approach to teaching Physics First developed to support physics for all.

Interest, engagement, and self-efficacy from early math and physics course experiences may support the student decision to take an AP Physics course which places them on the pathway to a STEM degree and career. No studies have been found that look for associations between middle school algebra and Physics First on AP Physics enrollments or why they may or may not exist. This study assesses the power of that algebra and physics accessibility on AP Physics course enrollments leading toward STEM degrees and careers. Chapter 3 describes the methodology used in the study.

CHAPTER 3: METHODS

Introduction

The historical literature on the placement of algebra and physics in the school curriculum revealed a professional debate about the timing of when to offer each course. At the beginning of the 20th century, algebra and physics were reserved for students planning to attend college; however, mid-century historical events pushed the need for more students to take algebra and physics. That need has surged in the 21st century as STEM worker availability is critical for the U.S. to compete in a global economy. The recent pandemic has shown that human survival depends upon innovation and knowledge in STEM. The school curriculum needs to change to adapt to these needs.

National standards in science (NGSS) and mathematics (CCSSM) designed for the next generation of learners are slowly being adopted in practice. Algebraic thinking in pre-K-12, early algebra, and eighth grade algebra are emerging to support algebra for all. The NGSS science and engineering practices and conceptual approach to teaching Physics First are supporting physics for all. It can be argued that the power of algebra before high school and Physics First for all is that it provides students greater accessibility to AP Physics courses and STEM degrees and careers. Even if students do not take AP Physics, their conceptual understanding of physics and greater understanding of science and engineering practices developed in Physics First will help them be flexible thinkers and workers in the post-pandemic world.

This study was designed to determine if eight years of AP Physics course enrollment data from a Physics First high school supports this argument. The purpose of this study was to provide data to help math and science curriculum leaders make informed decisions on course sequencing that give all students access to STEM gatekeeper courses, specifically AP Physics. The most recent national data shows that most students do not have access to algebra before ninth grade and/or Physics First (U.S. Department of Education, 2018; White & Tesfaye, 2014). Even if a school does not have the resources to offer these courses face-to-face in a school, virtual versions of these courses should be considered as offerings.

This chapter begins with the research questions along with null and alternative hypothesis for each question. A positivist research methodology for the study is discussed. The quantitative observational research design includes an experimental and control group along with dependent, independent, and controlled variables that are described. The school population and sample are outlined. The collection of data, and use of SPSS statistical software to analyze the data are explained. The chapter concludes with a discussion of the limitations and delimitations of the study, followed by a summary.

Research Questions and Hypotheses

It is not known how or to what extent a student's decision to enroll in AP Physics is associated with the student taking middle school algebra and Physics First. Knowing this information will be helpful to schools considering middle school algebra or Physics First programs. These curricular programs may provide more students the opportunity to access STEM gatekeeper courses and STEM college majors and careers. The U.S. need for a diverse STEM career workforce is a national concern.

The following research questions, hypotheses, and alternative hypotheses guided this quantitative study:

RQ1: What is the impact of middle school algebra on AP Physics course enrollments?

H1_0: Taking middle school algebra was not associated with higher AP Physics course enrollments than taking algebra with Physics First.

H1a: Taking middle school algebra was associated with higher AP Physics course enrollments than taking algebra with Physics First.

RQ2: What is the impact of Physics First on AP physics course enrollments?

H2_0: Taking Physics First was not associated with higher AP Physics course enrollments than taking physics as a junior.

H2a: Taking Physics First was associated with higher AP Physics course enrollments than taking physics as a junior.

RQ3: What is the impact of Physics First on the enrollment of women in AP physics courses?

H3_0: Taking Physics First was not associated with higher AP Physics course enrollments for women than taking physics as a junior.

H3a: Taking Physics First was associated with higher AP Physics course enrollments for women than taking physics as a junior.

The questions were answered using eight years of AP Physics course enrollment data pulled from the school's student information system. The math and science courses taken during ninth grade were included in the data along with student gender.

Research Design

This was an observational study of archived enrollment data from one high school. Patterns were seen in the data collected during the eight years following the implementation of a Physics First program. The data was quantitatively explored to look for statistically significant associations between taking AP Physics and middle school algebra, Physics First, and gender. Statistically significant associations are ones which mathematically could not have occurred by chance alone. This is the type of data that school leaders need to support the decisions to make curricular changes.

A positivist or scientific approach was selected to study the data. The positivist approach asserts that scientific knowledge gathered through observational, empirical, and measurable evidence is authentic (Ayiro, 2012). According to Neuman (2014), causal laws can be discovered and used to predict patterns of human activity; in this case, enrolling in AP Physics. Patterns showing associations between Physics First enrollment and subsequent AP Physics enrollment leading to student pursuit of STEM majors and careers would help make the case for implementing the Physics First curriculum in schools.

Using AP Physics enrollment data from the school student information system over an eight-year period, students were placed in a control group if they took physics during their junior year or in an experimental group if they took Physics First. The exception was RQ1 in which middle school algebra was the control group, and ninth grade algebra was the experimental group. The independent variable was enrollment in middle school algebra for the first question; enrollment in Physics First for the second question; and gender for the third question. The dependent variable for all questions was AP Physics course enrollment. The independent and dependent variables are all categorical data.

After loading the data into the SPSS software program, Pearson's Chi-square tests for independence (Pallant, 2020, p. 225) were used to determine if the strength of the association between two variables was statistically significant, meaning it was unlikely to have occurred by chance alone. Chi-square tests were conducted for middle school algebra or ninth grade algebra and AP Physics; Physics First or traditional physics and AP Physics; and gender and AP Physics. Research questions were answered accordingly.

The controlled variables in the study included that the data was taken from the same school with the same group of teachers using the same curriculum and similar methods of instruction. The cohorts were each from a four-year time frame to reduce confounding variables such as the promotion of STEM careers in schools and changes in the middle school science and math programs.

Population and Sample Selection

This study took place at a public suburban four-year high school north of Chicago, Illinois. The medium-sized high school of approximately 1700 students offers a college preparatory curriculum to best serve over 90% of graduates who attend a four-year college after graduation. Other graduates attend a two-year college, enter vocational programs, take a gap year, join the military, or find jobs in the workforce. This school historically has been recognized as a high performing high school in the Chicagoland area, as well as the state and nation.

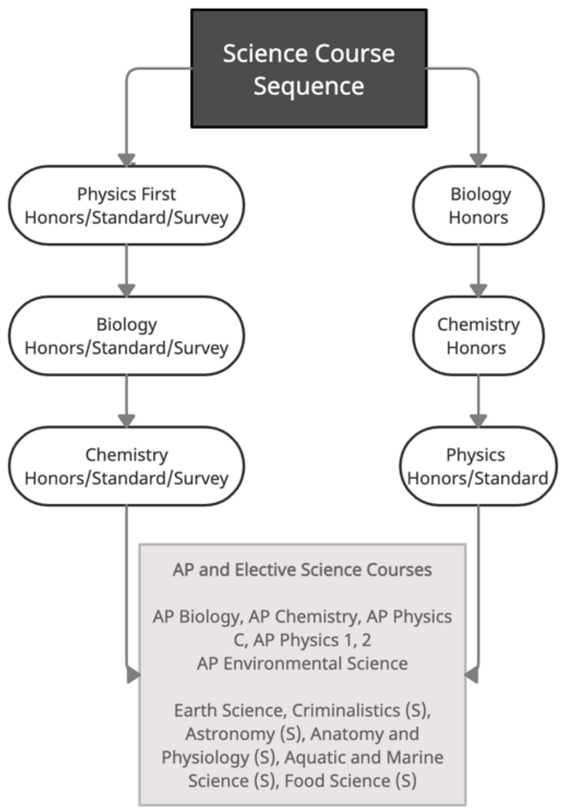
The student body at the school is high achieving, with an average ACT composite score of around 27. Students are generally eager to learn and prepare for college. Approximate 88% of the student body is white, 4% is racially mixed, 4% is Hispanic/Latino, 3% is Asian/Pacific Islander, and 1% is Black/African American. About 4% of the students come from homes with low socioeconomic status. Approximately

15% of students have an IEP and 15% of students have a 504 plan. The student body identifies as about 50% female and 50% male.

Figure 2 is a model of the science course sequences at the school during the time of this study.

Figure 2

Science Course Sequence



The designation of a class being survey, standard, or honors was for the purpose of student support as all classes were college preparatory. All classes of the same course used the same course targets for instruction and assessment. Survey classes were smaller and offered study skills support. Standard classes challenged students to be independent thinkers with some study skills support. Honors classes provided the greatest rigor with less support and enrichment.

Incoming eighth graders were placed into science courses based on middle school science teacher recommendations, grades, standardized test scores, counselor concerns, special education articulation meetings, and family input following an Eighth Grade Curriculum Night held at the high school prior to registration. Once a student was registered, the family had the opportunity to make changes prior to the start of the school year in the fall.

The school adopted a Physics First curriculum for all students in 2007 to better prepare students for STEM majors and careers. The traditional pathway to physics for juniors was available for students unsure of a new program or for students who transferred into the school. Instead of taking a Physics First course, these students began with an honors biology course which ensured that they most likely had the math skills to take traditional physics which required algebra-trigonometry. The traditional pathway was closed after this study due to a lack of enrollment.

Data from the school student information system provided a baseline for AP Physics enrollment as well as identification of two four-year cohorts of students to study. The number of students enrolled in AP physics included both students who took physics during junior year and students who took Physics First. The AP Physics courses available to students in Cohort 1 were AP Physics C and AP Physics B. Due to a change by the College Board, the AP Physics courses available to students in Cohort 2 were AP Physics C and AP Physics 1,2. Table 1 outlines the cohorts used in the study.

Table 1

Cohorts Used in Study

School Year	Number of Students Enrolled in AP Physics	AP Course Status	Role in Study
[a]2009-2010	18	No AP Physics B offered—only AP Physics C	BASELINE not to be used in SPSS Analysis
2010-2011	35	First year offering AP Physics B because the first group of ninth graders taking physics were seniors; AP Physics C	Cohort 1
2011-2012	28	AP Physics B & C	Cohort 1
2012-2013	50	AP Physics B & C	Cohort 1
2013-2014	51	AP Physics B & C	Cohort 1
2014-2015	66	AP Physics 1,2 & C The College Board changed AP Physics B to AP Physics 1 and AP Physics 2[b]	Cohort 2
2015-2016	59	AP Physics 1,2 & C	Cohort 2
2016-2017	58	AP Physics 1,2 & C	Cohort 2
2017-2018	44	AP Physics 1,2 & C	Cohort 2

[a]First year using Infinite Campus student data management system. Data prior to this date is unavailable.

[b]The College Board intended for AP Physics 1 to be taught as a junior year physics course with AP Physics 2 being taught as an additional course senior year. Because students already had a year of physics as freshmen, the school opted to change the name of AP Physics B to AP Physics 1,2, with the expectation that students meet for two periods some days and eventually to two periods every day. The additional time provided the teacher time to support all students.

Data Collection and Analysis Procedures

Data from the high school student information system, Infinite Campus, was obtained with the permission of the principal. An Excel spreadsheet was coded with the data for each student who took an AP Physics course for the time studied. Initial variables included physics course taken, when algebra was taken, gender, race, special education services, socioeconomic status, and the AP physics course taken. Student names were not identifiable. The data was uploaded into IBM SPSS statistical software.

The software ran descriptive statistics, including percentages and frequencies, for participant demographics in the cohorts. Descriptive statistics were also run for the independent and dependent variables.

SPSS retrospective causal comparative quantitative research methods were used to answer the research questions by looking for relationships between the independent and dependent variables. The questions were answered with the use of cross-tabulation tables, as both variables were categorical (Pallant, 2020, p. 225). Pearson's Chi-square tests for independence were used to determine if the strength of the association between two variables was statistically significant, meaning it was unlikely to have occurred by chance alone. Larger chi-square values indicate greater association. Non-parametric tests, such as Chi-square tests for two categorical variables, have the potential to be less powerful than parametric tests with continuous variables (Pallant, 2020, p. 215). For that reason, Yate's Continuity Correction values for Chi-square values were reported.

The strength of the association was determined by calculating the effect size. The cross-tabulation tables were small, and so a phi coefficient was used for effect size. The phi coefficient ranges from 0 to 1, with higher values pointing to a greater effect. According to Cohen's criteria for effect size, a small effect is .1, medium effect is .3, and large effect is .5 (Pallant, 2020, p. 228).

Ethical Considerations

The study was approved by the Internal Review Board at Marquette University prior to the release of data to the researcher. Permission from the high school principal and district were obtained for the release of non-identifiable student data for the purpose of this study. The data provided from the student information system was from students who graduated from the high school before 2018. These students are not minors and many no longer live in the community.

Limitations and Delimitations

There are limitations or influences on a research study which cannot be controlled, and delimitations, or intentional choices made in the study to set boundaries. The limitations and delimitations of this study are described in this section to help define the context of this research.

One limitation of the study is that the researcher was the science department chair at the school during the eight-year period over which enrollment data was later collected. The data was not analyzed until the researcher left the school due to retirement. This helped to reduce biases the researcher may have held as an employee of the school. There was no benefit to the researcher in doing the study, regardless of the outcomes.

Another limitation of the study was sample size. Some Chi-square analyses could not be run because $n<5$ in a cell. The data was consolidated several times so that $n>5$. This limited the research questions asked. For example, it would have been interesting to find out associations between other underrepresented groups in STEM in addition to women. Due to the lack of diversity in the sample population, these answers could not be found.

The data set reflects the first eight years of AP Physics enrollments after Physics First was implemented. Two four-year cohorts were built into the study to accommodate for the College Board change of AP Physics B to AP Physics 1 and 2. Additionally, examining each four-year cohort reduces the confounding variables that occur when looking at the total eight years. During this time there were changes in the math and science programs at the middle school. The school also participated in STEM programs, such as MIT Women's Initiative promoting engineering and Camp Invention promoting design thinking.

A delimitation of this retrospective study is that it does not include variables that may have been measured had researched instruments been used with students when they were taking AP Physics. For example, the influence of teachers, interest and engagement in physics, and self-efficacy are variables that may have influenced enrollments in AP Physics. These variables could have been collected through surveys and quantitatively analyzed to add to the study.

Summary

This quantitative study was designed to examine the impact of middle school algebra and Physics First on AP Physics course enrollments in two four-year cohorts at a suburban public high school. Using a positivist research methodology, students who took traditional physics or 9th grade algebra were placed in control groups and students who took Physics First or middle school algebra were placed in experimental groups. The independent variables included the timing of when algebra and physics were taken and gender. The dependent variable was AP Physics enrollment.

The categorical data pulled from the district student data system was uploaded to IBM SPSS statistical software. Descriptive statistics, cross-tabulation tables, and Chi-square analyses were used to answer the research questions. Although some aspects of the sample size were small, many associations between variables were statistically significant so that the research questions were answered. Chapter 4 presents the findings of the research study.

CHAPTER 4: RESULTS

Introduction

At the macroscopic level, the U.S. has been a world leader in science and engineering for decades. This position is threatened by global competition. To compete in the global economy, the perspectives of a diverse STEM workforce are needed. STEM occupations in the U.S. are expected to grow by 8.0 percent compared to 3.9 percent for all other occupations during the next decade (Zilberman & Ice, 2021). Efforts have been made to promote STEM in schools to attract more students into STEM fields. Although these efforts are helpful, math and science course pathways and opportunities for advanced coursework in the STEM gatekeeper courses should be considered. It is not known how or to what extent a student's decision to enroll in AP Physics is associated with the student taking middle school algebra and Physics First. Having this information may inspire school decision makers to consider new ways of sequencing courses, reimagining teaching methods, and providing supports that will help all students reach their STEM career potential.

This quantitative observational study examined the impact of algebra and physics course placement on AP Physics enrollments. Eight years of AP Physics enrollment data from a high school offering both Physics First and traditional junior year physics was obtained. Statistically significant associations between taking middle school algebra, Physics First, and AP Physics were determined for both women and men.

The following research questions, hypotheses, and alternative hypotheses guided this quantitative study:

RQ1: What is the impact of middle school algebra on AP Physics course enrollments?

$H1_0$: Taking middle school algebra was not associated with higher AP Physics course enrollments than taking algebra with Physics First.

H1a: Taking middle school algebra was associated with higher AP Physics course enrollments than taking algebra with Physics First.

RQ2: What is the impact of Physics First on AP physics course enrollments?

$H2_0$: Taking Physics First was not associated with higher AP Physics course enrollments than taking physics as a junior.

H2a: Taking Physics First was associated with higher AP Physics course enrollments than taking physics as a junior.

RQ3: What is the impact of Physics First on the enrollment of women in AP physics courses?

$H3_0$: Taking Physics First was not associated with higher AP Physics course enrollments for women than taking physics as a junior.

H3a: Taking Physics First was associated with higher AP Physics course enrollments for women than taking physics as a junior.

This chapter presents the quantitative results of the study used to determine if the null or alternative hypotheses be accepted for each research question. It begins with the descriptive statistics for the sample population and for the variables. A summary of the number of students who pursued each of the four pathways is given. The Chi-square test results and effect size statistics are given for the two variables in each research question studied. The results are summarized, including a summary table of the Chi-square test results and effect sizes.

Descriptive Statistics

Descriptive statistics for students who enrolled in AP Physics from 2011-2014 (Cohort 1) and from 2015-2018 (Cohort 2) are described in this section. The frequency and percentage for each characteristic describing the students are shown in Table 2. This information will be helpful in the discussion in Chapter 5.

Cohort 1 included 164 students and Cohort 2 included 227 students. The number of students enrolled in AP Physics increased over the time studied. 86.0% of Cohort 1 was comprised of male students; 14% was comprised of female students. 71.8% of Cohort 2 was comprised of male students; 28.2% of Cohort 2 was comprised of female students. The number of men enrolled in AP physics increased slightly over this time. The number of women enrolled in AP physics nearly tripled from Cohort 1 to Cohort 2.

Students enrolled in AP Physics were predominantly white. From Cohort 1 to Cohort 2, the number of Asian/Pacific Islander students nearly tripled, the number of Hispanic/Latino students increased from 0 to 3, and the number of multiracial students more than doubled. This reflects the increase in non-white students in the general school population. Although the numbers increased, they were initially small due to the school demographics at the beginning of this study.

Cohort 2 saw the largest number of students receiving special education services, with the number of students with 504 plans quadrupling from 6 in Cohort 1 to 26 in Cohort 2. This is aligned with an increase in 504 plans seen in the general school population. The number of students with IEPs remained about the same from Cohort 1 to Cohort 2.

Several students with low socioeconomic status enrolled in AP Physics in Cohort 2. There are few students of low SES in the general school population overall; however, the numbers in the school population increased from Cohort 1 to Cohort 2.

Table 2

Demographic Characteristics of Students by Cohort

Characteristic		*n*		%	
		Cohort 1	Cohort 2	Cohort 1	Cohort 2
Gender	Male	141	163	86.0	71.8
	Female	23	64	14.0	28.2
Race	Asian/Pacific Islander	5	14	3.0	6.2
	Hispanic/Latino	0	3	0.0	1.3
	White	155	201	94.5	88.5
	Multiracial	4	9	2.4	4.0
Special Education	None	153	193	93.3	85.0
	IEP	5	8	3.0	3.5
	504	6	26	3.7	11.5
Low SES	No	164	224	100.0	98.7
	Yes	0	3	0.0	1.3

Descriptive statistics for the independent and dependent variables include the frequency and percentage for each variable as shown in Table 3. This information is related to answering the research questions. When looking at total cases in both four-year cohorts, n=391. Cohort 1 includes students whose AP Physics options were AP Physics C, pre-engineering physics, and AP Physics B, general college physics. Just over 40% of the total cases were in Cohort 1; nearly 60% of the total cases were in Cohort 2. Cohort 2 includes students whose AP Physics options were AP Physics C, pre-engineering physics, and AP Physics 1,2, general college physics.

The percentage of students in Cohort 1 who took Physics First was 67.1%. That percentage rose to 76.7% in Cohort 2, an increase of almost 10%. The percentage of students in Cohort 1 who did not take Physics First, opting for the traditional pathway of physics during their junior year, was 32.9%. That percentage decreased by about 10% as 23.3% of students in Cohort 2 enrolled in the traditional pathway.

The percentage of students in Cohort 1 who took algebra in middle school was 90.2%. That number decreased to 84.1% in Cohort 2. That means that in Cohort 2, there were fewer students enrolled in AP Physics courses having taken algebra in middle school.

The change in AP Physics B to AP Physics 1,2 was made by the College Board. The intent of the College Board was for students to take AP Physics 1 during junior year and AP Physics 2 during senior year. As most students at this school experienced Physics First, it was decided to offer AP Physics 1,2 during two, instead of one period plus a lab period, class periods during senior year. Despite the change and increasing demand of time to take AP Physics 1,2 in Cohort 2, the number of students taking general college physics increased from 43.9% in Cohort 1 to 70.9% in Cohort 2. This is in alignment with the number of students taking pre-engineering physics decreasing from 56.1% in Cohort 1 to 29.1% in Cohort 2. Students from Physics First tended to take AP Physics B or 1,2 instead of AP Physics C. Although there were more topics covered in AP Physics B and 1,2, the pace and math rigor were more comfortable to students in that course than AP Physics C.

Table 3

Variables in Study

Variable		*n*		%	
		Cohort 1	Cohort 2	Cohort 1	Cohort 2
Cohort		164	227	41.9	58.1
Physics First	Yes	110	174	67.1	76.7
	No	54	53	32.9	23.3
Middle School Algebra	Yes	148	191	90.2	84.1
	No	16	36	9.8	15.9
AP Physics Course	AP Physics C	92	66	56.1	29.1
	AP Physics B	72	-	43.9	-
	AP Physics 1,2	-	161	-	70.9

In the conceptual model for this study, students who enrolled in AP Physics over an eight-year period followed one of four pathways: middle school algebra and traditional physics, middle school algebra and Physics First, ninth grade algebra and traditional physics, or ninth grade algebra and Physics First. Students in the traditional physics pathway were in the control group, and students in the Physics First pathway were in the experimental group. Table 4 reveals the number of students who pursued each pathway to an AP Physics course. Pathways 1 and 2 contributed to a higher number of AP Physics course enrollments; however, the total number of students in Pathways 3 and 4 was lower. This will be elaborated upon in the discussion.

The number of women who enrolled in AP Physics increased from 23 in Cohort 1 to 64 in Cohort 2. The number of women who followed each of the four paths is included in Table 4 for further discussion.

Table 4

Pathways and AP Physics Enrollment Numbers

	Pathway		AP Physics Enrollment *n*		Women Only
1	Middle School Algebra	Traditional Physics	AP Physics C	73	10
			AP Physics B	8	3
			AP Physics 1,2	16	10
2	Middle School Algebra	Physics First	AP Physics C	68	11
			AP Physics B	50	8
			AP Physics 1,2	124	35
3	Ninth Grade Algebra	Traditional Physics	AP Physics C	8	1
			AP Physics B	0	0
			AP Physics 1,2	2	0
4	Ninth Grade Algebra	Physics First	AP Physics C	9	1
			AP Physics B	14	1
			AP Physics 1,2	19	7

Research Questions

The first research question asked, *What is the impact of middle school algebra on AP Physics course enrollments?* A Chi-Square Test for Independence (with Yate's Continuity Correction) indicated a significant association between taking middle school algebra and AP Physics course enrollment for Cohort 1. For Cohort 1, X^2 (1, n = 164) = 11.8, p <.001, *phi*= -.29). The effect size was medium. The alternative hypothesis was accepted. A Chi-Square Test for Independence (with Yate's Continuity Correction) indicated an insignificant association between taking middle school algebra and AP Physics course enrollment for Cohort 2. For Cohort 2, X^2 (1, n = 227) = 2.6, p=.11, *phi*=

.12). The null hypothesis was accepted. For combined cohorts, X^2 (1, *n* = 409) = 4.4, *p* =.11, *phi*= .10). The null hypothesis was accepted.

The percentage of students in Cohort 1 who took algebra in middle school was 90.2%. That number decreased to 84.1% in Cohort 2. That means that in Cohort 2, there were fewer students enrolled in AP Physics courses having taken algebra in middle school. Additionally, *n* was larger in Cohort 2. This may account for the insignificant association between taking middle school algebra and AP Physics course enrollment for Cohort 2.

The second research question asked, *What is the impact of Physics First on AP physics course enrollments?* A Chi-Square Test for Independence (with Yate's Continuity Correction) indicated a significant association between taking Physics First and AP Physics course enrollment. For Cohort 1, X^2 (1, *n* = 164) = 25.9, *p* <.001, *phi*= .41). For Cohort 2, X^2 (1, *n* = 227) = 43.5, *p*<.001, *phi*= .45). In both cohorts, there was a medium to large effect size of Physics First on AP physics course enrollments in comparison to traditional physics on AP physics course enrollments. For combined cohorts, X^2 (1, *n* = 409) = 96.1, *p* <.001, *phi*= .49). The alternative hypothesis was accepted for both cohorts individually and combined.

The third research question asked, *What is the impact of Physics First on the enrollment of women in AP physics courses?* To answer this question without a cell of *n*=5 or less, Cohort 1 and Cohort 2 were combined. The AP Physics courses were collapsed into engineering (AP Physics C) and general physics (AP Physics B or AP Physics 1,2). A Chi-Square Test for Independence (with Yate's Continuity Correction) indicated a significant association between taking Physics First as a woman and AP

Physics course enrollment, X^2 (1, n = 87) =5.1, p <.05, *phi*=.27). The effect size was medium when rounded to .3. The number of female students taking AP Physics C was nearly the same for those who took Physics First (n=11) and those taking the traditional pathway (n=12); however, the number of female students taking AP Physics B or AP Physics 1,2 was about four times higher for those who took Physics First (51) versus the traditional pathway (13). The alternative hypothesis was accepted.

Summary

Descriptive statistics indicate that just over 40% of the total cases were in Cohort 1; nearly 60% of the total cases were in Cohort 2. The percentage of students in Cohort 1 who took Physics First was 67.1%. That percentage rose to 76.7% in Cohort 2, an increase of almost 10%. The percentage of students in Cohort 1 who took algebra in middle school was 90.2%. That number decreased to 84.1% in Cohort 2. 86.0% of Cohort 1 was comprised of male students; 14% was comprised of female students. 71.8% of Cohort 2 was comprised of male students; 28.2% of Cohort 2 was comprised of female students. Regarding pathways, most students took middle school algebra plus either traditional physics or Physics First. There were some students who took an AP Physics course with ninth grade algebra and traditional physics or Physics First.

A summary of the findings of the research questions for each cohort and combined cohorts is provided in Table 5. The alternative hypothesis was accepted for each question except for Cohort 2 in HQ1. Effect sizes were medium to large. The significance of the findings will be discussed in Chapter 5.

Table 5

Findings of Study

Variable	Cohort	X^2	Sig	Effect Size
Middle School Algebra (Q1)	1	11.8	$p<.001^{***}$	0.29
	2	2.6	0.11	0.12
	Combined	4.4	0.11	0.10
Physics First (Q2)	1	25.9	$p<.001^{***}$	0.41
	2	43.5	$p<.001^{***}$	0.45
	Combined	96.1	$p<.001^{***}$	0.49
Enrollment of Women(Q3)	Combined	5.1	$p<.05^{*}$	0.27

CHAPTER 5: DISCUSSION

Introduction and Summary of Findings

The United States has been a world leader in science and engineering for decades. In 2019, the United States performed 27% of the world's research and development followed by China at 22%, Japan at 7%, Germany at 6%, and South Korea at 4%. The United States has also led the world in the number of science and engineering doctorates awarded; however, that position is slipping as China is quickly catching up (National Science Board, 2022).

Currently about 20% of the U.S. STEM workforce is foreign-born because the U.S. is not producing enough STEM workers (National Science Board, 2022). Within this decade, STEM occupations in the U.S. are expected to grow by 8.0 percent compared to 3.9 percent for all other occupations (Zilberman & Ice, 2021). As other countries have need for STEM workers, fewer may come to the United States.

The STEM pipeline is of national concern as it moves students through high school and into college in pursuit of STEM degrees. Professional organizations and government entities have generated STEM initiatives in schools over the past decade with the goal of generating interest and engagement in STEM as a career. Although this is important, most STEM degrees require rigorous work in the gatekeeper courses of chemistry, calculus, and physics (Redmond-Sanogo, 2016). Many high school students do not have access to these courses because of how they are placed in the curriculum.

Only 24% of all high school students take algebra prior to ninth grade (U.S. Department of Education, 2018) to be placed in geometry as high school first-year students. This placement provides the opportunity for students to take calculus before college. Yet many families may be unaware of this fact. Course placement decisions in middle school may have an impact on a student's STEM degree options in college. In the United States, 41% of all middle schools do not offer algebra to students so it is not even a possibility (U.S. Department of Education, 2018). The lack of a course offering is often due to limited resources to staff classes and/or a lack of school leadership understanding the student opportunities lost because of the course deficit.

According to Chu and White (2021), the results from the 2018-2019 Nationwide Survey of High School Physics Teachers showed that about 41% of all students graduate from high school with at least one year of physics. About 16% of all high schools do not offer physics annually. Approximately 6% of all high school students take ninth grade physics or Physics First (White & Tesfaye, 2014). Taking physics early in high school provides a course pathway to an AP Physics course in preparation for college STEM degrees.

If all students could take their first algebra course before ninth grade and take Physics First in high school, they would have greater access to AP Physics. Earlier studies have shown that AP Physics enrollments increase when students have access to Physics First (Gaubatz, 2013; Goodman, 2006). These studies used two and four years of AP Physics enrollment data, respectively. This study used eight years of AP Physics enrollment data to determine the impact of Physics First and middle school algebra on AP Physics enrollment.

The conceptual model of this study is based on Physics First. A positivist or scientific approach was used. Students who enrolled in traditional physics or middle school algebra were in the control group, depending on the research question. Students who enrolled in Physics First or ninth grade algebra were in the experimental group, depending on the research question. The independent variables were the timing of algebra and physics course taking and gender. The dependent variable was enrollment in AP Physics. The sample population was divided into two four-year groups, Cohorts 1 and 2. This was done to account for a change in AP Physics B to AP Physics 1 and 2. It also minimized the effects of confounding variables such as exposure to STEM experiences and changes in the middle school science and math curricular programs. The research questions for this study were:

RQ1: What is the impact of middle school algebra on AP Physics course

RQ2: What is the impact of Physics First on AP physics course enrollments?

RQ3: What is the impact of Physics First on the enrollment of women in AP physics courses?

Eight years of AP Physics student enrollment data were uploaded into IBM SPSS statistical software to answer the questions. The software ran descriptive statistics, including percentages and frequencies, for participant demographics in the cohorts. Descriptive statistics were also run for the independent and dependent variables.

SPSS retrospective causal comparative quantitative research methods were used to answer the research questions by looking for relationships between the independent and dependent variables. The questions were answered with the use of cross-tabulation tables, as both variables were categorical (Pallant, 2020, p. 225). Pearson's Chi-square tests for independence were used to determine if the strength of the association between two variables was statistically significant, meaning it was unlikely to have occurred by chance alone. Larger chi-square values indicate greater association. Non-parametric tests, such as Chi-square tests for two categorical variables, have the potential to be less powerful than parametric tests with continuous variables (Pallant, 2020, p. 215). For that reason, Yate's Continuity Correction values for Chi-square values were reported.

The strength of the relationship was determined by calculating the effect size. The cross-tabulation tables were small, and so a phi coefficient was used for effect size. The phi coefficient ranges from 0 to 1, with higher values pointing to a greater effect. According to Cohen's criteria for effect size, a small effect is .1, medium effect is .3, and large effect is .5 (Pallant, 2020, p. 228).

School leaders need data from research on Physics First programs to make changes to curriculum sequences. The answers to the research questions will provide that data. For schools offering Physics First, knowing the algebraic thinking that best supports success in Physics First could inform changes in math instruction and course sequencing in grades 6-12. For schools not offering Physics First, knowing the influence that algebra course placement and Physics First can have on AP Physics course enrollments could lead to different course sequencing in math and science from middle school through high school. This could result in a greater percentage of students taking algebra before ninth grade, Physics First, and AP Physics. Additionally, students from underrepresented groups may also have greater access to college STEM majors and high paying jobs in the STEM sector of the global economy.

The purpose of this study was to determine the impact of Physics First and middle school algebra on AP Physics course enrollments. The data suggests that Physics First increased AP Physics enrollments overall, notably among women. The results also indicated that taking algebra in middle school did not impact AP Physics enrollment as significantly as taking Physics First. Taking middle school algebra did have a greater effect on students enrolling in AP Physics in Cohort 1 as opposed to Cohort 2, due to the sample size and math support. There is a relationship between taking Physics First and enrolling in AP Physics.

This chapter discusses the findings related to each research question along with limitations, implications, and recommendations of the study.

The Impact of Middle School Algebra on AP Physics Course Enrollments

The findings showed a significant association between taking middle school algebra and an AP Physics course in Cohort 1 but not in Cohort 2. The effect size for both cohorts was small, with Cohort 1 approaching medium. The Cohort 2 result was unexpected. It was explainable after reviewing the history of the department. A review of historical department data highlighted the efforts made by teachers to tailor the Physics First course to meet the mathematical needs of students.

Supporting Algebra Skills

During the first several years of the new program, teachers gave their Physics First students anonymous surveys about their experiences in the course. Students were asked about their overall experience, course difficulty, science skill attainment, favorite and least favorite labs, and science AP and elective course preferences. One of the concerns was that students needed support with mathematical problem solving. As a result, Physics First teachers learned how to support algebra instruction while teaching Physics First. Staff development activities included collaboration meetings between the algebra and Physics First teachers. They learned how to reinforce the curriculum targets of both disciplines. Extra efforts were made to scaffold problem solving, offer alternate ways of problem solving, and increasing the visuality of problems. Thus, students entering high school with weaker algebra skills were supported and encouraged to be successful in both algebra and physics.

Within the high school, an academic resource center was developed in 2014, with a focus on math and physics student support. Students could quickly visit the center and get help in algebra and Physics First from staff and peer tutors throughout the day. Physics teachers volunteered to help in the center as their supervision assignment. Students met in groups and helped one another with homework. Students who may have thought they could not find success in Physics First because they did not have strong algebra skills found they could be successful. They may have developed the self-efficacy needed to return senior year to take AP Physics 1,2. AP Physics 1,2 was taught by a teacher endorsed as a math and physics teacher. This teacher was very approachable, encouraging, and made students feel supported and confident they could be successful in AP Physics 1,2.

Ninth Grade Algebra Students Could Reach AP Physics

Again, the need for graduates in STEM may have had an impact. Students were encouraged to pursue AP Physics courses as a pathway into engineering. AP Physics was no longer a course for the strongest math students at the school. Students who did not have the opportunity to take middle school algebra could still reach AP Physics in high school. Evidence of this can be seen in pathways 3 and 4 in Table 4 of Chapter 4. Regardless of traditional or Physics First, about the same number of students who took algebra in ninth grade enrolled in AP Physics C, the most mathematically challenging AP

Physics course. When combined with Physics First, twice that number took either AP Physics B or AP Physics 1,2, depending upon the cohort.

The Impact of Physics First on AP Physics Course Enrollments

The findings showed a significant association between taking Physics First and AP Physics course enrollment. Prior to offering Physics First, about half of the student body at this high school completed a physical science, biology, and chemistry course. They did not choose to take a physics course as a fourth year of science. Replacing physical science with Physics First made a difference as students who had a positive Physics First experience enrolled in AP Physics as a fourth year of science. Offering a general physics course (AP Physics B or 1,2) in additional to pre-engineering physics (AP Physics C) provided an attractive option for those pursuing a STEM degree in college as many STEM fields require a general physics course. Offering Physics First made the science course sequence streamlined so that all students graduated with physics, biology, and chemistry with senior year open for AP Physics or another AP science course or elective.

Traditional Physics Pathway Disappeared

Although enrollment at this high school remained steady from 2010-2018, Cohort 1 included 164 students as opposed to 227 in Cohort 2. The significance and effect size were greater in Cohort 2. During the first years of offering Physics First, some students and families chose the traditional path of biology, chemistry, and physics because they were skeptical of the Physics First program. As time went on, the program grew in popularity as Physics First was engaging and provided many hands-on activities and labs that gave ninth grade students opportunities to work together. Incoming students preferred to take Physics First over Biology. The traditional pathway disappeared from course offerings after this study due to lack of enrollment. Students learned that they could be successful in an AP Physics course with Physics First, as indicated in Pathways 2 and 4 in Table 4 of Chapter 4.

There were also a few Physics First students who enrolled in AP Physics C and a few traditional physics students who enrolled in AP Physics 1,2. AP Physics enrollments remained strong, even though students in AP Physics 1,2 in Cohort 2 gave up two solid periods a day for the course compared to AP Physics B students in Cohort 1 who gave up 1.5 periods per day in their schedule for a second physics experience. Many AP Physics students also took AP courses in other subjects. AP Physics B and AP Physics 1,2 were less rigorous than AP Physics C and helped balance schedules and workloads.

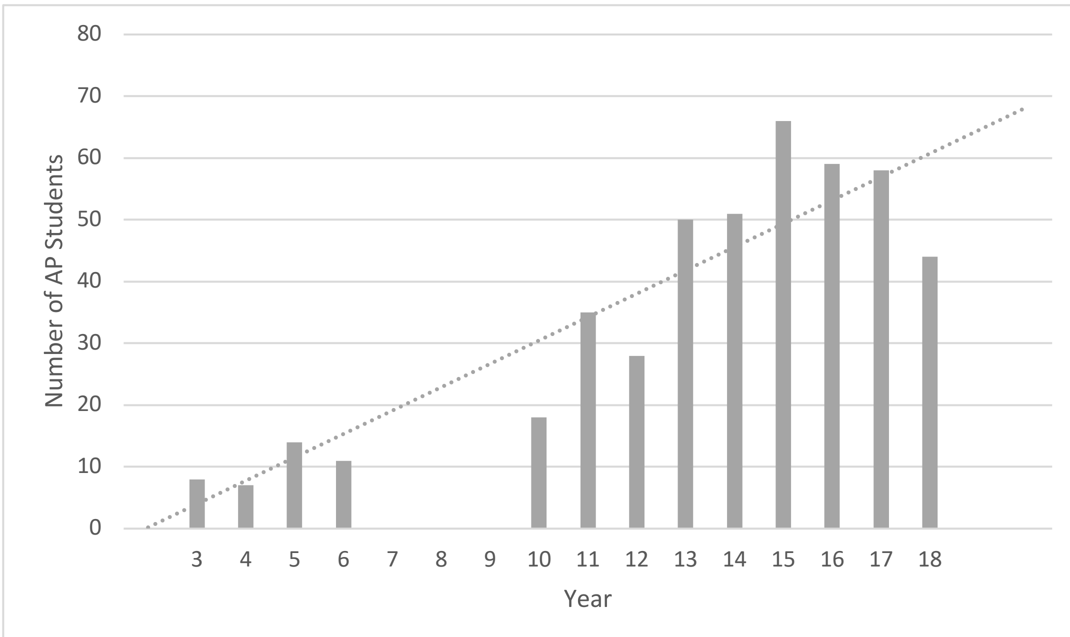
AP Physics Enrollments Increased

Descriptive statistics showed that the number of AP Physics enrollments increased from 2010-2018. Before Physics First, there were less than 20 students enrolled in AP Physics C annually. With the addition of Physics First, AP Physics B was also offered, and both courses filled with students. One may assume that without Physics First, about 20 students would have enrolled in AP Physics C over eight years for a total of 160 students. With Physics First, the total number was 391. This means that approximately 230 additional students took AP Physics from 2010-2018. It also means that even if students did not enroll in AP Physics, they had a physics experience to learn more about the world around them a develop science skills. Figure 3 shows the trendline for AP Physics enrollments (data unavailable 2007-2009) prior to students havingPhysics

First experience (2003-2010) and after. Overall, there is an upward trend in AP Physics enrollments with some variation among the years.

Figure 3

AP Physics Enrollments by Year



STEM Influences

The STEM acronym was first used in 2005, and by 2008, it was commonly seen in headlines (Loewus, 2015). The need for students to pursue STEM degrees was promoted in the media, meaning that parents and students may have been influenced by what they heard and saw. Parents may have encouraged their children to take AP Physics in support of them pursuing STEM degrees and careers.

The science department promoted STEM careers in many ways. STEM Women was a student-generated group that promoted STEM careers through annual STEM

Career Days. Parents with STEM careers volunteered to present information about their jobs to students who signed up to attend on STEM Career Day. The science department was also selected to host the MIT Women's Initiative one year. Women who were physics students at MIT traveled to the high school and middle school to engage students in an engineering activity and learn about the branches of engineering. In later years, Northwestern University's Women in Engineering group volunteered to lead physics activities and discuss the branches of engineering.

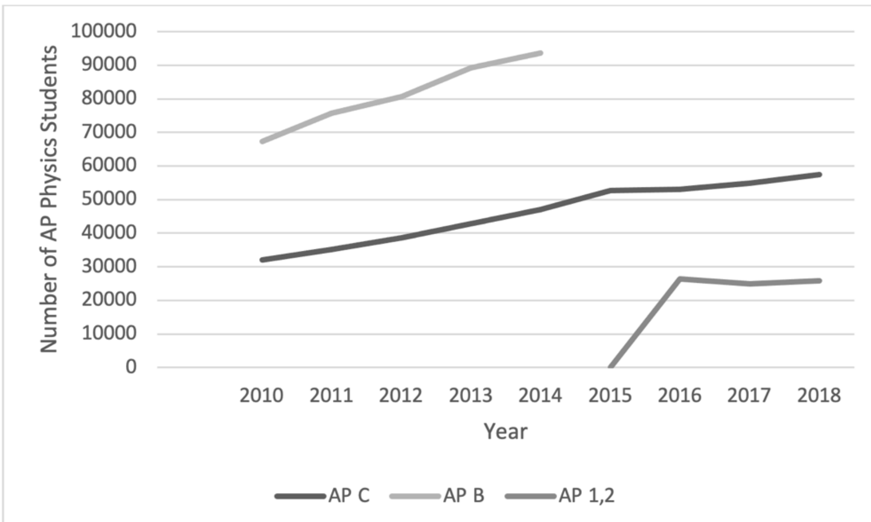
Students were encouraged to enroll in science AP and elective classes, including AP Physics, with videoclips played during science classes to inform students of the curriculum and expectations before enrolling for the upcoming year. Teachers talked about course pathways with students and educated them on the value of taking rigorous science electives, including AP Physics.

It is impossible to know the additional STEM influences that students experienced through summer camps and area STEM programs. These influences may have helped increase the number of students enrolling in AP Physics from 2010-2018. Students across the nation may also have experienced similar STEM influences.

Figures 4 and 5 compare the national AP Physics enrollment trends, based on AP Physics exams taken, to the school's AP Physics enrollment trends. For AP C, the national enrollment increased, but the school enrollment fluctuated and then decreased. This may have been due to the presence of AP B or AP 1,2 as enrollment options. For AP B, the national enrollment increased, and the school enrollment increased at a greater rate after its introduction in 2012 before declining. For AP 1,2, the national enrollment slightly decreased after its introduction in 2016 as did the school enrollment. The magnitude and scale of the two graphs impacts comparisons. Total school enrollment remained steady. Changes in AP and elective offerings in the school may have attracted students into other classes.

Figure 4

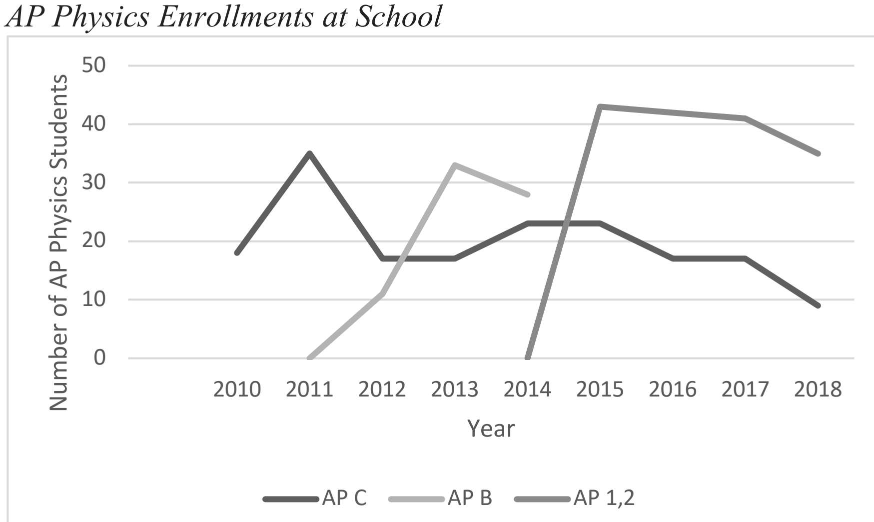
AP Physics Enrollments Nationwide



Note: The AP C Mechanics and AP 2 exam numbers were used.

Figure 5

AP Physics Enrollments at School



All Students Graduated with a Physics Course

About 55% of students in this school took a physics class prior to the time of this study, yet in this school, almost 100% graduated with a physics experience after Physics First was implemented. Even if they did not enroll in AP Physics, they still had a physics experience to reinforce math skills, broaden their science background, and have a physics course on their transcript. Although there were not enough students of color, students with IEPs and 504 plans, and students of low SES to statistically analyze in this study, it is important to note that they also took physics in high school, and some did take an AP Physics course senior year.

The district goal during this time was “Equity and Excellence,” and the move to Physics First was in support of that goal. From 2010-2018, 35 students of color, 45 students with IEPs or 504 plans, and 3 students of low SES took AP Physics. Although the percentages of students of color, students with IEPs and 504 plans, and students of low SES in AP Physics was not reflective of the percentages in the school, everyone had an initial physics experience due to Physics First.

Comparison to Previous Data

Two studies were found with data on Physics First and AP Physics enrollment. (Gaubatz, 2013) reported the enrollment in AP Physics C doubled during two years of available data. Goodman (2006) found that enrollment in the total number of students taking AP Physics B and AP Physics C increased over four times during four years of available data.

This study showed that AP Physics C enrollment doubled the first year and was 1.5 times greater after two years. This is close to what the Gaubatz study found. In comparison to the Goodman study, enrollment in AP Physics B and AP Physics C increased over two times during the first four years. This was about half of the value found in the Goodman study.

It is important to remember that all schools are unique and the outcomes in one school might not be those in another due to differences. The important finding is that AP Physics course enrollments increased significantly in these three studies.

The Impact of Physics First on Enrollment of Women in AP Physics Courses

Although all students took a physics course and half of them were women, the men enrolled in AP Physics at higher numbers than women. During the time of this study, 87 women and 304 men enrolled in AP Physics.

A study of surveys taken by introductory college physics students about their high school experiences offered some insights as to why women are less likely to take AP Physics. Women reported spending a lot of time on studying, reading, problem solving, and preparing for test questions requiring memorization which may indicate that they need help with learning strategies. They may lack life experiences with physics from life, such as working with mechanical and electrical things. Influences like parents and teachers can help women develop a greater interest in the field and build confidence in physics (Hazari et al., 2008). These findings account for the impact the work the department did in generating interest in STEM through STEM Women, MIT Women's Initiative, and Northwestern University's Women in Engineering collaboration.

Findings after combining the two cohorts showed a significant association between women taking Physics First and enrolling in AP physics. About equal numbers of women from Physics First and the traditional pathway took AP Physics C. This is an interesting finding because women in Physics First felt confident enough in their abilities in physics to take pre-engineering physics, the more rigorous course of the two.

More Women Attracted to AP Physics B or 1,2 Than AP Physics C

The number of female students taking AP Physics B or AP Physics 1,2 was about four times higher for those who took Physics First (51) versus the traditional pathway (13). Physics First students overall enrolled in AP Physics B or AP Physics 1,2 more than AP Physics C. White and Tesfaye (2011) reported from the 2008-9 Nationwide Survey of High School Physics Teachers that 32% of students enrolled in AP Physics C were female; 41% of students enrolled in AP Physics B were female. In this study, 15% of students enrolled in AP Physics C were female, and 17% of students enrolled in AP Physics B were female. The percentages may have changed with more time as AP Physics B only ran three years before shifting to AP Physics 1,2.

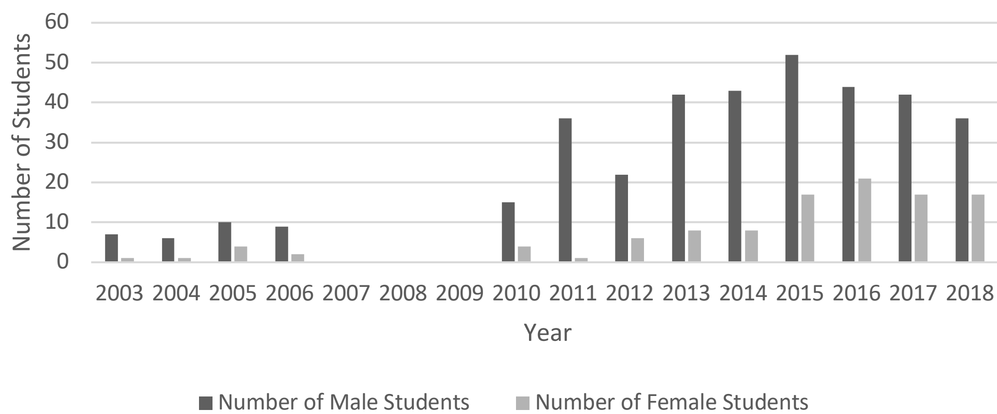
AP Physics B and AP Physics 1,2 were supportive of students returning senior year for a physics experience after having taken physics during the first year. The teacher for these courses was a woman who encouraged and supported students in the courses.

More Women Enrolled in AP Physics

Descriptive statistics show that 86.0% of Cohort 1 was comprised of male students; 14% was comprised of female students. 71.8% of Cohort 2 was comprised of male students; 28.2% of Cohort 2 was comprised of female students. The number of men enrolled in AP physics decreased slightly over this time. The number of women enrolled in AP physics nearly tripled from Cohort 1 to Cohort 2. Figure 6 shows the proportion of male to female students prior to and during this study (data unavailable 2007-2009). Cohort 1 includes 2011-2014 and Cohort 2 includes 2015-2018.

Figure 6

AP Physics Enrollments by Gender



Strengths and Weaknesses of the Study

This study was imperfect and had strengths and weaknesses to acknowledge. One weakness of the study was that the researcher was the science department chair at the school during the eight-year period over which enrollment data was later collected. The data was not analyzed until the researcher left the school due to retirement. This helped to reduce biases the researcher may have held as an employee of the school. There was no benefit to the researcher in doing the study, regardless of the outcomes. This weakness was also a strength because the researcher understood the Physics First program at this school from experience rather than as an outsider.

A limitation of the study was sample size. Some Chi-square analyses could not be run because $n<5$ in a cell. The data was consolidated several times so that $n>5$. This limited the research questions asked. For example, it would have been interesting to find out associations between other underrepresented groups in STEM in addition to women. Due to the lack of diversity in the sample population, these answers could not be found.

The data set reflects the first eight years of AP Physics enrollments after Physics First was implemented. The length of time was a strength. No research study was found that included this type of data for more than four years. Two four-year cohorts were built into the study to accommodate for the College Board change of AP Physics B to AP Physics 1 and 2. Additionally, examining each four-year cohort reduced the confounding variables that occur when looking at the total eight years. For example, STEM influences in society were occurring during this time in addition to changes in the math and science programs at the middle school.

This research study provided quantitative results which will be useful to schools considering changes to math and science curriculum pathways to STEM careers. The impact of middle school algebra and Physics First on AP Physics course enrollments is documented as a resource.

Implications

The way in which schools traditionally order their math and science courses has given the mathematical elite the best opportunity to pursue STEM degrees in college, leading to greater socioeconomic status. This study provides data to help math and science curriculum leaders make informed decisions on course sequencing that give all students access to a 21st curriculum that helps them understand the world, pursue technical careers, or enroll in college STEM career programs. The most recent national data shows that not all students have access to middle school algebra or physics. Physics

First may be the key to opening the door for all students to access advanced math and science courses needed for career advancement in the 21st century.

All schools are unique: what works well in one school may not necessarily work the same way in another school. The data collected in this study may be useful to schools considering changes in math sequencing and/or offering Physics First. The data is important; however, the way in which change is made is also important. Appendix B provides a timeline for Physics First course development and implementation at this school in the spirit that it may help others.

To gain access to advanced math courses in high schools, elementary and middle school leaders need to work collaboratively to plan a course sequence that includes middle school algebra for all students. Elementary school teachers need to learn how to incorporate algebraic thinking, such as mathematical relationships, into arithmetic as it is taught. This will prepare students for pre-algebra and algebra in middle school. Although the Physics First teachers at the school in this study learned to teach algebra with Physics First to students needing that support, getting all students to algebra in middle school would be more efficient and effective.

It is important that teachers be a part of the decision-making process, and that they work with a strong staff development program to learn how to incorporate algebraic thinking into elementary school. Then they need to work on the best ways to use those skills in pre-algebra in middle school in preparation for algebra. Students need to be algebra-ready before they are placed in an algebra course. Algebra readiness will support success. If they are not algebra-ready, students may feel defeated. Having an algebra support system within the school is also important to help students who need extra support.

High school administrators need to recognize that Physics First provides all students a physics experience that can lead to AP Physics course enrollments, STEM interest, and potential STEM careers. The concepts taught in Physics First are essential knowledge for all students. Many schools could replace ninth grade physical science classes with Physics First to provide this knowledge and experience. Physics First provides an introduction into STEM careers and builds foundation science skills. However, making the shift to Physics First needs teacher support and leadership to be successful.

The challenges of implementing a change can be mitigated with communication to students, families, and staff. Effective physics teacher staff development is also necessary. Physics teachers need to be prepared to teach and reinforce algebra concepts as they teach physics, regardless of whether students took middle school algebra or not. The conceptual approach and hands-on learning are effective teaching methods to meet the developmental needs of ninth grade students. Gathering student feedback regarding their perceptions of the course can help to shape it into a course that works well for students.

Schools offering Physics First need to have AP Physics available the third year after Physics First runs. This is also something that takes planning as teachers planning to become AP teachers need to go to AP workshops for training to learn the curriculum. Schools need to decide if they will offer AP Physics C or AP Physics 1,2. Some schools are offering AP Physics 1 as an honors Physics First course followed by AP Physics 2 as the senior year course.

The nation needs STEM workers from diverse backgrounds to work together to solve problems. Physics has always been a field of study pursued mostly by white men. High schools can make a difference by giving everyone a Physics First experience that builds self-efficacy in students to continue into AP Physics. Physics First classes need to be interesting and engaging, using the conceptual approach with hands-on learning. Teachers need to be supportive and encouraging of all students. Schools should have academic resource centers where all students can get additional support outside of class. STEM clubs, STEM career programming, and STEM experiences outside of school can also help promote STEM careers for all.

The role of self-efficacy in influencing students to take AP Physics and pursue STEM majors and careers is significant, particularly for underrepresented groups. When students see themselves in STEM careers because of role models, they develop self-efficacy. When students find success in math and science, they develop self-efficacy. When students are encouraged to pursue STEM careers because of the influence of parents, teachers, and mentors, they develop self-efficacy. When they have positive feelings toward STEM and have a network of friends who share those feelings, they develop self-efficacy.

AP Physics course enrollment is a decision. It is influenced by the opportunity to earn college credit and the addition of an AP course on the high school transcript. It is also influenced by the interest and engagement students experienced in their first physics course. Therefore, teachers and their instruction are very important to the success of the course. The self-efficacy developed is also a factor in making the decision to take an AP Physics course.

Future Research

To measure interest, engagement, and self-efficacy as factors influencing AP Physics enrollments, students could be anonymously surveyed in their AP Physics classes. The surveys could also be used as a measure of teacher support and encouragement.

Self-efficacy was introduced by Albert Bandura as part of his social cognitive theory (Bandura, 1999). According to Bandura, there are four factors that contribute to self-efficacy. First, self-efficacy is shaped by experiences: successes build self-efficacy and failures undermine it. Second, when students see others like themselves be successful at something they believe they could achieve; they develop self-efficacy. Third, social persuasion influences self-efficacy. When peers and mentors encourage and believe in students, self-efficacy increases. Fourth, physical and emotional states play a role in developing self-efficacy. A student's high school experience is connected to these four factors and the factors can be positive or negative. Self-efficacy also influences the decision of a student to pursue a STEM major in college. Perhaps a survey assessing these factors would be useful.

It would also be interesting to gather similar data on a larger scale to see if the findings from this study hold true. This could be done by working with the AP College Board to add questions to the survey given at the beginning of an AP Physics exam. Students could self-report on when they took algebra and physics. If students from Physics First programs nationwide are finding success in AP Physics and are pursuing

STEM degrees and careers, Physics First may be the direction of physics education in the 21st century.

Conclusion

The purpose of this study was to determine the impact of Physics First and middle school algebra on AP Physics course enrollments. In the sample population studied, Physics First increased AP Physics enrollments overall, notably among women. There is a correlation between taking Physics First and enrolling in AP Physics.

Taking algebra in middle school did not impact AP Physics enrollment as significantly as taking Physics First. Taking middle school algebra is helpful in Physics First; however, it is not an imperative. Perhaps staff development, including algebra and physics teachers working together, can help students learn to use algebra to solve for variables in real-life problems characteristic of physics, such as speed and weight problems. The support of a school academic resource center is also recommended.

Using this data and recommendations, school leaders should consider developing a Physics First program to serve the needs of all students in this age of science, technology, engineering, and mathematics. The foundational knowledge of physics helps all students better understand the physical world in which they live. Some students may discover a STEM career path that leads them to solving world problems faced now and in the future. The future of the U.S. economy and science and engineering leadership in the world is dependent on developing a diverse STEM workforce. This paper suggests a course pathway to support that need.

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APPENDIX A

NGSS and Common Core Math Standard Connections

Next Generation Science Standard for Physics	Science and Engineering Practice (Using Mathematics and Computational Thinking) Expectation	Common Core Math Standards
HS-PS2-2 Motion and Stability: Forces and Interactions	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.	*HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. *HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. *HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. **HSA.CED. A.1 Create equations and inequalities in one variable and use them to solve problems. **HSA.CED. A.2 Create equations in two or more variables to represent relationships between quantities, graph equations on coordinate axes with labels and scales. **HSA.CED. A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
HS-PS2-4	Use mathematical representations of Newton’s	*HSN.Q.A.1 (see above) *HSN.Q.A.2 (see above)

	Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	*HSN.Q.A.3 (see above) **HSA.SSE. A.1 Interpret expressions that represent a quantity in terms of its context. **HSA.SSE. B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.
HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	*HSN.Q.A.1 (see above) *HSN.Q.A.2 (see above) *HSN.Q.A.3 (see above)
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	**HSA.SSE. A.1 (see above) **HSA.SSE. B.3 (see above) **HSA.CED. A.4 (see above)

* High School: Number and Quantity Domain

** High School: Algebra Domain

APPENDIX B

Timeline for Physics First Course Development and Implementation

Year	Month	Action
2004	September	Science department discussed the ninth-grade physical science course changing to a physics course.
	October	Department reviewed samples of Physics First textbooks, including *Active Physics* and *Physics: A First Course.*
2005	May	Spring hiring resulted in the addition of a new staff member who had taught Physics First.
	June	Department offered a Camp Invention program for middle school students to promote STEM.
2006	January	Teachers in the department were encouraged to add a physics endorsement to their teaching certificates in case additional teachers were needed.
	January	Department chair met with middle school science teachers to explain the Physics First curriculum and discuss impact on course recommendations in the future.
	January	Department chair met with counseling department about Physics First to discuss concerns and receive feedback.
	January	Department chair met with a group of eighth grade parents about Physics First to discuss concerns and receive feedback.
	February	Department members divided into teams to visit area schools with Physics First programs and learn how they were implemented.
	March	Department chair attended a regional symposium on Physics First.
	April	Department chair met with a group of ninth grade parents about Physics First to discuss concerns and receive feedback.
	April	The department reviewed data from stakeholder meetings and decided to move forward with a course proposal. Physics First was best aligned to the skill outcomes the teachers write and scaffolded for grades 9-11.
	June	Department offered a Camp Invention program for middle school students to promote STEM.
	June	Class of 2005 was surveyed about their first-year college science experience to gather STEM major data.
	September	Course proposal submitted and approved for 2007-2008. Permission given to pilot course materials in physical science during the current year.
	October thru December	Course textbooks and equipment were received. A trainer from *Physics: A First Course* visited several times to train the physical science teachers on the program and how to best implement it.
	November	Began annual STEM careers update to department, including promotional materials for classroom.
	December	Department chair presents to counselors on Physics First relative to other course options.

2007	January	Department chair presents to incoming eighth grader and families on Physics First relative to other course options.
	May	Physics First Pep Rally staff development for the department to build understanding of the content and enthusiasm for the program.
	June thru August	Physics First teachers attend workshops on teaching physics including Fermilab classes and Abbott's CRASH program.
	August	Physics First implemented as new course
	December	Physics First teachers reflect on how course is going--math, equipment sharing, and storage are identified as issues.
2008	January	MIT Women's Initiative is sponsored by department to build interest in engineering among women.
	April	Physics First students survey for course experiences and input.
	May	Department members visit Physics First classes.

Ongoing professional development has included differentiation, supporting struggling students, social emotional learning, and aligning to the NGSS. Physics First teachers have worked with the freshman advisory program to build academic skills and with the school psychologist to build student ownership of learning and self-efficacy.