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## **An Effective High School Inquiry-Based Physics First Curriculum: Student and Alumni Perceptions**

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LOYOLA MARYMOUNT UNIVERSITY

An Effective High School Inquiry-Based Physics First Curriculum: Student and Alumni  
Perceptions

by

Fawzia Bibi Qazi

A dissertation presented to the Faculty of the School of Education,  
Loyola Marymount University,  
in partial satisfaction of the requirement for the degree  
Doctor of Education

2019

An Effective High School Inquiry-Based Physics First Curriculum: Student and Alumni  
Perceptions

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by

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This dissertation written by Fawzia Qazi, under the direction of the Dissertation Committee, is approved and accepted by all committee members, in partial fulfillment of requirements for the degree of Doctor of Education.

7-23-2019

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## **DEDICATION**

This study is dedicated to my family, educators and students. My parents made countless sacrifices to provide educational opportunities so that I could pursue my own path in life. My teachers were ahead of their time, teaching inquiry and keeping me engaged in high school. My science department's talent and professionalism inspire me every day. This is dedicated to educators who are always looking to improve how and what they teach and listening to student voices. Last but not least, this is for the students. I hope you are forever engaged as science learners.

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## LIST OF ABBREVIATIONS

AAPT	American Association of Physics Teachers
AP	Advanced Placement
BCP	Biology first secondary science sequence. Biology is first (introductory and descriptive), chemistry is second, and physics is the terminal science course.
BSCS	Biological Sciences Curriculum Study
FCI	Force Concept Inventory. A diagnostic exam to measure conceptual understandings of students in Newtonian mechanics.
NRC	National Research Council
NSF	National Science Foundation
NAEP	National Assessment of Educational Progress
PCB	Physics First secondary science sequence. Physics is first (introductory and foundational); chemistry is second, followed by biology.
PF	Physics First is the common name of a high school curriculum where ninth-graders take physics and 10th-graders take chemistry
PISA	Programme for International Student Assessment. This is an assessment sponsored by the Organization for Economic Cooperation and Development (OECD). Launched in 1997 it aims to evaluate education systems worldwide every three years by assessing 15-year-old student competencies in key areas such as mathematics and science.
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Trends in International Math and Science Study
5E	Educational model comprised of the following stages: Engage, Explore, Explain, Elaborate and Evaluate

## ABSTRACT

### An Effective High School Inquiry-Based Physics First Curriculum: Student and Alumni Perceptions

by

Fawzia Bibi Qazi

Efforts to improve science education have resulted in proposed innovative teaching methods and changing course sequences such as the inquiry-based Physics First curriculum. This study examined student and alumni perceptions of a Physics First course in a modified curriculum that inverted the traditional course sequence of Biology-Chemistry-Physics (BCP) to an inquiry-based Physics First (PF) curriculum in which students take an inquiry-based physics course as freshman and chemistry as sophomores. This study explored the experiences of students in their ninth grade physics course and how the Physics First curriculum influenced students' and alumni future STEM course choices and experiences. The qualitative study included a sampling of 16 male students and alumni selected from students currently enrolled and alumni who graduated within five years of the study. All the students interviewed recalled positive, memorable experiences in their Physics-9 course as they explained in their interviews that they enjoyed their Physics-9 course and remembered details about the engaging, hands-on projects as their favorite activities. Since the adoption of the PF curriculum more students were taking honors and AP science courses and over 90% of the students at the site enrolled in four years of science even

though only three years were required. Almost all of the students liked science for the first time because of the Physics-9 course.

## CHAPTER 1

### BACKGROUND OF STUDY

The preferred course sequence of high school science, proposed in 1892 by the Committee of Ten (CoT), placed physics before chemistry (National Education Association [NEA], 1893) and recommended that physics be taught before chemistry. Even though most educators agreed that physics should precede chemistry (Sheppard & Robbins, 2007, 2009), several factors, such as college admission requirements, availability of lab equipment and the emergence of new science courses, resulted in the adoption of a biology-chemistry-physics (BCP) course sequence (Sheppard & Robbins, 2009) rather than the physics-chemistry-biology (PCB) sequence.

Nobel laureate, Leon Lederman (2001), coined the term *Physics First* (PF) as he proposed that physics should be taught first, because pedagogically it made more sense as physics conceptually provides the foundation for chemistry and biology. Lederman (1998) promoted PF through the formation of the American Renaissance in Science Education (ARISE) project. The American Association of Physics Teachers (AAPT) reported that only 30% of high school students take physics, blaming this low percentage on the placement of physics in the course sequence. If the physics course appeared first in the sequence, it would allow more students to be exposed to this discipline, which provides the foundation to engineering and real-world math applications (American Association of Physics Teachers [AAPT], 2006). The National Science Foundation (NSF) and other organizations have identified the need to support science literacy, and many science education community members support the PF course sequence (Bybee et al., 2006).



Physics First teachers support PF and report students are eager to learn physics, are taking more science courses in high school, and are more likely to take a more rigorous second year physics course (AAPT, 2006). PF teachers report that teaching physics to ninth graders makes it easier to challenge their misconceptions (AAPT, 2006). In *Putting Physics First: Three Case Studies of High School Science Department and Course Sequence Reorganization*, Larkin (2016) described the lessons learned from the three schools that underwent the curriculum change from BCP to PCB for various reasons, including an anticipated increase in math scores and to prepare more students for higher level math courses. Increased conceptual understanding of physics has been reported among ninth graders when compared to the 12th graders after both grades took physics for the first time (O'Brien & Thompson, 2009). Studies have also reported that PF curriculum improves math performance (Glasser, 2012). Gaubatz (2013) reported no significant increase in standardized math test scores but indicated that transition to a PCB program resulted in increased Honors and Advanced Placement (AP) course enrollments, a better understanding of the nature of science, and increased student interest in science, including students anticipating that they could be successful in college science.

### **Statement of Problem**

Despite efforts to continually improve science education, achievement in science among American students has been average compared to other countries (Mullis & Martin, 2015) and 12th-grade science scores remain stagnant over the past six years (National Center for Education Statistics [NCES], 2015a). The efforts to improve science education have resulted in proposed innovative teaching methods and changing course sequences such as the inquiry-based PF curriculum. Therefore, the influence of such programs on students' choices for future science

courses in high school and beyond must be examined. While a few studies have demonstrated the impact of PF programs on science achievement (Gaubatz, 2013; O'Brien & Thompson, 2009) and mathematics (Bouma, 2013; Glasser, 2012), fewer have explored other impacts of PF, including its impact on the selection of future science courses. The need to investigate the perceptions and influences of PF has been repeatedly recommended in literature (AAPT, 2006; Larkin, 2016). The perceptions of PF curriculum and its impact on future science courses and STEM career choices has yet to be explored and is the purpose of the current research.

### **Research Questions**

The research will be guided by the following questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
- How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
- How has the Physics First curriculum influenced alumni career choices?

### **Purpose of the Study**

The purpose of this study is to explore and understand the perceptions of current and former high school students who participated in an inquiry-based PF curriculum and to examine the influence of the curriculum on students' future science course choices. Trends of enrollment in honors and AP courses will also be examined along with student choice of college majors, future fields of study and careers chosen for the students who have participated in the PF program.

## Significance of the Study

The examination of how enrollment in a high school inquiry-based PF curriculum has influenced students' future science course choices aimed to add to existing research and fill a gap articulated in the literature (AAPT, 2006; Larkin, 2016). Many studies on PF programs call for further studies to address impacts of PF programs (Bouma, 2013; Glasser, 2012; Gaubatz, 2013). While there are a few studies that have demonstrated the connection to math achievement (Bouma, 2013; Glasser, 2012), more information is needed to determine the connection between PF curriculum and whether students enroll in more science courses, enroll in more challenging science courses, and demonstrate a greater interest and participation in science, technology and engineering careers (Glasser, 2012). Research on the impacts of PF programs will help inform science educators and educational leaders looking to update and improve science curricula (Gaubatz, 2013).

Finally, inquiry-based PF curricula can possibly address the social justice concern about accessibility of science by making physics accessible for a more diverse group of students (Eisenkraft, 2010). Low participation of minorities and women in science careers is a social justice concern. While recent trends in college enrollment demonstrate growth of minority groups, women, and minorities remain underrepresented in the science, technology, engineering, and mathematics (STEM) professional careers (National Research Council [NRC], 2011; National Science Foundation [NSF], 2017). Underrepresented minorities' participation in science and engineering has not shown growth and participation in mathematics has dropped (NSF, 2017). Not only are minority groups underrepresented in science and engineering occupations, they also have limited access to advanced AP courses (College Board, 2013). Literature

regarding minorities in science support the social justice concern that there is an issue to access in science education and careers for minority students, which PF has the possibility to remediate.

Studying the perceptions of current and former students of a high school inquiry-based PF curriculum and how the curriculum may influence students' science course choices will provide insight into a PF program that been established for a decade. The student perceptions may help determine possible outcomes of such a science program, and if shown that this program helps increase interest in science careers, it may be adopted by other schools and districts and help increase student interest and participation in science careers. Data from this study may also help determine factors that help students successfully engage in STEM education and careers and thus help address the important social justice issue regarding the access to science education. Additionally, the student perceptions may help determine an appropriate science course sequence for students, a sequence that allows students to take physics earlier and thus increase access to a subject critical to STEM fields (AAPT, 2006). Lastly, insights obtained from this study may provide evidence to encourage more schools and districts to adopt a more suitable curriculum, improving access for all students. Increased access aims to answer the decades old call for *Science for all Americans* (American Association for Advancement of Science [AAAS], 1990) and subsequently physics for all (Eisenkraft, 2010).

### **Conceptual Framework**

This study was grounded in a constructivist conceptual framework, consistent with many other works about PF (Bouma, 2013; Gaubatz, 2013; O'Brien & Thompson, 2009).

Constructivism views learning as a process in which students actively construct or build new ideas and concepts based on prior knowledge. A constructivist teacher facilitates the learning of

students and is not the “sage on the stage.” Important contributors to different aspects of constructivism and inquiry-based learning include Vygotsky (1978), Piaget (1963), Papert and Harel (1991), and Dewey (1938), among many others. Vygotsky (1978) described how social connection between people helped learning, which is applied frequently in inquiry-based physics classrooms. Piaget suggested that individuals construct new knowledge from their experiences through accommodation and assimilation. Piaget’s theory of constructivism was not only applicable to the teaching and learning of science today (Wavering, 2011), but also gave rise to other theories, including Papert’s constructionism (Papert & Harel, 1991). Papert, influenced by Piaget, described that students learn when they are highly engaged while making a product (Papert & Harel, 1991). Papert’s approach, constructionism, involved inquiry-based discovery learning and problem-solving situations in which students draw upon past experience and existing knowledge to construct new knowledge (Papert & Harel, 1991).

Nineteenth century philosopher Herbart’s (1901) psychology of learning and John Dewey’s (1938) “complete act of thought” philosophy both contributed to the development of the 5E instructional model—engagement, exploration, explanation, elaboration, and evaluation—used in inquiry-based physics instruction (Van Scotter, 2006). Herbart’s psychology of learning included an instructional model, which described that learning begins with students’ current knowledge and builds on that knowledge to establish connections between the prior knowledge and new ideas. According to Herbart (1901), “The best pedagogy allows students to discover relationships among their experiences” (as cited in Van Scotter, 2006, p. 43). Dewey’s (1938) philosophy inspired an instructional model, which gained popularity in the 1930s. The instructional model developed by Dewey included the following steps: “sense a perplexing

situation, clarify the problem, formulate a hypothesis, test the hypothesis, revise tests, and act on solutions” (as cited in Van Scotter, 2006, p. 45). It was a predecessor to the 5E model.

In *How People Learn*, Donovan, Bransford, and Pellegrino (1999) described best teaching practices as structured activities so that students are able to explore, explain, extend, and evaluate their progress. Students need to see a reason for the use of ideas and concepts taught in class so that they can connect the relevant uses of the knowledge to make sense of what they are learning. The follow-up book to *How People Learn*, *How Students Learn: Science in the Classroom* (Donovan & Bransford, 2005), described the application of the principles of learning elementary, middle, and high school levels and details development of successful curricula and teaching approaches. Donovan and Bransford (2005) presented models for curriculum development, classroom instruction and discusses how to build straightforward science experiments into true understanding of scientific principles. The PF curriculum in this study was an inquiry-based curriculum founded on the principles of the 5E learning cycle.

### **Research Design and Methodology**

A qualitative research methodology was used to accurately capture students’ perceptions of an inquiry-based freshman level PF curriculum. Qualitative methods allowed for a complex, detailed understanding of the issues, and qualitative research followed up the prior quantitative studies to allow for further exploration and explanation (Creswell, 2007). This study was a qualitative follow-up study to *Physics First: Impact on SAT Math Scores* (Bouma, 2013). The study included a purposeful sampling of 16 students. Purposeful sampling was used because “the research participants can speak to the research question” (Creswell, 2009, p. 81). Eight current students and eight alumni who graduated within five years of the study were included. All 16

participants completed the inquiry-based physics course (Physics-9) as freshmen at the high school site. The characteristics of the participants included the following:

1. Four 11th-grade students (juniors) currently enrolled at the school,
2. Four 12th-grade students (seniors) currently enrolled at the school,
3. Four alumni who pursued science majors and/or careers in science, and
4. Four alumni who have not chosen science majors and/or careers in science.

Two juniors followed the Physics-9 course with sophomore-level Honors Chemistry and were enrolled in a junior-level AP science. Two of the juniors took regular-level chemistry. Two seniors took Physics-9, followed by regular-level chemistry. Two seniors took Physics-9 followed by sophomore Honors Chemistry and a junior-level AP course. The purpose for each of the varying characteristics was to explore student perceptions at various levels of course sequences and experience. This allowed examination of ways in which Physics-9 informed and influenced course selections and experiences at the sophomore, junior, and senior levels. The study of alumni in science and non-science fields helped explore influences of PF in their choices of courses and careers. The sample of 16 students and alumni participated in a semi-structured interview. The interviewer used an interview protocol (see Appendices A through C), consisting of 14 questions for students and 17 questions for alumni.

The research site, an all-male private Catholic secondary school with a PF curriculum introduced 10 years ago, allowed for the study of future course choices of current students and future course choices and career choices of alumni due to the length of time that the PF curriculum has been offered. However, the exclusion of female students at the private secondary

school and the school's access to fiscal resources and human capital presented a limitation to the application of the results of the study to other coed and lower socioeconomic contexts.

### **Limitations**

Several limitations emerged in this qualitative study of the perceptions of a PF curriculum including experimenter bias, self-reported data, survey validity and sample size. The researcher was the science department chair and a teacher at the site of the study. Although she aimed to study the data objectively by coding the interviews, the interpretation of the qualitative data was subject to personal bias as viewed through the lens of the researcher.

In addition, the data consisted of qualitative interviews and surveys and thus the responses were self-reported by current students and alumni and were as accurate as the reflections of the subjects of the study. Current students and alumni may have tended to recall their perceptions of the PF curriculum as extremely positive or negative based on their overall experience as a student.

The survey and interview protocol designed by the researcher was not a standard survey and so may be limited in its validity. The small sample size of 16 students emerged as an additional limitation. Due to the in-depth nature of the interviews, only a limited number of students and alumni were interviewed.

Finally, the site of the study, an all-male, private college preparatory high school with access to resources and a history of high academic achievement, presented a limitation to the generalizability to other schools that are coed and low socioeconomic status (SES).

### **Delimitations**

Delimitations were the characteristics of the study controlled by the researcher. This



study took place at a single sex, college preparatory high school with resources to implement a 10-year standing PF program.

### **Definition of Terms**

The following definitions were used in this study:

- *Constructivism*: A learning theory in which learning is viewed as a process whereby students actively construct or build new ideas and concepts based on prior knowledge (Piaget, 1963).
- *Curriculum*: A designed sequence of study to learn knowledge, skills, and understandings of a particular discipline. (National Research Council, 2012).
- *Inquiry-based instruction*: An instructional method of teaching in which a teacher creates learning experiences and guides the inquiry process by addressing preconceptions, formulating questions, setting up a problem, investigating, sharing results, discussing and reflecting. Students arrive in the classroom with conceptions, skills, and abilities. A meaningful context promotes the conditions to further develop concepts, skills, and abilities (Bybee et al., 2006).
- *Inverted science curriculum*: A high school science program that teaches the traditional science disciplines in the following order: physics, chemistry, and biology (Lederman, 2001).
- *Physics First (PF)*: A science curriculum that begins with a ninth-grade physics (Lederman, 2001).
- *Physics-9*: The name of the freshman PF course at the site.
- *5E instructional model*: An instructional model that describes a five-stage teaching

sequence teaching sequence (engage, explore, explain, elaborate and evaluate) used for programs, units and lessons (Van Scotter, 2006).

### **Organization of Dissertation**

Improving science education and increasing access to science education emerges as an issue of significance in the nation. As many schools are modifying curriculum to help better prepare students for science it is imperative the perceptions of the programs are evaluated. Chapter 1 consisted of the introduction, problem, research question, purpose, significance, and conceptual framework of the research. Chapter 2 reviews the history of science education in the United States and provides current research about PF education. Chapter 3 describes the research methodology. Chapter 4 reports the research findings and the analysis of the data. Chapter 5 discusses the implications of the findings and offers recommendations for future research.

## CHAPTER 2

### REVIEW OF THE LITERATURE

This study examined the influence of a Physics First (PF) curriculum at an all-male private Catholic high school on the current student science course choices and alumni career choices for alumni who have pursued science and non-science careers. This literature review will first address the crisis in science education in the United States, including disappointing student achievement on assessments and fewer students who are prepared for STEM careers. The chapter will next review the early history of science education, educational theories and reforms leading up to the development of the national science standards, and the beginning of the PF movement. Finally, findings from current PF literature will be presented, demonstrating the need to evaluate the effectiveness and the perceptions of existing PF programs.

#### **The Problem with the Current State of Science Education**

##### **Student Achievement on Assessments**

Scientists and the American public share a dim view of U.S. science education. A 2015 survey reported that 29% of Americans considered science and technology education in the United States as below average while 46% of the scientists surveyed from the American Association for the Advancement of Science (AAAS) considered the science education to be below average (Pew Research Center, 2015). Unfortunately, these perceptions of science education in the United States are supported by average and below average student achievement on international and national exams.

**Program for international student assessment.** The Program for International Assessment (PISA) is an international study that has tested reading ability, math, and science

literacy of 15-year-old students every three years since 2000. Since the onset of PISA testing, U.S. science results have been average and not significantly improving. In 2015, United States students placed 24th out of 71 countries participating in the study (Organisation for Economic Co-operation and Development, 2015).

**Trends in international mathematics and science study.** The International Association for the Evaluation of Educational Achievement conducted a series of math and science assessment internationally. The Trends in International Mathematics and Science Study (TIMSS), has tested fourth- and eighth-grade students every four years since 1995. The performance by fourth graders has shown a decline from third place out of 48 countries in 1995 to 10th place in 2015. The eighth graders did not score in the top 10 until 2003, declined and fell to 11th place in 2007, and have scored 10th place in 2011 and 2015 (Mullis & Martin, 2015).

**National Assessment of Educational Progress.** The National Assessment of Educational Progress (NAEP) is a project of the U.S. Department of Education testing student performance since 1969. The science scores were reported on a scale from 0-300 based on responses to assessment questions and are categorized as basic or proficient. The recent average score for fourth and eighth graders has shown a small improvement from 150 to 154 out of 300 from 2009 to 2015, while the 12th-grade average score remained 150 out of 300 (NCES, 2015a). Most recent data from 2015 shows that 38% of fourth graders, 34% of eighth graders and 22% of 12th graders earned proficient or higher ratings in science, while 24% of fourth graders, 32% of eighth graders and 40% of 12th graders were rated below basic in science (NCES, 2015a). This disturbing trend suggested that students are less prepared in science as they move to higher grades.

## **Workforce and STEM Education**

The international assessment scores, which indicate that American students are less capable than other nations in science, require the U.S. educational system to provide a sound science education for preparing students for STEM careers in the workforce. A 2017 NSF report stated that the “first step in enabling workforce pathways is to ensure that all Americans have access to a high-quality, well-rounded education that includes foundational concepts in STEM” (p. 15). The 2017 report described, “the STEM workforce has an outsized impact on a nation’s competitiveness, economic growth, and overall standard of living” (NSF, p. 11). Therefore, a well-prepared STEM workforce serves an important role to further the nation’s economic growth and will benefit workers, as STEM jobs are associated with lower unemployment and higher wages. A quality science education can prepare American workers for better paying jobs while also supporting national economic growth (NSF, 2017, p. 11). The subsequent sections will trace the history of American science education and educational reforms aimed to improve the quality of science education.

### **History of Science Education and Inquiry**

#### **Early History**

**Inquiry in science.** Reforms in science teaching have been characterized by shifts from teaching science as a body of knowledge to a more student-centered approach (Gess-Newsome, Luft, & Bell, 2009). *Science as Inquiry in the Secondary Setting* (Gess-Newsome et al., 2009) described that science teaching today should be initiated by focusing on scientific theories and models, asking researchable questions, generating hypotheses, gathering information, presenting evidence, and forming arguments. Teachers should provide opportunities for students to

investigate and explore the applications, history, and nature of science. Teaching science as inquiry “challenges students to form deep understandings about natural phenomena by engaging in the construction of scientific knowledge through an active process of investigation” (Gess-Newsome et al., 2009, p. 22).

**First American science courses.** In the early 1800s, the privileged class attended secondary schools to prepare for college admissions. The few science courses that existed prepared students for college and focused on the practical sides of science and technology, such as astronomical calculations, navigation, measurement and surveying. Additional courses including botany, meteorology, mineralogy, physiology, and zoology were added by 1860. The science courses were mostly lecture based without labs. In those courses, instructors without science backgrounds taught science as a “body of facts” as “watered down” (Gess-Newsome et al., 2009) versions of the college science courses. Teachers covered lots of content, without addressing science process and student interest. Concerns about the overrepresentation of college courses in the high school science curriculum lead to attempts to standardize high school science.

**First attempts to standardize curriculum.** In the late 1800s, the CoT, a group of educators formed by the NEA (1893), proposed to standardize the high school curriculum. The committee reported that high schools did not exist only for college preparatory education and recommended an alignment of elementary through high school programs. The preferred course sequence of high school science, proposed in 1892 by the CoT placed physics before chemistry (NEA, 1893). Even though most educators agreed that physics should precede chemistry (Sheppard & Robbins, 2007, 2009) several factors, such as college admission requirements, availability of lab equipment, and the addition to emergence of new science courses resulted in

the adoption of BCP course sequence rather than the PCB sequence (Sheppard & Robbins, 2009).

**Shifting goals of science education.** The recommendations of the CoT decreased the influence of colleges in high school science curriculum. By the late 1800s and through the early 1900s, students in the United States experienced lecture-based college preparatory courses or learned about the mathematics applications for industrial society. Events such as World War I, and the Great Depression followed by World War II, changed political and social circumstances and the goals of public and science education. School science programs stressed the practical aspect of science to prepare students to become productive members of society (Gess-Newsome et al., 2009).

In the 1920s, the term *inquiry* began to appear in national committee recommendations and as the number of students in public education grew, the goals of science education changed. The Commission on the Reorganization of Secondary Education developed seven goals of science teaching (Caldwell, 1920) and published a report encouraging science educators to incorporate the seven goals into science teaching (Caldwell, 1920). The goals included applications for health, vocation, citizenship, leisure time, and ethics. In addition to the seven goals, national committees recommended an inquiry-based approach to science instruction and the importance of observation, experimentation and scientific thinking (Caldwell, 1924).

### **Educational Theorists Supporting Inquiry**

While national committees recommended student inquiry in the science curriculum during the first half of the 1900s, the recommendations were not implemented in most of the classrooms (Bybee, 1977). During this time, in the development of science education reforms,

scientists contributed to the content and process of inquiry, while psychologists such as Dewey (1938), Piaget (1970), and Bruner (1961) proposed educational theories and models supporting experience-based student-centered learning.

**John Dewey.** Dewey (1938) proposed an experience-based educational model in which students build upon prior experiences, preconceptions and knowledge. Dewey's philosophy inspired an instructional model, which gained popularity in the 1930s, included the following steps: (a) sense a perplexing situation, (b) clarify the problem and (c) formulate a hypothesis, (d) test the hypothesis, (e) revise tests, and (f) act on solutions (Van Scotter, 2006). Dewey's model inspired the steps of exploration, invention, and discovery in the Atkin and Karplus learning cycle used in the Science Curriculum Improvement Study (Van Scotter, 2006). The terms were modified as *exploration*, *term introduction*, and *concept application* as the learning cycle influenced the development of the 5E model—engage, explore, explain, elaborate and evaluate (Van Scotter, 2006).

**Jean Piaget.** Piaget (1970) described intellectual development through the construction of thinking skills that develop when learners figure out puzzling events. Piaget's theory of constructivism is not only applicable to the teaching and learning of science today (Wavering, 2011), but also gave rise to other theories, some of which are most pertinent in science education including metacognition and constructivism. Constructivism views learning as a process in which students actively construct or build new ideas and concepts based on prior knowledge. Thus, Piaget suggested that individuals construct new knowledge from their experiences through accommodation and assimilation.



**Jerome Bruner.** Bruner (1961) advocated discovery learning, as he believed that the main purpose of education was to teach students how to learn and not to simply accumulate information. Bruner described four benefits of discovery learning: the increase of intellectual potency, the shift from extrinsic to intrinsic rewards, the heuristics of discovery, and the aid to the memory process. Bruner believed that students would figure things out themselves if teachers did not give the students answers to puzzling events.

Educational theories proposed by Dewey (1938), Piaget (1970), and Bruner (1961) supported the inquiry-based, process-oriented science education recommended by the committees of science educators in the early history of American science education. The models of education proposed by aforementioned education theorists served as the foundation of the national science standards described in the next sections.

### **Recent History and Standards-Based Education**

*National Defense Education Act (1958).* After World War II, the United States transitioned to a time of economic expansion and population growth. The Cold War with the Soviet Union necessitated scientific and technological advancement, but scientists reported that college students were not prepared for science, students were not pursuing science majors, and high school courses lacked rigor (Gess-Newsome et al., 2009). While these observations began small-scale science curriculum reforms, the launching of Sputnik in 1957 began a significant curriculum reform in science and mathematics education. After Sputnik, the nation's schools were expected to produce engineers and scientists (Johanningmeier, 2010) and scholars from various disciplines updated public school curriculum. The U.S. Congress concluded that the United States school system failed to produce technical specialists to keep up with the Soviet

Union and the Congress passed emergency measures including *National Defense Education Act (NDEA)* in 1958, increasing funding for science education. This government funding supported up-to-date science content and promoted inquiry-based instruction, but the reform efforts did not reach all high schools in the country and the government funding was not sustained (Gess-Newsome et al., 2009).

***A Nation at Risk (1983)***. As the funding for the *NDEA* (1958) expired and Japan rose as a competitor in the manufacture of automobiles, electronic equipment and steel, a renewed interest in updating national education standards occurred. Science education was criticized for not preparing students as published in the report *A Nation at Risk* (1983) (Johanningmeier, 2010). *A Nation at Risk* (1983) from the National Commission on Excellence in Education stated, “Our education system has fallen behind, and this is reflected in our leadership in commerce, industry, science and technological innovations, which is being taken over by competitors throughout the world” (p. 5). Other reports, funded by the NSF, followed. Project Synthesis summarized thousands of pages of reports from professional organizations on the state of science education and recommended four goals for science education: personal needs, societal issues, academic preparation, and career education (Yager & Lunetta, 1984). Many science and learning organizations such as the American Chemical Society (ACS), the Biological Sciences Curriculum Study (BSCS), and the National Science Resources developed innovative science curricula focused on inquiry and the updated goals of science education (NRC, 1996).

**National Science Education Standards**. In 1989, in its Project 2061, the AAAS published *Science for All Americans*, which defined scientific literacy for high school graduates. Soon after the National Science Teachers Association (NSTA) followed by publishing of the

Content Core standards. These all set the foundation for the National Science Teachers Association “reflecting a unanimous vote of the NSTA board” (NRC, 1996) to write to the President of the National Academy of Sciences and chairman of the National Research Council (NRC) “to coordinate development of national science education standards” (NRC, 1996). As a result, the National Science Education Standards (NSES) were established and included standards for science teaching, professional development, assessment, content, education programs and education systems. Inquiry-based education pedagogy was at the heart of the NSES.

**How people learn.** After the NSES, the NRC report, *How People Learn* (Donovan, Bransford, & Pellegrino, 1999), resulted from the studies of by two committees, the Committee on Learning Research and Educational Practice and the Committee on Developments in the Science of Learning. In *How People Learn*, best teaching practice was described as inquiry-education, having activities structured so that students can explore, explain, extend, and evaluate their progress. Students need to see a reason for the use of ideas and concepts taught in class so that students can connect the relevant uses of the knowledge to make sense of what they are learning (Donovan et al., 1999).

**How students learn.** *How People Learn* was followed by *How Students Learn: Science in the Classroom* (Donovan & Bransford, 2005), which described the application of the principles of learning elementary, middle, and high school levels and details development of successful curricula and teaching approaches. *How Students Learn* presented models for curriculum development, classroom instruction, and discussed how to build straightforward science experiments into true understanding of scientific principles.

**Labs in high school science.** *America's Lab Report: Investigations in High School Sciences* (NRC, 2006) emerged as a follow up to the NSES and examined the role of labs in high school science education. The report supported inquiry-based instructional models and stated that science education includes both learning about the methods of scientific inquiry and the knowledge derived from those processes. The learning goals that should be attained as a result of laboratory experiences included the following: enhancing mastery of subject matter, developing scientific reasoning, understanding the complexity and ambiguity of empirical work, developing practical skills, understanding the nature of science, cultivating interest in science and interest in learning science, and developing teamwork abilities (NRC, 2006).

**Next Generation Science Standards.** After the publishing of the NSES, followed by *How People Learn, How Students Learn*, and *American's Lab Report*, the NSES were updated and replaced by Next Generation Science Standards (NGSS) to include three dimensions: (a) science and engineering practices, (b) crosscutting concepts, and (c) core ideas. The National Research Council (NRC) scientific practices in the NGSS included “the critical thinking and communication skills that students need for postsecondary success and citizenship in a world fueled by innovations in science and technology” (NRC, 2012, p.45). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* described science and engineering practices based on the skills that scientists and engineers use daily. The standards were based on the findings about research on how students learn science effectively including other NRC publications such as *How People Learn* (Donovan et al., 1999) and *How Students Learn* (Donovan & Bransford, 2005). The purpose for the science education standards was to “describe clear, consistent and comprehensive science content and abilities. Then based on the

standards, reform essential components of the science education system programs for school science, teaching practices and assessments” (Bybee, 2014, p. 212).

**First step of NGSS development.** The development of NGSS began in 2010 as a two-step process. The first was the development of *A Framework for K-12 Science Education* by the NRC. The NRC developed a committee of 18 national and international experts including not only scientists and researchers, but two Nobel Laureates as well. The framework had three parts: (a) vision for science education, (b) content for science and engineering education, and (c) integration for content, implementation and equity and guidance for NGSS. The NRC recommended a set of rigorous goals for all students and presented a scientifically accurate curriculum, informed by research on learning and teaching. The concepts progress coherently across and within grades while the performance expectations integrated all three dimensions (NRC, 2012).

**Second step of NGSS development.** The second part of the two-step NGSS development was managed by Achieve, Inc., an independent, nonpartisan, nonprofit education reform organization (NRC, 2012). Twenty-six states pledged their commitment to create teams to give feedback on the drafts of NGSS. The final document resulted from a collaborative effort of the 26 states and “important stakeholders in science, science education, higher education, and business and industry” (Bybee, 2014, p. 213). Several drafts were reviewed and two of the drafts were released publicly, “which provided all interested and involved individuals and groups with an opportunity to inform the proposed content and practices as well as organization of the NGSS” (Bybee, 2014, p. 213). The process resulted in “a set of rigorous, high quality K-12

science education standards that passed a final review for fidelity by the NRC” (Bybee, 2014, p. 213). The National Academies Press released the NGSS in April 2013.

**Changes in NGSS.** Pruitt (2014) described changes in the standards as increased rigor in the NGSS in comparison to NSES and explained that the performance expectations (PE) were practices that the students should have been able to complete in addition to the knowledge of the content and that “while there [was] a practice coupled with specific content in the NGSS, this should not [have been] misinterpreted to mean it [was] the only practice to be used in classroom instruction nor should it [have] diminish[ed] the content requirement on students” (Pruitt, 2014, p. 150). In addition, Pruitt (2014) explained that instructional planning and focus needed to change as a “key aspect of both the Framework and the NGSS is the commitment to coherence” (p. 152). This meant that to correctly implement the NGSS, instruction must have been designed as a full instructional plan rather than a series of lessons, as “attempting to teach the NGSS from day to day will negate coherence” (Pruitt, 2014, p. 151). There had to have been a carefully thought out learning progression and some PE’s should have been bundled or grouped together to “ensure the coherence of science instruction stay intact” (Pruitt, 2014, p. 150). Trying to teach each PE one at time would “lead to a disjointed view of science” (Pruitt, 2014, p. 150). Finally, the subject of engineering, a new aspect of the standards for most states, was integrated in the NGSS in in three ways: (a) as a component of the Scientific and Engineering Practices, (b) as a standalone set of Pes supporting engineering design, and (c) used to connect to science and society (Pruitt, 2014).

## The Physics First Movement

### Early History of Course Sequence

**Lack of standardization.** Science education reforms traditionally focused on how science was taught and the promotion of inquiry rather than didactic lecture methods. However, the sequence of science courses has also been subject of reform. Many important decisions made between 1890 and 1930 influenced the sequence in which science courses are taught today (Sheppard & Robbins, 2005). When chemistry was introduced into the classrooms in the 19th century, there was no specific high school science sequence (Newell, 1976). In 1892, out of 40 schools surveyed, only 28 offered chemistry. Of the schools that did offer chemistry, physics preceded chemistry (Krug, 1964). Some schools offered chemistry two periods a week while others offered chemistry two periods a day. The lack of standardization in high school science curriculum led to the creation of a national committee tasked to address the issue of standardization.

**Committee of Ten.** The National Educational Association organized the 10 individuals, the Committee of Ten (CoT), tasked to determine what should be taught in high school so that students were prepared for college. The CoT organized three subcommittees for the sciences, and they were given questions to answer about how much time should be devoted to each subject, when and how the subjects should be taught and assessed, what would be the best teaching methods, and what content should be taught. The physical science subcommittee presented their findings to the CoT, which then decided upon final recommendations for implementation. The CoT and its subcommittees offered three different rationales for the suggested placement of physics and chemistry: (a) physics should be in the 12th grade and chemistry in 11th grade

because of the mathematical ability needed for physics, (b) physics should be in 11th grade and Chemistry in 12th grade since physics was a prerequisite for other sciences, (c) physics should be in 10th grade and chemistry in 12th grade so that all students might be exposed to physics.

**Chemistry last.** The Committee on College Entrance Requirements (CCER), appointed by the National Educational Association in 1896, implemented the findings of the CoT. The committee followed the CoT's proposals and recommended that chemistry be taught after physics. The CCER recommended 16 required units, among which one unit was science and six units were electives. As general science and general biology were introduced in the early 1900s (Hunter, 1925), chemistry and physics became electives taken in the last years of high school. In 1920, the Committee on Reorganization of Science in Secondary Schools included general science and general Biology in their proposed four-year science sequence. Since both courses were descriptive and required little mathematics, general science and biology were placed before chemistry and physics. In 1924, the ACS Committee on Chemical Education advised chemistry teachers to teach chemistry after the students have had a year of general science, and a year of biological science and physics, in agreement with the reasoning of the CoT (Hunter, 1925).

**Biology first.** Although no committee recommended it, the BCP sequence gained popularity by the 1940s (Sheppard & Robbins, 2005) and remained as both the physics and chemistry communities preferred for their subjects to be last in the sequence. This course sequence had no pedagogical bases, as biology was not a prerequisite for chemistry, and chemistry was not a prerequisite for physics (Haber-Schaim, 1984; Robinson, 1963). However, conceptually the logical progression of PCB is apparent in most biology textbooks as most texts have energy, thermodynamics and basic chemistry in the first few chapters.



## **Beginning of Physics First**

Nobel laureate Leon Lederman (1998) brought attention to the problems with the popular BCP sequence, as he promoted that physics conceptually provides the foundation for chemistry and biology. Lederman (1998) coined the term *Physics First* and promoted Physics First through the formation of the American Renaissance in Science Education (ARISE) project. Lederman (1998) noted that since society relies more upon science and technology, more students need to learn more science, and this will be achieved by a conceptual physics course that addresses experiences from students' daily lives. Physics allows connections to sports, transportation, safety and popular science fiction, increasing student engagement. Lederman (2005) stated that a PCB sequence leads the student from the simple to the complex, an approach that is in harmony with current understanding of how the brain learns. ARISE published three reports supporting inquiry-based PF in a three-year science curriculum (Bardeen & Lederman, 1998), the state of PF programs (Pasero, 2003) and published a document to help with implementation issues (Schmidt, 2003). The NSF, among other organizations, had identified the need to support science literacy and many science education community members support the PF course sequence (Bybee et al., 2006).

Supporters of PF critiqued the limited time given to the study of physics (Sheppard & Robbins, 2009). Biology/advanced placement biology or chemistry/advanced placement chemistry were given two years of study in high school while physics was often limited to one year, if studied at all. Sheppard and Robbins (2009) suggested that high school introductory physics should be at least a two-year course with an introductory first year in the ninth grade and then a more mathematically rigorous course in 12th grade. AAPT reported that only 30% of

students take physics and blame its placement in the course sequence. If the physics course appeared first in the sequence it would allow more students to be exposed to this discipline that provides the foundation to engineering and real-world math applications (AAPT, 2009).

**Early implementation challenges.** In the early 2000s, PF was supported by several school districts. Districts in Maryland (Baltimore, Carroll, and Prince George), California (San Diego), Arkansas (Little Rock) and Massachusetts (Boston and Cambridge) offered Physics First at most or all schools (Popkin, 2009). However, implementation challenges existed including not being able to find teachers to teach the additional ninth-grade classes, the need for a significant amount of professional development, and difficulty expressed by experienced teachers accustomed to teaching a mathematically advanced course struggling to teach conceptual physics. In 2001, the superintendent in the San Diego Unified School District decided to implement PF in all of the district's high schools, but the teachers felt the program was being forced upon them and parents considered the curriculum to lack rigor. In response, the San Diego district stopped requiring schools to teach physics to ninth graders in 2006 (Popkin, 2009).

### **Review of Physics First Literature**

While a general search in an education database with key words, "high school physics" resulted in hundreds of articles, a search refined and limited to the key words: "Physics First" resulted in less than 30 articles including many master's theses and doctoral dissertations rather than peer-reviewed academic journals. The majority of the *PF* literature focuses on the history of the curriculum and on the pedagogical rationale for the PF course sequence. There was a very limited number of empirical research articles about the perceptions and effectiveness of the PF curriculum (AAPT, 2009; Dreon, 2006; Korsunsky & Agar, 2008; O'Brien & Thompson, 2009).

## **Study 1: Physics Curriculum**

In *Study of Physics First Curricula in Pennsylvania*, Dreon (2006) sought out 13 schools that reported to have PF curriculum and examined the textbooks and content topics covered in those programs. The study summarized results determined by analysis of curriculum guides from each of the schools, including major units covered and textbook used. Many of the courses had different names, since private schools called the PF courses Physics, or the course was named after the textbooks used. Some schools using Hewitt's (2004) *Conceptual Physics* gave the course the same name, and schools using Eisenkraft's (2013) *Active Physics* did the same. Many public schools named the course physical science. Despite their different names, all schools taught motion and most other topics such as Newton's laws, forces, sound, energy, optics, and electricity and magnetism. Other similarities that emerged included that 10 of the 13 schools taught chemistry in the 10th grade following the ninth-grade physics course, and eight of the 13 schools used *Conceptual Physics* by Paul Hewitt. The diversity of PF courses was apparent as most schools were teaching different units, different number of units and from different textbooks. This study brought to the forefront the different curriculum used in PF programs, calling for further studies in the effectiveness of the courses.

## **Study 2: Mathematically Rigorous Physics First**

Goodman and Etkina (2008) reported a new approach to the PF curriculum with a two-year program in which the first year includes teaching a mathematically rigorous physics course with algebra and AP Physics B content, and the remaining Physics B content taught during the second year. The effectiveness of the program was evaluated by the number of students passing the AP exam with 3 or above. As a result, more AP exams were taken, and more students passed

the exam at a rate 14 times greater than the average pass rate in the state. All students, whether they passed the AP exam or not, scored higher on the Trends in International Mathematics and Science Study (TIMSS). In addition, students in the PF courses were taking more science courses overall in high school (Goodman & Etkina, 2008).

### **Study 3: Surveying Physics Students**

While Goodman and Etkina (2008) studied student achievement, Korsunsky and Agar (2008) conducted student surveys of attitudes and expectations of eighth-grade students toward the upcoming ninth-grade physics course before they took the course. The student surveys informed pedagogy and curriculum improvements so that students could experience a more effective course. The authors reported that in their research they found many opinion papers but no actual PF research studies.

### **Study 4: Comparing Ninth and 12th-Grade Physics**

Published after the calls for more research on PF, O'Brien and Thompson (2009) presented pre- and post-assessment results in *Effectiveness of Ninth-Grade Physics in Maine: Conceptual Understanding*. The authors compared assessment results from physics classes taught in ninth and 12th grade and addressed the question of the difference in the performance of ninth and 12th graders taking physics for the first time. The 27-question multiple choice assessment included questions from the well-established Force Concept Inventory (FCI), Force and Motion Conceptual Evaluation (FMCE), and the Test for Understanding Graphs in Kinematics (TUG-K) to evaluate students understanding of mechanics. The assessment was given as a pretest in September and posttest in the spring. Results indicated that, although both grades experienced similar content knowledge and course difficulty, the ninth graders scored

higher on the assessment. The study included seven schools: Three schools offered physics to ninth graders, three offered physics to 12th graders, and one school had both a ninth-grade physics course and a course for 12th graders who had not taken physics. There were five different courses including a ninth-grade traditional, ninth-grade modeling-based instruction, ninth-grade honors traditional, ninth honors modeling and 12th-grade traditional. The ninth-grade non-honors modeling course had the highest gains and the gains were the same for honors modeling and non-modeling. Twelfth graders outscored the honors ninth graders (O'Brien & Thompson, 2009).

### **Study 5: Modeling and Physics First**

While O'Brien and Thompson (2009) used a modified version of the Force Concept Inventory (FCI) in their assessments, Liang, Fulmer, Majerich, Clevestine, and Howanski (2012) evaluated a modeling PF program using the FCI. Five teachers and 301 ninth- through 12th-grade students in two mid-Atlantic high schools participated in the study in which the FCI measured conceptual physics learning. It was found that the ninth graders enrolled in the model-based PF program achieved greater conceptual understanding of the physics content than those 11th and 12th graders enrolled in the non-modeling honors physics courses. Similar to O'Brien and Thompson (2009), Liang et al. (2012) reported that the ninth graders enrolled in the model-based PF program achieved a greater conceptual understanding than the 11th and 12th graders in a conventional non-modeling, non-PF program. The 11th and 12th graders enrolled in the modeling classes outperformed the conventional non-modeling classes. They also called for more research on the sequence and coordination of science and math courses to inform policies (Liang et al., 2012).

### **Study 6: Physics First and Math Scores**

One of the reasons the PF movement had been supported was due to the belief that when freshman take physics while they are taking algebra, their math performance would improve (Mervis, 1998; Myers, 1987). However, this conclusion was based on anecdotal evidence only. An academically competitive K-12 coed private day school demonstrated that an inversion of curriculum with a change to freshman physics positively impacted math performance on standardized tests (Glasser, 2012). Students were tested using an algebra-based problem-solving test during the spring of eighth grade, prior to taking physics. Then the students took the PSAT in the fall of 10th grade, after taking the physics course. The difference in pre- and post-test scores before and after PF was statistically significant, indicating a strong association between physics in ninth grade and improved test scores on the PSAT test (Glasser, 2012).

In addition to PSAT score improvement, Bouma's (2013) research indicated increased math SAT scores after two cohorts of students completed a PF program. Statistical analysis demonstrated the PF program significantly impacted SAT math scores. The mean SAT math scores for PF students were higher than their non-PF counterparts when controlling for prior math achievement, socioeconomic status, and ethnicity/race.

### **Study 7: Physics First and Increase and Science Course Interest**

While the study by Glasser (2012) reported higher math PSAT scores and Bouma (2013) reported higher math SAT scores, another study reported no difference in EXPLORE or ACT scores. In *Evaluation of a Secondary School Science Program Inversion: Moving from a Traditional to a Modified-PCB Sequence* (Gaubatz, 2013), a five-year program evaluation focused on the implementation of a modified PCB sequence. Teachers were surveyed and the

teachers predicted an increase in upper-level science course enrollment and student success. After the program inversion, more students were enrolling in AP biology and AP chemistry. Although the percentage of students passing the tests decreased, the actual numbers of students passing the test increased significantly because more students were taking the exam. The department created a 25-item survey to assess students' understanding of nature of science and experimentation as well as student perception toward themselves as learner and toward their science courses. Results demonstrated that the inversion of the curriculum, starting with PF, increased students understanding of the nature of science. In addition, teachers reported that the inversion helped with the placement of students in the correct courses. Prior to the inversion, the students were placed into Honors Science based on entrance test scores, but the test scores were not a good predictor for success in Biology. However, students were placed in honors physics based on the math class they were taking concurrently and that was reported to be more effective (Gaubatz, 2013).

### **Study 8: Three Districts Implementing Physics First**

In *Putting Physics First: Three Case Studies of High School Science Department and Course Sequence Reorganization*, Larkin (2016) described the lessons learned from the three schools that underwent the curriculum change from BCP to PCB. The article examined the shifting to a PF sequence in three school districts and described the lessons learned in these school districts that successfully changed the order of their course sequences and made physics a ninth-grade subject for all students. The study was presented as a collective case study of the high school physics programs in the three school districts in a single state.

**Case 1.** The first, large urban district had several high schools while the two smaller suburban districts had a single high school. Two sites had been using PF for five years. The first case was at a larger urban high school with 80% of the students qualifying for free or reduced lunch. A shortage of qualified physics teachers emerged as an initial barrier to PF adoption. However, an education program at a nearby university not only had a comprehensive three-year PF curriculum field tested for 10 years, but also worked with previously certified teachers to recertify the teachers to obtain a certification in physics. The goal of switching to PF was to help students' math performance in two state mandated standardized math tests as an algebra-based physics course for ninth graders promised more time exposed to mathematics and presented an applied setting for the math concepts. The second goal was to increase enrollment in AP classes. From 2009 to 2013, after the 2008 curriculum change, the number of students taking AP Physics increased but the total number of AP courses taken did not increase. The curriculum shift led to gains in math scores at the expense of language arts.

**Case 2.** The second school in the case study was in a densely populated suburb in which less than 20% identified as economically disadvantaged (Larkin, 2016). The school had many teachers with multiple certifications so the availability of teachers to teach the physics courses did not present a challenge. The initial motivation to move to physics for the ninth graders was driven to improve math scores on the state examinations and to address the student's perceptions of a disconnect between high school physics and algebra. In addition, students taking more advanced Biology course appropriate for the 11th grade were supposed to raise scores in the state mandated biology exam. With all freshmen taking physics, there was a coherent math experience. Students who needed extra math support took an extra math class that focused on



state test preparation. There was a common period once a week on Fridays and a quarterly math and physics project allowing collaboration between math and physics teachers. Common use of data between math and physics courses also led to greater data collection techniques in the math courses (Larkin, 2016).

**Case 3.** The third school was a small suburban community with less than 3% identifying as economically disadvantaged, 75% of the ninth graders who had one or both parents working in STEM industry. The PF switch began when the state science standards influenced the district to alter the science courses to address the high school graduation exam. But, after the exam was postponed, the curricular sequence did not make sense, so it was reorganized. A new hire teacher attended a national conference and a residential workshop at University of Arizona to learn the physics-modeling curriculum and came back to share the modeling pedagogy to the other teachers at the school. By 2005, modeling practices spread through the department and the teachers aligned their practice by using white boards. All ninth graders were taking physics in a modeling environment. Goals for shifting to PF included teaching a 21st-century biology and biochemistry to juniors. Physics was macroscopic and matched the cognitive abilities of the ninth graders who were concrete operational learners. In addition, the ninth graders would see a purpose for algebra, as the physics courses would allow another venue for students to use and practice the math they were learning. Finally, PF would address the gender inequity in the upper level science courses as a gendered pattern of physics course taking emerged with more girls enrolled in science elective courses rather than physics. For the third school, the goal of ensuring access for all students to physics had been achieved. However, the constraints included the

limited number of trained professionals available to teach physics and the inflexibility of the algebra curriculum (Larkin, 2016).

This case study of the three schools highlighted some interesting results regarding math achievement, other science courses and staffing. All three schools reported improvement in mathematics due to the curriculum switch. However, not all reported increased science courses taken after the PF courses. Finally, schools reported issues for finding trained teachers for the physics course. The study called for more research on the effectiveness of the PF programs as the study did not examine the effectiveness of the change (Larkin, 2016).

### **Conclusion**

The efforts to improve science education are imperative, as graduates who are adequately prepared for STEM careers will help boost the national economic growth in addition to benefiting from more competitive salaries. Physics First curricula allowed science to be taught in a coherent matter and while PF teachers reported students taking more science courses in high school. In addition, PF teachers reported that teaching physics to ninth graders makes it easier to challenge their misconceptions and students were eager to learn and therefore were more likely to take a more rigorous second-year physics course (AAPT, 2009). However, most of the studies call for more data to support PF curriculum. Studies have also demonstrated increased conceptual understanding of physics (O'Brien & Thompson, 2009), improved math performance (Bouma, 2013; Glasser, 2012) increased honors and AP course enrollments, a better understanding Nature of Science, and increased student interest in science including students anticipating that they could be successful in college science (Gaubatz, 2013). For the PF gains to help all students, more studies need to be completed so more students can take a more coherent

course sequence. This study qualitatively described the student and alumni perceptions of the PF curriculum. Chapter 1 introduced the problem, purpose and significance of the study. Chapter 2 outlined the history of science education in the United States, the PF movement and reviewed the limited current PF studies. Chapter 3 describes the methods of the qualitative study to describe student and alumni perceptions.

## **CHAPTER 3**

### **METHODOLOGY**

Disappointing results in interest and achievement in science among American students as compared to international counterparts (Mullis & Martin, 2015; NCES, 2015a) have justified continual efforts to improve science education using innovative teaching methods and modified course sequences such as the inquiry-based Physics First (PF) curriculum. To gauge the influence of such programs, student course choice for future science courses in high school and beyond must be examined. Few studies have demonstrated the impact of PF programs on science achievement (O'Brien & Thompson, 2009) and mathematics (Bouma, 2013; Glasser, 2012), and fewer have explored the impact on future science education. The examination of the perceptions of how enrollment in a high school inquiry-based PF curriculum has influenced students' future science course choices aims to add to existing research and to fill gaps of research, a concern repeatedly articulated in the literature (AAPT, 2009; Larkin, 2016). Research on impacts of PF programs will help inform science educators and educational leaders looking to update and improve science curricula (Gaubatz, 2013).

While the previous chapter explored the problems with the current state of science education, history of science education and inquiry, standards-based science education and PF programs, this chapter will explore the research question and design for the study. The study employed qualitative research methodology consisting of semi-structured interviews and field notes. This chapter will describe site selection, data collection, participant sampling methodology, data management, and analysis. Finally, the chapter will address the positionality of the researcher, trustworthiness and limitations of the study.

## **Research Question and Purpose**

The research was guided by the following questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
- How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
- How has the Physics First curriculum influenced alumni career choices?

The purpose of this study was to explore and understand the perceptions of current and former students of a high school inquiry-based PF curriculum and to examine the ways the curriculum has influenced students' future science course choices. Trends of enrollment in honors and AP courses were also examined along with student choice of college majors and future fields of study.

## **Rationale of Qualitative Research Approach**

To capture students' perceptions of how enrollment in a high school inquiry-based PF curriculum has influenced their future science course choices at a private Catholic all male high school, a qualitative research design was used. Qualitative research allowed for the exploration of complex and rich experiences and perspectives (Flick, 2014) and detailed understanding of the issues (Creswell, 2007). A case study of student and alumni interviews from the site comprised the qualitative data. Qualitative research can follow up the prior quantitative studies to allow for further exploration and explanation (Creswell, 2007) as this study was a qualitative follow-up study to *Physics First: Impact on SAT Math Scores* (Bouma, 2013).

## **Methodology**

The study included semi-structured interviews using an interview protocol co-developed with my doctoral committee and piloted on the intended population, survey of questions about student and alumni course sequence, detailed field notes about the participants and courses and enrollment data evaluation. The three sources of data—interviews, field notes, and enrollment information—provided several dimensions to allow for data collection triangulation. Flick (2014) described triangulation as the combination of different methods, groups, settings and perspectives. Semi-structured interviews effectively allowed participants to relay information and support the process of making new meaning in their own voices (Flick, 2014). A separate interview protocol was developed for the juniors (see Appendix A), for seniors (see Appendix B) and alumni (see Appendix C). Enrollment data evaluation allowed a fuller description the research setting and provided additional context. Field notes taken during the interviews allowed for observations of the participants that may not be apparent in the interview responses.

## **Research Setting**

The investigation took place at a private Catholic grade 9-12 high school in a diverse urban setting. Student enrollment was approximately 1,200 students from over 200 zip codes and 100 elementary/middle schools. Ninety-nine percent of the graduates pursued higher education and 96% enrolled in four-year universities and colleges. The high school reflected the diversity of the surrounding area since over 50% of the students are non-White. The school implemented a PF program in 2007. The researcher was employed by the school during that time and granted access to students and alumni.

## Grades 9-12 Course Curriculum

The site adopted a PF curriculum in 2007 and restructured the course sequence for the science courses to a PCB sequence. Figure 1 shows all the possible course sequence students can now take during their four years at the school site.

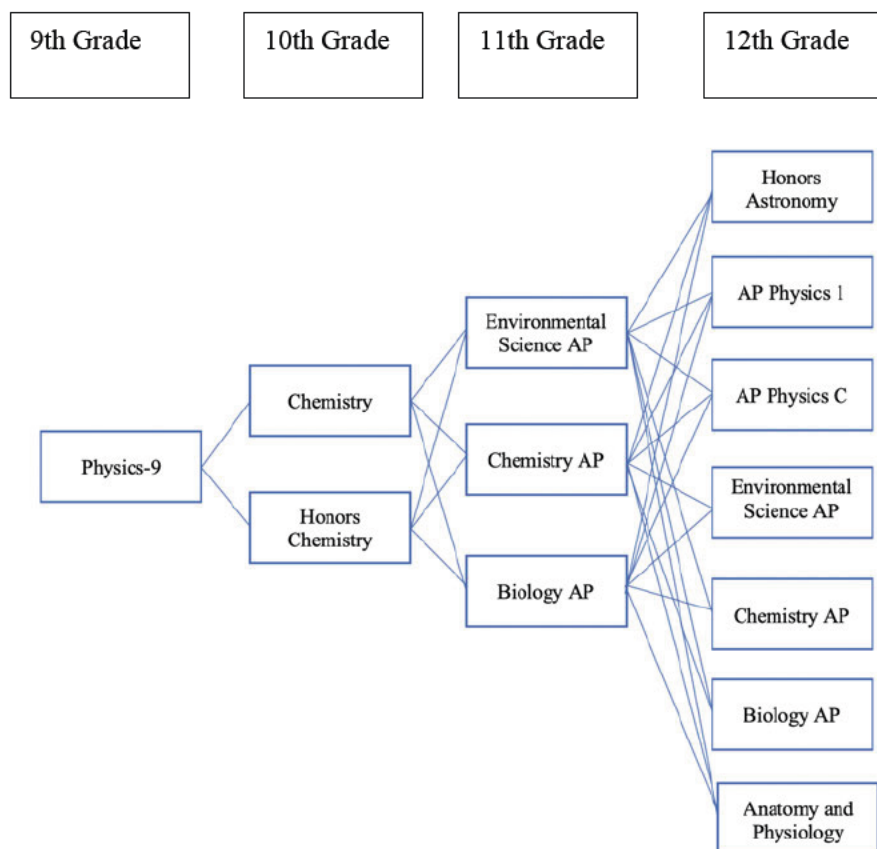


Figure 1. Course sequence for Grades 9-12.

Physics-9 was offered to freshman as an elective but was not required from 2007-2014.

Sophomores were required to take chemistry or honors chemistry, juniors were required to take biology, AP Biology or AP Environmental Science (APES) and seniors took AP Physics or one of the many other offerings (see Figure 1). Although Physics-9 was not a required freshman

science course, Physics-9 became so popular that approximately 75% of the freshman enrolled in the course. The popularity of Physics-9 and its impact on SAT scores (Bouma, 2013) convinced the administration to modify the graduation requirements to make the Physics-9 course a requirement for all freshman. Starting fall of 2015, all freshman students were required to take Physics-9.

### **Physics-9 Classroom**

A detailed description of the Physics-9 classroom, curriculum and mode of teaching inquiry follows.

**Typical inquiry cycle.** The Physics-9 course employed a guided-inquiry based format based on the 5E model as presented in *Active Physics* (Eisenkraft, 2013), the textbook used in the Physics-9 course. The course was divided into five units—kinematics, dynamics, momentum, waves, and electricity—and each unit was further divided into seven to nine sections. The entire freshman class, between 300-320 students at the school take Physics-9 so there were 14 sections of the course taught by four different teachers. Each teacher followed a common curriculum with the same activities, content and assessments. Each section began with the instructor showing a picture or cartoon to the class to foreshadow what the students would learn in the section and elicit students' prior knowledge. This comprises the “engage” and “elicit” parts of the 5E model. Teachers asked the students “What do you see?” They respond to the picture and discuss the concept in the picture and then are asked a “What do you think?: Question about the topic or phenomenon presented. The “What do you see?” concerned on a particular picture and “What do you think?” asked a specific question that focused on the physics concepts of the section. The “What do you see?” and “What do you think?” activities were fun ways to engage the students



while the instructor identified and addressed prior understandings and misconceptions. During the “What do you see” and “What do you think?” parts of the lesson, students were seated at their desks while actively raising their hands and being called upon by their instructor. Some of the instructors held a soft ball or other projectile they threw to the student whose turn it was to speak. This maintained an ordered, but dynamic classroom environment in which students were speaking one at a time. All instructional activities were student-centered and directed toward the common “What do you think?” question.

After the initial questions to engage the students and elicit prior knowledge, the instructor guided students to collaborate and investigated with a lab activity. The laboratory activities occurred in the separate lab section of the classroom. Each classroom was outfitted with a lecture area for class discussion and with a lab area for the activities. The students worked in groups of three as they followed instructor’s written and oral directions throughout the lab procedure. The lab activities followed the “Activity Before Concept” model and preceded the direct instruction of a new concept. After the laboratory activity, students discussed and presented their results. The experiment, post-lab discussions and subsequent direct instruction comprised the “elaborate” and “extend” parts of the 5E cycle. The instructor elaborated and defined the physics concepts after the students had experienced the phenomenon. Reading and homework would typically follow each laboratory activity in the form of a reading assignment, written questions and problems that related to the concepts and skills explored in the lab. The homework functioned to extend and make the learning relevant. At the end of each section, students reflected on what they had learned and were challenged to answer a “What do you think now?” question in which they could reflect on their initial responses and modify them based on the evidence gathered

from their investigation. This was a crucial reflection piece that could help students and instructors address initial misconceptions and make explicit the learning targets of the lesson.

**Journals.** Students keep a journal to record their responses for the “What do you see?” and “What do you think” questions, laboratory data, class notes, homework and “What do you think now?” questions. The journal entries reflected student construction of knowledge through the cycle of inquiry. The journal showed student progression through the guided inquiry experience and their findings. Students formed explanations and were prompted to reflect on what they learned and had the opportunity to elaborate and extend their learning. Each unit culminated in a performance task (chapter challenge) where students had the opportunity to apply their new knowledge and demonstrated their understanding of content learned in the unit through an authentic, alternative assessment.

**Unit challenges.** The chapter challenge was not only the focus and motivation for student-learning, but successful completion of the challenge required physics content knowledge, application and synthesis of that knowledge. Students were presented with the chapter challenge during the beginning of the chapter before completion of the activities and were prompted by the instructors to make the connection between each activity and the chapter challenge. The students realized the importance of the activities as concepts learned in each activity built to help complete the chapter challenge. Students took traditional summative assessments at the end of each unit and the end of the semester consisting of multiple-choice and free-response questions. Thus the “evaluate” portion of the 5E learning cycle consisted of the traditional assessments and the chapter challenge.

**Kinematics.** The chapter challenge in the kinematics unit allowed students to demonstrate their knowledge of the physics of driving by presenting the physics of driving to a panel of driving instructors. Students presented the physics of braking distances, friction and curves, safe following distances, and yellow-light intersections. In the first activity, students explored the time it took to react to a situation and measure the reaction time. This first activity of the year introduced students to the process of beginning with their own ideas and predictions, then implementing an investigation that resulted in both qualitative and quantitative data. Other activities in the unit included counting the number of strides needed to cover a selected distance, using motion detectors to measure walking speed and to obtain computer-generated motion graphs. Thus, students explored speed and velocity and connected those concepts to reaction distance with a discussion on tailgating in driving. Students used sloped tracks to investigate the speed and distance an automobile travelled before stopping and examined data on time and distance required to stop a vehicle moving at various speeds.

**Dynamics.** The challenge in the Dynamics unit included a two- to three-minute voiceover for a sports clip explaining the physics involved in the sport. The students wrote and presented an entertaining script in which they explained the physics principles in the sports plays. The activities in this unit allowed students to explore Newton's laws. In one activity, students rolled a ball down and then up the sides of a curved track and recorded the ball's starting height and the recovered height to learn about the concept of inertia. In another activity, students recorded the motion of various objects using a timer and paper tape to calculate distance, time, instantaneous and average velocities and accelerations. To examine Newton's Second Law, students calibrated and used a simple force meter to explore the variables involved

in the acceleration of an object. To explore the motion of objects projected in a gravitational field, students recorded differences between objects being dropped, launched horizontally and launched at an angle. Students compared mathematical and physical models of projectile motion to that of a shot put. They applied this to describe the vertical and horizontal motion of the projected object and predicted its trajectory. Students measured the amount of force necessary to slide athletic shoes on a variety of surfaces and learned to calculate friction coefficients and consider the effect of friction on an athlete's performance. To study potential and kinetic energy, students used a penny launched from a ruler to model motion during the pole vault and connected their observations to the concept of energy conservation. Students learned to measure hang time and analyzed vertical jumps of athletes using slow-motion videos. This introduced the concept in play when jumping was force applied against gravity.

**Momentum.** The challenge for the momentum unit asked students to develop a safety system for protecting automobile, airplane, bicycle, motorcycle, or train passengers during a collision. To illustrate the safety of this system, students designed and built a prototype safety system to protect an egg in a moving cart that underwent a collision. This prototype would then be tested to see how effectively it protected the egg. Students identified and evaluated safety features in automobiles and considered what safety features they could use for their design of a safety system for their egg.

In the egg activity, students explained what occurred to passengers during a collision using Newton's first law and read about the concept of pressure and applied this concept while designing and testing a seat belt to secure a clay passenger in a cart undergoing a collision. Students investigated and observed how spreading the force of an impact over a greater distance

reduced the amount of damage done to an egg during a collision. Students explored the effects of a rear-end collision on passengers, focusing on whiplash. After observing various collisions, students were then introduced to the concept of momentum. Students designed a device on the outside of a cart to absorb energy during a collision to assist in reducing the net force acting on passengers inside the vehicle. Students used probes to measure the velocity of the vehicle and the force that acted on the vehicle during impact, and then described the relationship between impulse and change in momentum.

**Waves.** The challenge for the waves unit involved designing a simple musical instrument, performing in front of the class and explaining the physics principles involved in the show. The various activities in the unit allowed students to observe the vibration of a plucked string and investigated how changing the length of the string varies the pitch. Students then explored the effect of tension on the vibration rate and the pitch. Students used coiled springs to observe transverse and longitudinal waves, periodic wave pulses and standing waves. Students modelled wind instruments that used columns of vibrating air to produce sounds and investigated the relationship of pitch to the length of the vibrating column of air in longitudinal waves.

**Electricity.** The challenge for the electricity unit was to design electrical circuits in model homes and explored powering the home by a wind-driven generator. In one activity, students used a simple hand generator, wires and light bulbs to investigate electric circuits and electrical energy. Students studied the operation of a light bulb and played the role of electric charges as they moved through a circuit to develop a qualitative model of electricity, including how current flowed in series and parallel circuits and how electrical energy was delivered to devices. Students designed an experiment to determine the resistance of an unknown resistor.

Students were instructed on the proper use of a voltmeter and ammeter and students set up a series circuit to determine the current for a series of voltages applied to the resistor and Ohm's Law by graphing the relationship between voltage and current for a resistor. To learn about fuses, students constructed a simple fuse and the instructor connected a group of appliances to a power strip until a fuse in the circuit blew. Students explored how switches control the flow of electricity through section of a circuit by assembling a parallel circuit. Students investigated the amount of energy in joules needed to raise the temperature of water, and then calculated the efficiency of different water heaters. Students also considered alternative solutions to the expectation of hot water in a home.

Students conducted an experiment to determine and compare power consumption and efficiency of three systems that could be used to heat water.

### **Sampling Criteria for Participants**

The study included a purposeful sampling of 16 students. Purposeful sampling was used because "the research participants can speak to the research question" (Creswell, 2009, p. 78). Participating in the study were eight current students and eight alumni who had graduated within five years of the study. All 16 participants had completed the inquiry-based physics course as freshmen at the site. The characteristics of the participants included the following:

1. Four 11th-grade students (juniors) currently enrolled at the school,
2. Four 12th-grade students (seniors) currently enrolled at the school,
3. Four alumni who pursued science majors and/or careers in science, and
4. Four alumni who have not chosen science majors and/or careers in science.

Two of the juniors followed the freshman physics course with sophomore level honors chemistry and were enrolled in a junior-level AP course. Two of the juniors followed the freshman physics course with regular-level chemistry. Two seniors had taken freshman physics, followed by regular chemistry. Two seniors had taken freshman physics followed by sophomore honors chemistry. The purpose for each of the varying characteristics was to explore student perceptions at various levels of course sequences and experience. This allowed examination of ways in which freshman physics informed and influenced course selections and experiences at the sophomore, junior and senior levels. The study of alumni in science and non-science fields explored the influence of PF in their choices of courses and careers. The participants were given an interview protocol (see Appendix A, B, C) consisting of 14 to 17 questions. The interview protocol was developed and validated with the help of my doctoral committee and through piloting the protocol by a representative sample of the intended audience. Questions were piloted on students and data from these interviews were not collected to use for the study.

### **Methods of Data Collection and Management**

Permission to conduct the study with student participants and alumni participants was granted from the Institutional Review Board (IRB) at Loyola Marymount University and the principal of the school site. Participants for the study were selected from (a) students currently enrolled in the diverse private, Catholic 9-12 grade high school in an urban setting, and (b) alumni who graduated from the diverse, private Catholic 9-12 grade high school in the urban setting.

## **Student Participants**

The eight male students selected were within the age range of 15 to 18. Initial contact with parents/guardians was made through the school email system. The parents/guardians of juniors and seniors at the school site received an email informing them about the study, the voluntary nature of the study and an explanation that there would be no adverse effect on the student and their enrollment and standing at the school if the parents/guardians did not choose to participate. Parents/guardians were informed that students would be randomly selected based on established criteria based on the sequence of courses taken and not every student will be selected. After parents responded to an initial email, interested parents received a consent form to sign. Once the parents signed the consent form, an assent form was given to the students. The voluntary nature of the study, the right to discontinue study at any time and the assurance that there would be no negative effect on the student was emphasized since the researcher was an instructor and science department chair at the school.

After signed consent forms were received from the parents/guardians, an email was sent to each student whose parent filled out a consent form with an invitation to participate in the study. The purpose of the study was explained in addition to the voluntary nature of the study and how the participation of the study will not influence student academic standing at the school. Students were given an assent form in which they will be informed about the study and its confidential and voluntary nature and were asked permission to be recorded during the interview. After signed assent forms from student participants were received, the participants were emailed a survey of questions about their course sequence to provide the researcher



information to assist with the selection process of the participants. All student participants completed the inquiry-based physics course at the site while freshman.

Students were assigned numbers and grouped into categories based on the selection characteristics and two students from each category were randomly selected and scheduled to interview. The student participants were interviewed in the science department office at the school site. Only the researcher and the student were in the room, with the door open as is customary in student-teacher interactions. Each student participated in an approximately 45-minute interview. Student interviews were scheduled at times in which students did not miss class, so confidentiality was maintained. The junior students at the school had a Junior Advisory period which was a free period in which students could meet with teachers and counselors. The interviews for the juniors were scheduled during the Junior Advisory period. Seniors had a Magis period which was also a free period during in which students could meet with their teachers or counselors. Senior interviews were scheduled during the Magis period. Meetings during the Junior Advisory and Senior Magis periods ensured students were not being called out of class, not missing class and preserved their confidentiality.

The possible risks to the students included possible negative feelings or stress students may feel due to their past or present science educational experiences. Students were assured their responses would not impact their standing at the school and students could stop the interview at any time. Students met with the researcher alone, minimizing the risk of embarrassment. Counselors were available to meet with the students after the interview if any issues arose. The names and contact information of the counselors was listed on the consent and assent forms.

## **Alumni Participants**

The alumni participants were males within the age range of 18 to 24. Eight male alumni were selected. Alumni received an email explaining the purpose of the study, explaining its voluntary and confidential nature. Interested alumni received an informed consent form to sign if they were interested in participating in the study. After signed informed consent forms from alumni were received, the participants were emailed course sequence survey questions to provide the researcher with information to assist the selection process of the eight alumni participants. All alumni participants had completed the inquiry based physics course at the site as freshman. The characteristics for the alumni participants included the following: (a) four alumni who pursued science majors and/or careers in science, and (b) four alumni who had not chosen science majors and/or careers in science. After participants that fit each selection characteristic were selected, interviews were scheduled. The alumni participants were interviewed in the science department office at the school site or another convenient location. Alumni interviews were scheduled at a mutually convenient time for the participant and the investigator.

## **Data Collection**

The data collected included a recording, transcription, and written notes of each interview. The audio recording files were uploaded to the transcription website, Rev.com (2109) to be transcribed. Rev.com has a privacy policy and each participant was assigned a number. The confidentiality of the participants was maintained so students and alumni were assured that there will be minimum negative consequences and were assured confidentiality is protected. After the interviews, the participants had an opportunity to review their transcript (member checking) and make any changes (Flick, 2014).

The confidentiality of the subjects was maintained by assigning numbers to the participants so that only the researcher knew their identities. The confidentiality of the teachers of the PF courses was also maintained by assigning a number to the teachers named in the surveys and interviews. The Physics First Course Sequence Survey and the interview questions for both groups of participants asked them to provide the names of the teachers they had for various science courses to provide information about the course only. This particular data were confidential so that the teachers will not be put at risk in any way. The names of the teachers would not be published and there would be no published information that would single out a teacher and place them in any harm or risk of their standing at the school. Any data reported are in aggregate, and general findings about student perceptions of the courses are reported and information about the teachers and their identities will be confidential.

All the data collected, including audio recordings, transcripts, and notes, were stored electronically on the researcher's laptop with password protection security and backed up on an external drive stored in the researchers' home office in a locked safe. Data were stored in the secure location for the duration of the study and then destroyed three years after the study is completed. No images were collected.

### **Method of Data Analysis**

The data collected were initially in the form of handwritten field notes and audio recordings of the student and alumni responses to the 14 to 17 interview questions. The audio recordings were uploaded to a transcription website, Rev.com to be transcribed. The transcriptions of over 16 hours of recordings were initially read and checked for accuracy. Patton (2015) described pattern analysis as a process to identify patterns, themes, and categories that

emerge from qualitative data. The alumni interviews were first analyzed for emergent themes and patterns resulting in 15 themes. Subsequently, the related themes were combined into three main themes. The student interviews were similarly analyzed for patterns and themes and those themes combined. The themes focused on patterns which arose from student and alumni responses describing experiences and perceptions before their Physics-9 course, during their Physics-9 course and after their Physics-9 course. Data were coded to align with the conceptual framework of inquiry learning focusing on student's engagement and the inquiry cycle. Data were coded with the conceptual framework in mind, looking for aspects of inquiry learning in the student responses.

### **Limitations and Delimitations**

The school implemented a PF program in 2007 and had continued to teach the PF curriculum. Therefore, the site, which has taught the PF curriculum for over 10 years, was appropriate to study the perceptions of the PF program. This allowed for the study of future course choices of current students and future course choices and career choices of alumni due to the length of time that the PF curriculum has been offered. The researcher was employed by the school and had been granted access to students and alumni. The principal of the organization approved and agreed to provide access to students and alumni of the school to the researcher. The selection of participants who responded to the invitation to the study took place after IRB approval and was based on the courses taken so that varied student experiences were represented.

However, the exclusion of female students at the private secondary school and the school's access to fiscal resources and human capital presented a limitation to the application of the results of the study to other coed and lower socioeconomic contexts.

Several limitations emerged in this qualitative study of the perceptions of the PF curriculum including experimenter bias, self-reported data and small sample size. The experimenter was the science department chair and a teacher at the site of the study. Although she aimed to study the data objectively by coding the interviews, the interpretation of the qualitative data was subject to personal bias as viewed through the lens of the researcher.

The data, consisting of qualitative interview responses, were self-reported by current students and alumni and were as accurate as the reflections of the subjects of the study. Current students and alumni might tend to recall their perceptions of the PF curriculum as extremely positive or negative based on their overall experience as a student.

### **Trustworthiness**

Lincoln and Guba (1985) described four aspects of trustworthiness as credibility, transferability, dependability, and confirmability. In this study, trustworthiness was addressed by triangulation and member checking (Flick, 2014). Different participants answered the same research questions and data were collected from different sources and by different methods, including interviews and field notes. Participants had the opportunity to review the interview transcripts—member checking—and to verify their statement and fill in any gaps.

Transferability was established by including a thick description which Holloway (1997) described as the detailed account of field observation that allowed the researcher to explicitly identify and contextualize relationships.

### **Summary**

This chapter examined the research methodology that the study used to answer the research questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
- How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
- How has the Physics First curriculum influenced alumni career choices?

The study used a purposeful sampling technique and a qualitative research approach. The study included semi-structured interviews and field notes. Data were collected and maintained using secure electronic procedures and hard copies of notes and data were stored in a secure location for a specified amount of time after which the data were professionally destroyed. Data analysis used an inductive coding approach to identify major themes and ideas that emerged from the interviews recalling the experiences of the participants.

## CHAPTER 4

### RESULTS

Efforts to improve science education in response to average and stagnant science scores in national and international assessments include the development and implementation of innovative science curriculum and updated science standards. One such modified curriculum inverts the traditional course sequence from BCP to an inquiry-based PF curriculum in which students take an inquiry-based physics course as freshman and chemistry as sophomores. This inverted curriculum allows the science courses to be taught in a pedagogically sound, logical progression as prescribed in the early development of American curriculum. The purpose of this study was to explore and understand the perceptions of current and former high school students who participated in an inquiry-based PF, curriculum and to examine the influence of the curriculum on students' future science course choices. The research was guided by the following questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
- How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
- How has the Physics First curriculum influenced alumni career choices?

The site of the study, all-male private Catholic high school, implemented a PF program in 2007 and has continued to teach the PF curriculum as of 2019. Since 2014, all freshman (ninth grade) take Physics-9 as the required science course, followed by chemistry or honors chemistry during their sophomore year (10th grade). Juniors (11th grade) choose from AP chemistry,

APES, AP biology or biology. Finally, seniors may choose to take AP Physics C, AP Physics 1, AP Chemistry, APES, AP Biology, Biology, Oceanography, Honors Astronomy or Anatomy and Physiology.

The participants of the study included a purposeful sampling of 16 male students and alumni selected from students currently enrolled and alumni who graduated within five years. All participants completed the inquiry-based physics course as freshmen at the site. The characteristics of the participants include the following:

- Four 11th-grade students (juniors) currently enrolled at the school,
- Four 12th-grade students (seniors) currently enrolled at the school,
- Four alumni who pursued science majors and/or careers in science, and
- Four alumni who have not chosen science majors and/or careers in science.

Two of the juniors followed the physics course with sophomore-level honors chemistry and two of the juniors took regular-level chemistry. Two seniors took freshman physics, followed by regular chemistry and two seniors took freshman physics followed by sophomore Honors chemistry. The purpose of each of the varying characteristics was to explore student perceptions at various levels of course sequences and experience. This allowed examination of ways in which freshman physics informed and influenced course selections and experiences at the sophomore, junior, and senior levels. The study of alumni in science and non-science fields helped explore the influence of PF curriculum in their choices of courses and careers. The participants were given a semi-structured interview protocol.



Table 1  
*Alumni and Student Participant List*

Code	Graduation Year	Sophomore course	Junior course	Senior course	Intended college major
Alum 1	2016	Honors Chemistry	AP Chemistry	AP Physics C	Economics
Alum 2	2014	Chemistry Honors	Biology	AP Physics B	Urban Planning/ Architectural Design
Alum 3	2018	Chemistry	AP Chemistry	AP Physics C	Arts/Technology/Innovation
Alum 4	2018	Honors Chemistry	AP Chemistry	AP Biology	Chemistry and Classics
Alum 5	2018	Honors Chemistry	AP Chemistry	Honors Astronomy	Engineering
Alum 6	2018	Honors Chemistry	AP Chemistry	AP Physics C	Chemical Engineering
Alum 7	2018	Honors Chemistry	AP Chemistry	AP Physics C	Engineering
Alum 8	2017	Honors Chemistry	APES	Honors Astronomy	International Relations
Senior 1	2019	Honors Chemistry	AP Chemistry	AP Physics C	Computer Science
Senior 2	2019	Chemistry	AP Biology	AP Physics C	Engineering or English
Senior 3	2019	Honors Chemistry	AP Chemistry	AP Physics C and AP Biology	Engineering
Senior 4	2019	Chemistry	Biology	Anatomy and Physiology	Biology/Physiology
Junior 1	2020	Chemistry	APES	AP Physics 1	Business
Junior 2	2020	Chemistry	APES	AP Physics C	Computer Science
Junior 3	2020	Honors Chemistry	AP Chemistry	AP Physics C and AP Biology	Business
Junior 4	2020	Honors Chemistry	AP Chemistry	AP Physics C	Humanities

Table 2  
*Numbers of Sections of Science Courses Offered Each Year*

Course	2011-2012	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Physics-9	9	12	13	13	14	14
Chemistry	9	8	7	7	7	7
Honors Chemistry	4	5	6	6	6	6
AP Chemistry	1	1	1	2	2	2
AP Biology	2	3	4	4	4	4
Biology	6	7	7	7	7	7
Honors Astronomy	1	1	1	1	1	1
Anatomy and Physiology	2	1	1	1	1	1
APES	6	5	4	4	4	4
Robotics	1	1	1	1	0	0
Physics-12	2	1	1	1	1	0
Oceanography	2	3	3	3	3	4
Environmental						
Engineering	1	0	0	0	0	0
AP Physics C	2	2	3	3	3	4
AP Physics 1	0	2	1	1	2	1
AP Physics B*	2	-	-	-	-	-

\*College Board offered AP Physics 1 instead of AP Physics B beginning in 2014.

The data collected included a recording, transcription and written field notes of each interview. The recordings were transcribed after the interviews. After transcription, the interviews were checked for accuracy and an inductive coding method was used to study data and initially 15 themes emerged. Upon continued analysis, the 15 themes merged into about eight key themes. While there were many themes initially, through analysis several merged together, and some were omitted because the data were not consistent to support them. In the following pages, I present findings specific to juniors, seniors, and alumni. Most students reported a more positive Physics-9 experience compared to their previous three years of middle school science. Students with more a mathematically rigorous science background and alumni pursuing careers in science were more likely to critique aspects of their experience. Specific activities, such as the egg cart, model home wired with electricity and musical instrument were more memorable to the participants than were other activities.

## **Juniors**

### **Junior Experiences prior to Physics-9**

All the juniors reported taking three years of science in middle school. Three out of the four juniors described their experiences in Physics-9 as more positive than their experiences prior to Physics-9 in middle school.

Junior 1 stated that his science experience before Physics-9 as “it was okay, it wasn’t really interesting.” Junior 2 described his science experience in middle school as scattered:

We sort of bounced all over the place. We talked a lot about geothermics and plate movements, stuff like that. And then [in] eighth grade, some elements of Biology. I don’t remember a lot of it to be honest. A lot of it was like the chromosomes and XY, that was mostly it. We didn’t do a lot of physics; we did some physics like laws of gravity. We didn’t have a very great science program at my old school. (Junior 2)

While Juniors 1 and 2 both had science programs that were not active, without many labs or hands-on activities, Junior 4 recalled a lab-based program in which students did not actually do the labs and he still did not consider it engaging.

Junior 4 described his program as:

Experiment-based and worksheet-based. It's kind of boring. You just kind of watch like a video about the thing that you're going to learn and then they give you worksheets to do in class. It's not really that engaging. (Junior 3)

Junior 3 described attending an advanced middle school program and subsequently described a different Physics-9 experience. He had taken a similar course sequence as the other students, enrolled in Earth Science in sixth grade, Life Science in seventh grade, and Physical Science in eighth grade.

My middle school science teacher went really in depth. He went really advanced with bio, physics, and chem. Chem, all this stuff we did last year in honors chem, I did with him in eighth grade. Then physics, he gave us problems from AP Physics and all that stuff. Then bio, we had a lot of memorization from AP Bio stuff. (Junior 3)

While the other Juniors reported enjoying science more in high school than middle school, Junior 3 started to enjoy science in middle school which was late for him, but earlier compared to the other students:

So, I didn't start liking science really until middle school, and especially bio was the first time where I was really interested in it and being able to understand how things work in our body, and with other animals and evolution. Then eighth-grade physics, I thought was really interesting, seeing how patterns that we don't really notice in the world. But when we talk about them, you think to yourself, oh, why does that happen? Things that you wouldn't expect but they naturally happen, I thought that was when I really started to enjoy science. Then it just grew from there with physics and then chem. (Junior 3)

### **Junior Experiences during Physics-9**

All four juniors reported that Physics-9 offered different levels of challenge. However, none of the students described Physics-9 as one of their hardest classes. Juniors 1 and 2 had the

same physics teacher while Juniors 3 and 4 had different teachers. While three different teachers taught the Physics-9 course, the students described similar activities since the school followed a common curriculum.

When asked about the course difficulty, Junior 1 responded, “I wouldn’t say the concepts were difficult, I would say they were more, that you had to keep on working on it to understand it.” Junior 1 described his favorite activity:

The activity was with the motors and then most of the circuits, like my favorite activities were usually with electricity and making your own circuits and then . . . well just creating your own thing and then seeing it work is pretty nice. (Junior 1)

While Junior 1 described physics as easy, Junior 2 recalled that physics was harder but was very enthusiastic about the challenge:

I loved it. I had Teacher 1; he was an excellent teacher. It was great. We would do a lot of lab work; he was super fun. It was still really challenging though. I remember the class would be very crazy in the beginning of the year, but I liked the way he formatted his class. I loved how we would do a lot of lab work; we did a lot of experiments that was a lot of fun. (Junior 1)

Junior 2 recalled demos as being very memorable and appreciated the variety of topics:

I liked the way [Teacher 1] was very visual with explanations, I remember he did this big- it was one with the bowling balls, I forget exactly what it was. We had this giant tarp once where we figured out like the gravitational pull worked on big objects and like marbles and stuff. That was this cool little explanatory thing. We watched one documentary that I thought was really cool. He just did a really good job of balancing labs, class work, tests, then also we had watched a documentary on the Manhattan Project. That was really cool. We were going a little bit into quantum physics, that was cool. Trying to think. We did one really amazing lab, but I can’t remember what it was, that really piqued my interest. (Junior 2)

Both Juniors 1 and 2 reported positive Physics-9 experiences but both chose to take regular chemistry and not honors chemistry and they cited the same reason; they thought it would be too

difficult based on what they had heard from other students. Junior 4 described his Physics-9 experience:

I thought it was really fun. I liked the focus on hands-on activities that he would do there. I remember there were a couple. The one thing I remember distinctly is the shoebox, where you have to set up the lights with the shoebox project and learn about electrical currents and conductors and different types of outlets for electricity, like different types of currents.

Junior 4 recalled and described the electricity project in detail:

I thought that was really interesting and a cool way to do it. Then when you see everyone's projects, and then try to replicate, like a real-world thing, so we choose a gas station. We just tried to set up lights and decorate the box and then set up lights. . . . He just let us choose whatever we want, as long as it would fit in a shoebox thing and then they connected them all. It made a tiny town. I thought that was interesting. (Junior 4)

Juniors 1 and 2 did not describe the collaboration aspect of the physics course—even though they did complete activities in groups of 3. Junior 4 recalled collaborative efforts as a reason why he particularly liked the activity:

I liked the collaborative aspect of it as well, learning and building off of other people, because you would be working on the shoebox with three other people. I also liked how you don't choose your lab groups, so you end up having to talk and work with people that you don't normally do, especially if you're a freshman, that's kind of interesting in seeing people that you normally wouldn't interact with, especially in a younger level, because you don't know anyone, so you're just trying to make friends as well . . . in the shoebox project, it's like we were all physically working and building something . . . we're all working for one goal, and we're all striving to build something and working together. (Junior 4)

Junior 3 had fun in the course but thought the material was much easier than what he had learned in middle school. He chose to take honors chemistry during his sophomore year and then AP chemistry during his junior year. So, he related going from his middle school physics to Physics-9 to going from AP chemistry to honors chemistry:

Physics-9 was fun, but it was very difficult going from super in depth and the very math heavy physics that we did in eighth grade, to that, and I kind of wasn't expecting that.

Physics-9, I thought, was very concept based and I didn't like that there wasn't as much of the math and concept in that. But I enjoyed the class because I thought it was fun. We did a lot of labs and I really enjoyed that because we got to talk about all the concepts, and then do them in experiment. But that was probably my only critique about it, was that I felt like it was, not beneath me, but I had already learned it, so I wasn't as interested in it. But I don't think that's a problem with the course itself. I think it was just the order that I had gone of learning it. It could be now, if I had AP chem and then I took regular chem for last year. That's kind of how it felt. (Junior 3)

While Junior 3 was critical of the content of the course, he still saw the merit on how the activities connected different concepts together:

An activity that I really liked was with the carts, with the eggs in the cart and you had to build a cart. I thought that was really interesting because it was a culmination of a lot of different topics in that. We had to consider the speed of the slope and find out the force of that, and then talk about the distance of the cart and what would keep the eggs safe, what would absorb the force. I think it took a lot of things into making the experiment, it had a lot of different concepts all together. I really like that it brought everything together in one experiment, and that was really interesting to see. (Junior 3)

Junior 3 described the culminating activity in the unit about force in which students had to build a cart which would carry eggs and then the cart would crash. They had to build a safe cart to ensure the eggs would stay safe. Junior 3 also recalled the electricity unit in which they build and wired a house with circuits:

Also, I really liked the electricity in the house. So I think that's another experiment that I really liked because it was a blending of a lot of different concepts. I think that's something that you can do a lot with physics because I think a lot of different concepts play really well into each other. I think that blending and being able to see how this goes with that, and then these two concepts create that, I think that's something that I really enjoyed about physics, being able to see how different things can go together. (Junior 3)

### **Junior Course Choices after Physics-9**

After Physics-9 Junior 1 and 2 chose to take Chemistry and not Honors Chemistry.

Junior 1 said that he did not want to take Honors Chemistry:

I didn't want to take Honors Chem, it seemed too challenging, but Chemistry with Teacher 2 felt like it was good...I felt like I learned a lot about Chemistry, with the pH and everything about that. . . . Yeah, and it helps now with APES too. (Junior 1)

Junior 2 also took Chemistry but expressed that he should have taken honors Chemistry:

I took regular Chemistry. Sort of regret it, wish I had taken Honors Chemistry because I feel like Teacher 4 is a great teacher, it's a good course, but I wish I had challenged myself more. So maybe I'm overthinking it but I think I could've taken Honors—I wasn't sure if I was prepared for AP Chem or AP Biology so that's why I went with APES. (Junior 2)

As a result, Juniors 1 and 2 both took regular Chemistry and then APES. While Junior 1 seemed satisfied with his decision, Junior 2 wished he had taken Honors Chemistry so that he would have been better prepared for other Junior Level AP Courses such as AP Biology or AP Chemistry. While Junior 1 saw the path from physics to Chemistry to APES a natural one that was laid out for him, Junior 2 described how physics and Chemistry influenced his math course choices:

I think physics was a more math intensive course, which I really struggled through, but I figured out how to do it. I think I did pretty well in the class, I think I realized I like to do math. So that sort of influenced my math classes. . . . It influenced my math classes just [be]cause it provided a layer of math that I realized was more challenging than what I had been presented earlier on, made me want to explore more challenging math so I went into that. (Junior 2)

Junior 2 chose to take Honors Algebra 2 during his sophomore year as the Physics-9 course made him realize that he liked math, but he declined the honors chemistry course because he was worried about the course load and his grades.

Junior 3 took honors chemistry during his sophomore year to have a more mathematically rigorous science class:

I think it was because I wanted more of that math and content blend that I had had before, and I wanted to not only get to a higher level of understand chemistry, I wanted a better understand of chemistry than I thought I was going to get in regular chemistry. I wanted



to have a really heavy blend of math and concepts because that's what really interested me in science before, and something that I felt like I didn't. . . . That was a challenge for me in physics because there wasn't as much of that blend with the math and the concepts, and I wanted that again. I thought that Honors Chem would offer me that and it did.  
(Junior 3)

When asked if Physics-9 influenced his course choice, Junior 3 described how the conceptual physics made him realized he liked quantitative, math intensive science:

[Physics-9] has shaped a lot in very subtle ways that you wouldn't really think about. Like when I was considering Honors Chemistry, I wasn't thinking about Physics-9 affecting my decision, but it showed me what I liked about science and what I didn't like about science. That's what helped affect my decisions for the rest of my science courses.  
(Junior 3)

Junior 4 also chose to take Honors Chemistry and AP Chemistry after that because he wanted a challenge and was also mentioned his recommendations from upper-class students.

### **Summary of Findings for Juniors**

After reviewing four hours of transcribed interviews which responded to the interview protocol questions for the four junior interviews (see Appendix A), the data were coded, and the following summarizes the key themes found in the data.

**Junior Finding 1.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?* All the juniors described their Physics-9 experience positively. All reported that they enjoyed Physics-9 and found Physics-9 more valuable than their middle school science courses. Three out of the four students found the hands-on labs more engaging than what they had done in middle school and described the activities as the reason they liked Physics-9 more than their previous science classes. Even Junior 3, who thought the course was too easy, still saw merit in the activities.

**Junior Finding 2.** Addressing the second research question: *How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?* Physics-9 did not appear to influence sophomore year decision but it did potentially impact student attitudes in math and junior/senior science course choices.

Participants who decided to take Honors Chemistry were students who had planned to take all honors courses in their schedules. While the students did not think Physics-9 was not too challenging, the students who did not take Honors Chemistry cited the level of difficulty of Honors Chemistry as the main reason for not taking the course. Physics-9 helped them perceive science as fun but did not necessarily influence whether or not they would choose Honors Chemistry. Students who wanted to take Honors classes to challenge themselves were the one who chose Honors Chemistry. The students who took Honors Chemistry continued with AP Chemistry if they liked Chemistry, and students who took regular-level Chemistry chose APES. Regular-level chemistry and APES course had a similar inquiry-based format as Physics-9. Honors Chemistry delivered a more content-rich experience in a traditional manner with more direct instruction and less inquiry.

## **Seniors**

### **Senior Experiences prior to Physics-9**

All four seniors interviewed expressed neutral to favorable views toward science in middle school. The seniors had taken science in middle school and it was a blend of physical and life sciences.

Senior 1 stated that “I didn’t really like it any more than other subjects in middle school, but it was more on the fun side just because it wasn’t constant studying” while Senior 2 stated he

liked science because “my friends were always in the class. And I found it pretty interesting. More interesting than my other classes, I think.” Senior 3 discovered that he liked science in middle school as he stated, “I remember that’s when I realized that I enjoyed science.” Senior 4 remembers liking science but described the Chemistry as being more difficult “I liked science . . . I always enjoyed it. Chemistry was a little hard to understand because that was kind of new.”

Senior 1 and 2 recalled their middle school science departments as inadequate and reported that they did not do many hands-on labs in their middle schools:

So at my middle and elementary schools, I feel like the science department wasn’t as strong as it was at other middle schools and stuff. My old school used to like switch teachers a lot for science. I had a brand-new teacher that year in eighth grade, and it was like life sciences or something, and I feel like a lot of it wasn’t concrete. We didn’t do any like mathematics or anything, it was all terms, read from the textbook, and to be honest I guess I learned maybe the basics of what Biology is, but I don’t remember anything specific from middle school. (Senior 1)

Senior 2 described the brevity of their middle school science curriculum, “It wasn’t very extensive, and we didn’t learn that much, and we didn’t do very many labs. So, coming to freshman physics and doing labs was pretty cool.”

Senior 3 liked science and noticed in middle school the ideas presented were simple and he wanted to use the science knowledge to justify the inaccuracies in his teacher’s instruction:

I see where she was going with it, but it really was just by the time that I realized that I want to do science. And, I wanted to prove that she was wrong. Because I told her she was wrong. But she said no. (Senior 3)

Senior 1 compared his physics experience to his middle school experience and reported that in middle school the science was qualitative, and he only started to work with the quantitative in high school. Senior 1 also enjoyed the additional hands on experiments in Physics-9:

I really enjoyed it. It was the first time we actually applied like mathematical concepts to physics. I had really never used an equation in a science course before, so that was kind of cool, getting to use what I learned in math. So that, and also the experiments were a lot more tangible than they had been in middle school, just because in middle school experiments were like . . . we either didn't do them in class because we didn't have a real laboratory or we . . . just did them at home. I just remember stuff with like the carts and getting to see how velocity is affected my mass and stuff, or acceleration is affected by mass, and that's kind of cool. I guess because they were the first time I really . . . I guess it's like the three-way combination of like we're applying the mathematical concepts, we're applying the conceptual, then we also get to see it in real life, and it's kind of the first time it's happened, so like that's why memorable. (Senior 1)

Senior 4 had not taken physics in middle school and did not have many lab-based classes so he really enjoyed the Physics-9

I think it was good. I enjoyed it. There was a lot of labs and a lot of physical, I like a lot of the hands-on aspect of it so like I had Teacher 6 so doing all the labs, with the carts and other things and like seeing movement and kind of like being able to calculate how far if I dropped this cart at this angle with this bump here. How far it's going to pass, like travel because of the momentum letters so carries. That was interesting. I like that. (Senior 4)

Senior 3 stated he liked since eighth grade because he felt good at it and Physics-9 increased his interest level:

I just liked it because it wasn't English. Because I wasn't too good at English. I was good at science. So, that's how I felt. Then in eighth grade, I realized that I enjoyed science. And then, in Physics 9, it really just solidified that I liked science. (Senior 3)

### **Senior Experiences during Physics-9**

All four seniors, who had three different teachers, reported the egg cart activity, described in detail in Chapter 3, as the most memorable activity. Senior 4 liked the activity because they had to engage in a higher level of inquiry:

I think one of my favorites was toward the end of the year, when learned a lot of the concepts and we put an egg in a cart or you're given a certain amount of materials and he like sent it down like a ramp that was like 12 feet long and six feet high and we had to stop it from smashing on a cinder block. I was at the end. So that was, that was pretty fun, like having to just figure that out. (Senior 4)

Senior 3 liked the egg cart because he was able to connect and apply many different concepts they had learned about through other activities:

Favorite activity, I think it was the egg cart, where we had to make a cart that would help an egg not break. And I just thought it was cool to apply what we were learning to, with impacts, to soften the blow on the egg. I think it was memorable because that was probably the first time ever, really, that I got to apply, directly, what we were learning. Because with the mouse trap cart, we were kind of doing that, but it was kind of just like, here's an activity, we'll relate it after. But with the egg, it was like, we're relating this in this way, this way, this way. It was very structured. (Senior 3)

Senior 2 wished they could have spent more time in that lab, as he felt his particular teacher did not provide the longer opportunities to work in the lab:

I think just more time. I think we spent a lot of time not doing labs . . . I feel like I remember using the book, not the book, watching movies, I think. Watching videos to explain it. But I feel like using more lab time would be more helpful, because I feel like some of the labs were rushed. (Senior 2)

Senior 3 had critiques about his teacher but still liked the class:

Well, I enjoyed the class, learning about the physics of everything. But the class just went fast. Teacher 9 didn't really explain everything too well. So, there were a lot of holes there. And then with the final, I went into it knowing the majority of the stuff, and then the final was just stuff that I didn't know what to do. (Senior 3)

The main critique that all the students had was regarding the alignment of the assessments. Student felt that the assessment did not test the work students do in the lab:

I just remember sometimes he gave us standardized tests for like the finals and stuff and I would find some of the questions kind of out of nowhere, like we hadn't really gone over it. (Senior 1)

Senior 2 also critiqued the final exam and commented on the grading of the course:

I think [the course] felt disorganized. But I still liked the class and I learned a lot more. Just felt disorganized . . . because the final was hard. . . . I didn't know how to do half the final, and I still got an A on the final. I felt like the tests and the finals didn't really line up with what we were learning. So, they were too hard. No one knew what was happening in the tests, but then the grades were still regular. (Senior 2)

## Senior Course Choices after Physics-9

Seniors 4 and 2 decided not take Honors Chemistry. Senior 4 had earned a low grade in Geometry and did not think he was ready for a math-intensive science course. Senior 4 chose regular-level Chemistry, Biology and senior year took Anatomy and Physiology since he wants to study nursing in the future:

I didn't know if I could really, because I had a rough experience with honors geometry. I was like, I don't really know if I want another honors class. (Senior 4)

Senior 2 based his decision on student recommendations:

I heard honors Chemistry was impossible. I took honors English Two. So I didn't want to take both. I think just hearing what people said what's hard and what's not hard, I decided to try and even my load (Senior 2)

Seniors 1 and 3 both chose to take Honors Chemistry because they wanted the rigorous possible course schedule, and both followed with AP Chemistry junior year because they were already familiar with Chemistry and the teacher that taught course. Both stated that physics did not directly influence their sophomore and junior course choices. However, Physics-9 influenced their senior year science decision because he was already familiar with physics from Freshman year:

It affected my science decision. Just because I was already familiar with the subject. Felt that I could do better in physics, and also one other thing is that since I took. . . . I decided to take Biology during the summer just because I wanted to see whether I was interested in it or not, but also because some of the schools I'm applying for require that I take it before senior year, so I took it then and I would take it this year because I'm taking AP or . . . because then I would have to take two science courses and then also I wouldn't be able to apply to some these schools like Cal States. (Senior 1)

Senior 2 also chose senior AP Physics C course because of the teacher teaching the class:

Well, I wanted Teacher 1, so I signed up Physics C. I think a little bit because I just think physics had the best labs freshman year. So, when I was looking at [senior] year, which type of science I would take, I think I chose physics based on that, and then Physics C

was the teacher. (Senior 2)

Even though Senior 3 was critical of his Physics-9 teacher, he chose to take AP Physics C during his senior year:

I was interested in physics. It was interesting, even though it was confusing [in Physics-9]. And so, this year I'm in AP Physics because I wanted to further my knowledge and to understand it more. (Senior 3)

Senior 3 was also looking forward to using calculus in AP Physics C:

Well, because Physics-9 and my other ninth grade courses, they really just opened my interest. And then, with Physics-9, it was . . . the conceptual stuff, so. And in 12th grade, I'm taking the calculus to understand more of the math. (Senior 3)

In addition to AP Physics C, Senior 3 also chose to take AP Biology:

Well, I chose two because science is my favorite subject. I chose AP Bio because I wanted that life science, and some colleges require that life science. And then I took, well, physics was what I wanted to take, physics was my number one, because I just wanted to expand my knowledge on it. (Senior 3)

### **Summary of Findings for Seniors**

After reviewing four hours of transcribed interviews which responded to the interview protocol questions for the four senior interviews (see Appendix B), the data were coded, and the following is a summary of the key themes found in the data.

**Senior Finding 1.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?*, all the seniors reported enjoying Physics-9 more than their middle school courses and enjoyed the egg cart activity. The main critiques were the alignment in the assessments in Physics-9.

**Senior Finding 2.** Addressing the second research question: *How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?*, Honors Chemistry was perceived as a challenging course and only

students who felt like they wanted a challenging course chose to take Honors Chemistry. One of the students who took regular Chemistry sophomore year still chose AP Physics senior year because of the teacher who taught the course.

### **Common Findings Between Juniors and Seniors**

After reviewing a combined total of eight hours of transcribed interviews which responded to the interview protocol questions for the four junior interviews (see Appendix A) and for the four senior interviews (see Appendix B), the following summarizes of the common findings in the data.

**Junior and Senior Common Finding 1.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?* Students had a strong recall of engaging, hands-on activities such as the egg cart activity. Several juniors and all seniors remembered the egg cart activity. This was the activity in which students developed a safety system for protecting an egg in a moving cart that undergoes a collision. This prototype was tested to see how effectively it protected the egg and students identified and evaluated safety features for their design of a safety system for their egg. This activity combined the physics concepts of kinematics and momentum with engineering design. While the seniors discussed the misalignment of the exams with the content taught in the course, the juniors did not. This spoke to how the course diverged each year and perhaps the assessment alignment had been improving for the Physics-9 course and so the juniors felt more prepared for their assessments than did the seniors.

**Junior and Senior Common Finding 2.** Addressing the second research question: *How has the Physics First curriculum at an all-male private Catholic high school influenced students'*



*future STEM course choices and experiences?* Interview and enrollment data showed that the majority of the students were taking more than the required science course sequence. Although Physics-9 did not directly influence course choices at all levels, students perceived science more favorably and were open to taking more science classes after taking Physics-9. All the juniors and seniors in the study had taken the Physics-9 course as freshman and then chose their sophomore course based on the perceived rigor of the course and the decision was not significantly influenced by Physics-9. However, the sophomore course influenced the junior course choice since students from Honors Chemistry said they were prepared for AP Chemistry or AP Biology and students in regular-level Chemistry chose APES as their junior year course. As students progressed through their sophomore, junior, and senior years, more and more students took AP science courses. Enrollment data supported this assertion as more sections of AP science courses were offered in the senior year and more than 10% of the students took two science courses during their senior year. Almost 90% of the students took four years of science, even though only three were required.

### **Alumni**

Four alumni interviewed were pursuing science majors and careers in college and four alumni were pursuing non-science majors and careers.

#### **Alumni Pursuing Non-Science Majors and Careers**

**Alum 1.** Alum 1 was pursuing a degree in economics. His main influence for his major was his family and he initially wanted to pursue business but found economics more intriguing and challenging. He recalled his middle school science program as a good hands-on program but did not like science when he was in middle school:

My middle school teacher incorporated a lot of projects, a lot of experiments, they taught me a lot. Yeah, I really enjoyed how hands on the learning experience was. (Alum 1)

While he stated he enjoyed the hands-on science experience he said he did not like science:

I didn't like it because I probably wasn't good at it. I didn't understand it as much as I would have liked and I really hadn't done any reading on it, on the history of it. Which is something I did [in Physics-9]. I think Physics-9 was really good at walking me through the history of physics. I would go through, we'd kind of go chronologically, it was kind of like a history class, but we went through different physicists, we'd learn about their ideas and maybe how they were wrong later on. I thought that was a more coherent way of telling the story of science, it made more sense to me, I guess. (Alum 1)

His favorite project was working with circuits and after that his interest in science just increased:

I think there was one time when we were connecting circuits, like parallel circuits and closed circuits and whatnot. While we were doing that, we were using these hand crank generators to create electricity and that actually got me started for a very interesting journey. Basically, using those, I stayed back and asked how those worked and then he explained to me how we were actually moving a magnet and moving a magnet created moving electrons through a conductor and that started me off on a series of reading into physics and asking questions afterwards. (Alum 1)

He explained that the ninth-grade interest in Physics-9 led to the founding of the Physics club which was still in existence. After Physics-9, he chose to remain in the Honors track for science:

I think I wanted to continue, I was actually making a really good grade in Honors Chemistry I was around a group of kids that were really, really intelligent and I wanted to keep up with them, so that's why I went to AP chem. (Alum 1)

When asked if Physics-9 influence courses choices, he stated

I wouldn't say that when I was making my college choices I was thinking of Physics-9, but I think Physics-9 took me down a path. The reason I took Physics-9 . . . my experience there taught me to take honors Chem, then AP chem. AP Chem really shaped me, then AP Physics, I think one decision led to another and then that probably compounded to my decisions in college. (Alum 1)

**Alum 2.** Alum 2 started at his university as an engineering major but changed his major and found a new major, geo-design, which combined urban planning, architectural design, and

geospatial science. He had liked science since middle school and his father was an engineer and really wanted him to pursue engineering:

I went to a Catholic elementary and middle school, and so we had science, but we really didn't have a lab on campus, so they did more teaching us kind of the theory behind everything, but I think there was definitely a focus on science being important. (Alum 2)

While Alum 2 did not experience hands-on science in middle school, he stated that he liked science:

Yes, I did like science. I feel like I did very well in all of my classes growing up, 99 percentiles on all the tests and stuff. So I wasn't all that like I'm good at science I should like it. I just was genuinely very curious about how things worked and wanted to understand more about the world in that sense. (Alum 2)

Alum 2 enjoyed the Physics-9 course and saw it as foundational. But he took regular Chemistry and Biology during his sophomore and junior years and regretted his decisions:

I thought Physics-9 was good because it kind of sets a very good basis for the rest of your science education. (Alum 2)

For his sophomore year course, he could have taken Honors Chemistry or regular Chemistry:

I didn't really have an interest in that, so I ended up taking Chemistry. That was different, because that was one of the only general education, not honors courses that I was taking. So, I found it very easy and sometimes too simplistic. (Alum 2)

After sophomore year of Chemistry, he took Biology namely because he had not taken an honors course during his sophomore and did not want to be overwhelmed during his junior year. He did state that he wished he had made a different decision:

I wish that instead of Bio, I could have taken AP my Junior year. Also, the Bio class, was at that point, every other class I had was honors, so just like the caliber of learning was very different compared to Biology, which seemed very slowed down. I wasn't being challenged at all. (Alum 2)

While Alum 2 was less satisfied with his sophomore and junior year classes, he thought the Physics-9 course was the appropriate first course to take and gave him the confidence to take AP Physics during his senior year:

I think that [Physics-9] was the introduction to how students should approach science. That was probably most helpful. Also, physics is one of the courses, I thought it was just natural to start out with, but talking to classmates at other schools, they were like, we didn't do that, we didn't look at physics at all until later on. But, I still think the most important part was that it provided me with a basis for scientific understanding, and then I was comfortable taking AP Physics senior year. (Alum 2)

Alum 2 started with Physics-9 and continued with Chemistry, Biology, AP Physics and changed his major from engineering to design:

**Alum 3.** Alum 3 was pursuing an interdisciplinary design major and described a positive middle school experience but did not like science in middle school. He was interested in physics in high school because of theoretical physics he saw in movies:

Honestly, not at all. Like I didn't. and then I got really into science for most of high school. . . . I think the bizarre thing, about the high school physics is your taught that it is the most important. But you're not taught the stuff that's most interesting. But I remember imagining what theoretical physics must have been like even though that's not what we learned in class since it was so specialized. (Alum 3)

After Physics-9, Alum 3 took Honors Chemistry and AP Chemistry because he wanted to take the honors track and was planning to take Physics C his senior year since he was so intrigued by physics. His older brother who had gone to the same school had taken Physics C and he would hear his brother's friends talk about the course:

Honestly, like throughout my whole high school career, I remember taking Physics-9 and while alumni and my brother's friends were talking about relativity and stuff since they were taking AP Physics C. And I remember him being like, I like to learn about this in class. And like my brother would be like, you will. So I knew my whole time I was going to be an AP Physics C and like I was just like waiting for it. That class was definitely the most eye opening in terms of like the way, like I'd never done such complex math. (Alum 3)

Alum 3 took AP Physics his senior year and wanted to double up on science and take honors Astronomy also but decided to take painting and that lead to his interest to apply for a design major. His project for his design school admission was a Mars rover, allowing him to combine his love for science and art:

I was going to do honors astronomy because I actually found out honors astronomy I was interested in, and to be honest, they really just came down to I want to be a painting that was, the same period and they're both [offered] the one period only, so I chose painting over honors astronomy. (Alum 3)

**Alum 8.** Alum 8 wanted to pursue foreign service with an international relations major and international economics minor:

My mom was an international relations major in college, and when I was scouting out all the majors, I was like well what am I really interested in? It came down to like well I like. . . . I'm good at Spanish and I am pretty good with numbers and I think it'd be interesting to go around the world for a couple of years and see what the world has to offer and learn how all the trade deals and what not work. I mean ideally, I'd be a diplomat, but we'll see how that goes. It's pretty hard to get into that position but anything that gets me to interact with people out of my comfort zone would be pretty awesome. (Alum 8)

Alum 8 did not speak favorable of his middle school program and described it was reading the textbook and doing science fair each year:

I mean I didn't have that great of an experience with science in middle school, so it wasn't like. . . . I was like oh science. We're going to go read in something. I wasn't looking particularly forward to it, but it also wasn't something that I was like oh I have to take physics. (Alum 8)

After taking Physics-9 he said that he liked science:

I thought it was a great change from just reading. We're getting in the lab, we're doing stuff, and I thought the book that we had was great. (Alum 8)

Like many other students, he recalled the egg drop as a memorable experience:

I just I think I had a good group for that [project] doing it with a couple of my buddies. It was just a lot of fun like designing your own cart and it was fun competing against other people, like friendly competition within the course. (Alum 8)

After Physics-9 Alum 8 took Honors Chemistry, APES and Honors Astronomy:

I'd heard from a bunch of the older kids that I'd known that had gone through that honors astronomy was a great class and it had a great teacher and that it was really interesting. My dad had been particularly interested in watching Nova and all those science shows as a kid, so I was always around it. I thought it'd be interesting to learn it a little bit more about like the ins and outs of all that. (Alum 8)

### **Summary of Alumni Pursuing Non-Science Majors and Careers**

After reviewing four hours of transcribed interviews which responded to the interview protocol questions for the alumni interviews (see Appendix C), the data were coded, and the following summarizes the key themes found in the data for alumni pursuing non-Science majors and careers.

**Alumni pursuing non-science majors and careers finding 1.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?* alums pursuing non-science majors and careers had positive experiences of Physics-9 with no critiques of the course because it was a hands-on activity-based course that was made comprehensible to them.

Three out of the four alumni said they did not like science in middle school. Alum 1 said that he did not like middle school science even though there were hands on activities in the middle school science classes. Alums 2, 3, and 8 did not have much lab experience in middle school. But while Alum 1 did have an activity-based science curriculum in middle school, still did not like science because he said he did not understand the activities until high school. This indicates that having activities is not the only requirement for the positive science experience, but the activities have to be meaningful and comprehensible.

**Alumni pursuing non-science majors and careers finding 2.** Addressing the research

questions: *How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences? How has the Physics First curriculum influenced alumni career choices?* the influence of parents and student peers was the most significant factor in determining course choices. While Alum 1 had a very positive experience in Physics-9, started the Science Club, and took advanced AP science courses during his junior and senior years, he still majored in economics and cites family influences for his decisions. Alum 1 chose the “honors track to keep up with the honors kids.” Similarly Alum 3 also choose honors classes to be in the same classes as his friends.

Alum 2 thought science was important in middle school and was the only alum who liked science in middle school. His parents wanted him to pursue engineering, but he changed his major to an interdisciplinary major. Alum 8 also did not like science in middle school and after Physics-9 took APES and Honors Astronomy due to his love of science that developed in high school after taking Physics-9. Alum 8 cited his parents influence for his career choice. For alumni not majoring in science and not pursuing science careers, social influence of friends encouraged them to take honors classes in high school and family influence played a significant role on career choices.

### **Alumni Pursuing Science Majors and Careers**

**Alum 4.** Alum 4 declared a Chemistry and Classics double major and wants to pursue medicine. He liked his middle school science courses because they were quantitative:

Then my science courses back in middle school were a lot of math based, and math and science were my go-to subjects whenever things got difficult. That's what I always fall back on, is science and math. (Alum 4)

Taking Physics-9, which was more conceptual, and less math based, was a different experience:

I had mixed feelings about Physics-9. I like the content that was presented. I thought it gave a good foundation for advanced *physics*, and in later science courses I took at [the school]. But I felt that the instruction could've been better taught to be honest. I felt like it was a little forced, and I didn't interact with the teacher as much. (Alum 4)

The class environment was different for Alum 4, who was used to lecture based classrooms in which all students are seated:

I think when it came time for asking questions during class or during the lab, it would be kind of hard to get the attention of the teacher, just because there's a lot moving things going around, and I think our class was a little rowdy compared to the other periods. It was harder to get his attention during class. (Alum 4)

Alum 4 did state his favorite activity was the egg cart:

The one that we had to build a cart to hold an egg, and then making sure that when it went down the ramp it didn't crack the egg. I think that was really fun. A lot of team building went into planning the cart. Actually, designing the cart, because I think that's really cool. You get to create your own cart without copying other groups carts, and then seeing if it actually didn't crack. I think that was really cool. (Alum 4)

Alum 4 decided to take Honors Chemistry followed by AP Chemistry during his sophomore and junior years. Senior year he chose to take AP Biology and not AP Physics. (Alum 4)

Even though I had, looking back, thought I had a strong knowledge, I don't think I retained as much going into my senior year. I thought that since most of us took *physics* freshman year, that a lot of us would have a head start. I thought I would be a little behind in terms of the AP physics curriculum. My career goal was to do something in the medical field. I thought AP Biology would be a better field than AP Physics. That's why I chose AP Biology. (Alum 4)

When asked about his influence on his Chemistry and classics major, he described

Greatest influence on my major was my teachers. My Honors Chemistry and AP Chemistry teachers really ingrained in me a love of Chemistry. Then looking at a lens microscopically in terms of atoms and molecules, that's really interesting to me. Going to college now, taking these advanced courses now. Just seeing in a different lens with that. In terms of my classics major, My Latin teachers really showcased through their teaching that Latin is not dead per se. Really helped me enjoy translating Latin and exploring different authors and how their styles differ from each other. (Alum 4)



When asked about why he wants to pursue medicine, Alum 4 described his motivations as service to others:

One of my passions was to always help serve the community or provide a good deed to the community in any way I can. I felt that with my skills, I could use those to use in the medical field in whatever field I'm doing in medicine. (Alum 4)

**Alum 5.** Alum 5 wanted to pursue engineering as his major. He doesn't recall much middle school science but described as math as his favorite subject. He had a good experience in Physics-9 and appreciated the abundance of hands on activities:

It was a fun course. He was very enthusiastic and loved teaching everything, so it was fun. We got to go out and throw eggs at a thing to see if they'd break or something. We did a lot of cool labs. That was the most fun part. Half the time just sitting there playing with slinkies or the springs, playing with springs or whatever, building the fan, the turbine. There was a lot of cool stuff that was introduced there that was interesting. (Alum 5)

However, he realized that they weren't just playing around and that he was able to apply what he learned to college courses. He was critical of the teacher's instruction:

There was also we learned a lot of cool important stuff that I did end up using later. For example, work, this last semester in Calc 2 we did work calculations using integrals. It was kind of like everything suddenly came back. But at the same time, he wasn't the best at teaching, he wasn't very good at explaining it. (Alum 5)

When asked about a memorable project he described the wind turbines—a project not usually cited by the students and applications of cars:

I think the turbines were really fun. I remember always making the electrical circuit and stuff. I remember the ohms, the amps, and all that. I also remember there was a lot of stuff taught about the cars, because he's in the automotive club or whatever. He's a moderator and he loves cars, so we talk a lot about the car, the crashing scenarios and all that stuff. We talked a lot about that, so that was really interesting. That was most of it, I think. (Alum 5)

After taking Physics-9 Alum 5 took Honors Chemistry, AP Chemistry and Honors Astronomy during his senior year:

I wanted to take AP Physics alongside honors astronomy, but I didn't get into AP Physics because I didn't do very well in AP Chem or honors chem. And Honors Pre-Calc, it was also based off of that. I got a B in both of those classes, so they didn't really. . . . I didn't get in. AP Physics was the one class I wanted to take since freshman year and I never got a chance to take it, but that's fine. But I really wanted to take honors astronomy too because I love space and stuff. If I could my dream is to work for NASA or SpaceX.  
(Alum 5)

Alum 5 did describe Physics-9 in playing a role in his choice of major:

It was probably the easiest science that. . . . Or maybe easy because I understood it the most for me, so that's the main reason why I chose engineering. Engineering, it's great because I have a lot of fun in it, so I don't get stressed out studying or whatever. I did not understand a lot of Chemistry or really like it that much, so I didn't want to do that. And I'm happy [be]cause I only have to take one Chemistry class and no bio classes. (Alum 5)

**Alum 6.** Alum 6 also chose to pursue engineering but at a more competitive school than

Alum 5. Alum 6 attributed his love of science connected to mathematics. He wanted to pursue engineering before he entered high school:

I liked science from a very early age because I realized I enjoy doing math. My mom actually made me do times tables a lot, so I was able to do math fairly quickly and I caught up to science because I like how everything just made sense. There [are] subjective elements to it where like oh, you can apply creativity. Like oh I want to build a little car that moves, but how do I want to make this car? You can draw pictures and stuff and that's always kind of fun. And then applying it is actually even more fun because you realize like doing it, oh man this really sucks. It's really hard. And afterwards you're like, "Wow. It was worth it. It's awesome." (Alum 6)

He describes his Physics-9 experience has fun at times but frustrating:

It was frustrating because I wanted to understand but I knew that I couldn't understand yet, because I just did not have enough knowledge from math. . . . I wasn't at that level yet to understand. Because I'm the type of person, if I want to understand something you can't just give me half of the information, cause I can't just pause it . . . if you pause it like, "Oh, I'll give you this information but it's not all of it because it's introductory course." I would like to have all of it so it can all tie together, cause that's how I think. I'd like to have everything so I can make sense of it all at the same time. (Alum 6)

He chose to take Honors Chemistry so he can take AP Chemistry his junior year. He chose to not take Biology and expected to use some Physics-9 knowledge in Physics C:

I wanted to stick to the very traditional sort of physics, chemistry, bio, that sort of thing. But I chose not to take bio at all because I did take 2 years of chemistry, I would take 1 year of Physics C. I honestly did not feel like taking bio. I saw the trouble that my other friends going through at other schools and especially here, and I thought, “You know what, Physics C I’ve already taken a Physics-9 course, maybe I could apply some stuff there,” and that was not the case at all. (Alum 6)

**Alum 7.** Alum 7 was also pursuing engineering at a very competitive school. He said he always preferred science and math to other subjects always:

I always felt kind of like, just like problem solving like that, and I felt like I was the best outlet for that kind of thing. I guess just like compared to English, I always just had more fun doing numbers and stuff than writing essays. (Alum 7)

He has wanted to study engineering for as long as he can remember:

It was kind of just goes back to the problem solving thing where it’s like ever since I was a really little kid, I was always into numbers and I just like, I guess I just thought having a career like building stuff or designing stuff or working with, basically working, putting all of that math and science and numbers and all that into having a real impact on society, whether it’s building something or designing a structure or something like that, that’s always interested me. (Alum 7)

He described his Physics-9 experience as “doing a lot” since the students were keeping lab notebooks, reading and taking notes from the textbook and then working on an online source for problem solving.

We were doing a lot of labs and then if I remember correctly, I think it was we did labs and then we’d also have a textbook that we take notes out of and do homework out of, and then we also have web assign and stuff, and so it was a lot of stuff to just take in, but I feel like it was well intentioned but it just sort of, it might have been a little too much all at once, but it was definitely a good intro to physics concepts that are used later. (Alum 7)

His favorite project was making instruments, not the typical one mentioned by the alumni:

I remember at the end of the year we had to make instruments out of just household stuff, like soda bottles and what not, to see, I think it was how big it was, or how wide the opening was to determine like what kind of noise it was making. (Alum 7)

He chose Honors Chemistry and AP Chemistry as the sophomore and junior courses because he wanted the most challenging courses. He chose to take AP Physics during his senior year:

I already had experience with physics in ninth grade, so like 12th grade it was I already had a summary of foundation. It was basically just like you learn, not like now you learn calculus at the same time, seeing how the derivatives and stuff all playing, it kind of made my general understanding of physics from a freshman year way more solid. (Alum 7)

### **Summary of Alumni Findings for Alumni Pursuing Science Majors and Careers**

Alum 1 was a very high achieving student (valedictorian) and attended a top-ranked University in the country. Alum 1 earned an A in Physics-9 but did not think he learned enough to take AP Physics during his junior year. Alum 1 did well in Honors Chemistry and chose to take AP Chemistry during his senior year. The Honors Chemistry was a more traditional, content driven course. Alum 1 did not prefer the inquiry-based instruction and did not take physics senior year. Alum 5 took the same classes as Alum 1 during the freshman through sophomore years. Alum 5 preferred the Physics-9 course and did not do well in the Honors Chemistry and AP Chemistry courses. Alum 5 wanted to take physics during his junior year but because of his low grades in Honors Chemistry and AP Chemistry, did not qualify for the Physics C course. Alum 5 was majoring in engineering and was doing well at his university. Alum 6 and 7 both wanted to pursue engineering before starting high school physics and both were critical of the Physics-9 course in terms of alignments of assessments and assignments and preferred the more traditional science courses.

**Alumni pursuing science majors and careers finding 1.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?* The alum pursuing science careers generally had a positive

experience in Physics-9 but the higher achieving alums pursuing science majors at more competitive universities were more critical of the Physics-9 course. Main criticisms of the course included the misalignment of the activities, assignments and assessments.

**Alumni pursuing science majors and careers finding 2.** Addressing the research questions: *How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences? How has the Physics First curriculum influenced alumni career choices?* Most alumni pursuing science majors and careers had already decided they would major in those fields prior to starting high school. Their high school experiences validated and strengthened their interests in the science field.

### **Common Findings Between Students and Alumni**

After analysis of 16 hours of interviews including eight hours of student interviews and eight hours of alumni interviews, all students recalled positive Physics-9 experiences as evidenced by their memories of high levels of engagement. A few alumni critiqued test questions that were not properly matched with the course content and some students thought the course was easy, but nevertheless, all students enjoyed the course. Students did not remember the exact content of the exams and course topics, but they remembered the projects in detail. In addition, after the Physics-9 course all students were motivated to take junior and senior level AP courses and some even doubled up on science courses.

**Finding 1.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?* Most students had a more positive experience in Physics-9 than their middle school science courses. Students who were more advanced in science, such as Junior 3, Alum 4 and Alum 6 were more critical of the

Physics-9 course, while other students did not have any criticism for the Physics-9 course.

Students with proposed non-science majors recalled a more positive experience in Physics-9.

**Finding 2.** In response to the research question: *What were the experiences of students in an all-male private Catholic high school in their Physics First course?* Students remembered the most engaging projects as the hands-on activities and the most commonly described activity as a favorite project was the egg cart. While students remembered many different projects and activities such as the sports voiceover, making a musical instrument and wiring a house, all students remembered the egg cart, an activity that combined engineering design with physics concepts.

**Finding 3.** Addressing the research questions: *How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences? How has the Physics First curriculum influenced alumni career choices?* Students' course and career choices are influenced by other factors than their Physics-9 experiences. The decisions to take Honors Chemistry or Chemistry during the sophomore year was based on perception of the difficulty of the class and social influence based on what students' friends were taking and what their parents wanted them to take. Students in mostly honors classes chose to take Honors Chemistry. All juniors and seniors reported wanting to take AP courses—courses that are more similar in to Physics-9 than the sophomore Chemistry course. More students were taking honors and AP courses since the beginning of the PF curriculum at the site, more students were taking four years of science and more students are doubling up on science.

## Conclusion

Juniors, seniors, and alumni who had taken an inquiry-based physics course as freshman in a Physics First curriculum responded to an interview protocol designed to answer the following research questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
- How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
- How has the Physics First curriculum influenced alumni career choices?

All the students interviewed recalled positive, memorable experiences in their Physics-9 course as they explained in their interviews that they enjoyed their Physics-9 course and remembered details about the engaging, hands-on projects as their favorite activities. Even students who critiqued the alignment of the assessments and activities in the course, or who said the course was too easy, still reportedly enjoyed the course. Over 90% of the students at the site enroll in four years of science even though only three years were required. Students who were more advanced in their math and science were more likely to critique the course while others gained confidence in their abilities and interest in science. Almost all of the students liked science for the first time because of the Physics-9 course.

While Physics-9 did not appear to be an explicit factor in determining student and alumni course/career choices, the engaging nature of the class appeared to have set participants up for success in science and other classes, particularly mathematics and piqued their interest in computer science. While one student reported that Physics-9 gave him confidence to take honors

chemistry, for all the other students, the choice to take honors chemistry was more influenced by a desire to choose challenging courses and influences of their friends and parents. While the junior-level course choice was more influenced by the sophomore courses, the choice to take AP Physics during the senior year was sometimes influenced by Physics-9. Seniors who had a favorable experience in Physics-9 as freshman, even if they thought the course was easy, wanted to take a more advanced, calculus-based physics course. While most alumni cited other factors such as family, early interests and teachers rather than Physics-9 as influencing college major and career choices, all alumni shared a favorable perception of science after Physics-9 and their subsequent high school science course curriculum. The discussion of these findings, limitations, future research and implications for theory, practice and policy will be discussed in Chapter 5.



## CHAPTER 5

### DISCUSSION

This dissertation examined student and alumni perceptions of a Physics First course in a modified curriculum that inverted the traditional course sequence of Biology-Chemistry-Physics (BCP) to an inquiry-based Physics First (PF) curriculum in which students take an inquiry-based physics course as freshman and chemistry as sophomores. Not only did this inverted curriculum allow the science courses to be taught in a pedagogically sound, logical progression as prescribed in the early development of American curriculum, but the Physics First course effectively engaged the students and cultivates their problem-solving skills while helping them achieve a science-rich world view. The site adopted the Physics First curriculum over 10 years ago and was the subject of a quantitative study that examined the influence of the Physics First curriculum on SAT Math scores (Bouma, 2013). While the quantitative study by Bouma (2013) demonstrated benefits of the curriculum, a qualitative study was needed to capture richer, in-depth student and alumni perceptions.

The qualitative study included a sampling of 16 male students and alumni selected from students currently enrolled and alumni who graduated within five years of the study. All participants completed the inquiry-based Physics-9 course as freshman at the site. Two of the juniors followed the physics course with sophomore level honors chemistry and two of the juniors enrolled in regular level chemistry. Two seniors followed the freshman physics course by regular chemistry and two seniors took freshman physics followed by sophomore honors chemistry. The purpose for each of the varying characteristics allowed for the exploration of student perceptions and experiences at various levels of the course sequence.

The purpose of this study was to explore and understand the perceptions of current and former high school students who participated in an inquiry-based, PF curriculum and to examine the influence of the curriculum on students' future science course choices. The research was guided by the following questions:

- What were the experiences of students in an all-male private catholic high school in their Physics First course?
- How has the Physics First curriculum at an all-male private catholic high school influenced students' future STEM course choices and experiences?
- How has the Physics First curriculum influenced alumni career choices?

### **Discussion of Findings**

#### **Finding 1**

In response to the research question, *What were the experiences of students in an all-male private catholic high school in their Physics First course?*, the Physics-9 course proved to be a positive and enjoyable experience for all the freshman. The students had a more positive experience in Physics-9 than in their middle school science courses. Even the few students who were more advanced in science and slightly critical of the rigor and assessments of the Physics-9 course found themselves engaged in the hands-on activities of the course. It is remarkable to have one science course that is able to meet the needs of such a diverse group of students. Students entered the Physics-9 course with a broad range of middle school science experiences and abilities. The Physics-9 course allowed all students to engage in creative problem solving and collaboration with their peers and instructors. The course, rooted in real-world applications, provided students with a science-rich world view through high school and on to college.

In *How People Learn*, Donovan, Bransford, and Pellegrino (1999) described best teaching practices as activities structured such that students are engaged and able to explore, explain, extend, and evaluate their progress. Students need to see a reason for the use of ideas and concepts taught in class so they can connect the relevant uses of the knowledge in order to make sense of what they are learning. The PF course follows the suggestions of *How People Learn* by using the 5E model of instruction to allow students to engage, explore, explain, extend and evaluate their progress through the inquiry-based instruction. Each activity in the PF course engaged the students because each topic related to situations relevant to students' lives. The major projects in the course included activities such as presenting to a panel of driving instructors, creating a news voice over for a sports event, building a car to protect an egg passenger, and designing musical instruments or wiring a house. For ninth-grade boys who commuted to school every day, looked forward to driving during their sophomore year, participated in high school sports, and used technology constantly, these projects were relevant to their lives, hobbies and interests.

The structure of the course did not merely address topics interesting to ninth grade students, but allowed students to go deeper and build and design products to develop solutions to plausible real-world events surrounding the topics. This was why students and alumni liked science better in ninth grade than previous years because they were learning about topics that were interesting in an active way. It was remarkable how each participant was able to recall in detail the major challenges and outcomes of their projects. Even alumni who had graduated four years ago vividly recalled the course activities they performed in ninth grade. Such recall was

rare and provided evidence that the course was memorable, creating lasting, enduring understandings. Physics-9 changed their lives.

## **Finding 2**

In response to the research question: *What were the experiences of students in an all-male private catholic high school in their Physics First course?* Students remembered the most engaging projects as the hands-on activities and the egg cart emerged as the most commonly described activity as a favorite project. While students remembered many different projects and activities such as the sports voiceover, making a musical instrument and wiring a house, all students remembered the egg cart, an activity that combined engineering design with physics concepts. The students remembered concepts learned from that activity years after they completed the project. Improved student learning from hands-on projects was consistent with prior educational research (Donovan & Bransford, 2005; NRC 2005, 2013). This was consistent with the rationale behind the Next Generation Science Standards (NGSS), the new science standards being adopted by high schools over the following few years, which reflected the most recent advances in science education research. Students learned science by doing science.

While it was established that students learned science by doing science and the findings of this study indicated students enjoyed the activities of the Physics-9 course, what was it about the egg cart activity that all students and alumni recalled it in such detail and considered it one of their favorites? Students had different interests and students interested in sports liked the sports voiceover activity while students interested in computers and circuits better appreciated the house wiring activity. Why did all the students remember and love the egg cart activity? First, students had been learning about kinematics and momentum through smaller lab activities over

multiple chapters and that gave them the knowledge base to tackle a larger engineering design problem. The egg cart activities were a culmination of many smaller activities so that the students were prepared with a conceptual knowledge base to attempt to creatively solve a problem, to protect the egg. Secondly, the project was in the form of a competition. Students remembered whether they were successful or not based on how they compared to their peers, and because the students wanted to be successful in the competition, they collaborated to design the most successful project. A project whose success was measured in an obvious way—whether the egg broke or no—allowed students to work toward a goal and compete with their classmates.

The Physics-9 course was aligned with the three dimensions of the Next Generation Science Standards (NGSS): (1) science and engineering practices, (2) crosscutting concepts, and (3) core ideas. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), the precursor to the NGSS, described science and engineering practices based on the skills that scientists and engineers use daily. The NGSS standards were based on the findings about research on how students learn science effectively including other National Research Council publications such as *How People Learn* (Donovan et al., 1999), *How Students Learn* (Donovan & Bransford, 2005), and *Taking Science to School and Education for Life and Work* (NRC, 2012). The activities that students and alumni recalled, such as the egg cart and the house wired for electricity, allowed students to combine the physics concepts with engineering practices.

Effective science curriculum required that science was taught not only via inquiry-based methods, but also science should be taught in the correct sequence. All science curriculum should be taught in a coherent manner, and putting physics first provided the concepts needed to

properly understand chemistry which then provides the foundation for biology. While the multidimensionality of the NGSS allowed for several maps for course sequences to address the standards, the suggested Course Map 1 (NRC, 2012) was comparable to a Physics First curriculum with the physics science concepts addressed in the first course sequence.

Science courses should first help connect students' own experiences with the concepts. This allows students to be more interested in the course, as it better relates to them and the experiences that are important in their lives. Once the students are engaged, hands-on activities help them explore the concepts, collect data, build models and construct their understanding of the concepts. This is done via the small lab activities, followed by homework assignments that reinforce the concepts and experiences. Culminating projects such as the voice over, egg cart or wired electrical house allow for the connections of all the concepts and to extend and elaborate students' understandings. The engineering design and collaborating aspects of the course are integrated into these culminating projects. This is what science education should look like: hands-on inquiry activities every day allowing students to develop their understandings so they can apply the concepts to culminating projects allowing students to collaborate and design.

### **Finding 3**

Addressing the research questions: *How has the Physics First curriculum at an all-male private catholic high school influenced students' future STEM course choices and experiences? How has the Physics First curriculum influenced alumni career choices?* Students course and career choices were influenced by other factors than their Physics-9 experiences. Why students took particular courses and choose majors was very complex. Their decisions were influenced by many factors including teachers, parents, friends, hobbies and interests. The decisions to take

Honors Chemistry or Chemistry during the sophomore year were based on perception of the difficulty of the class and social influence based on what students' friends were taking and what their parents wanted them to take. Students in mostly honors classes or students who wanted a challenging course chose to take Honors Chemistry. Sophomores who wanted to take a more lab-based course or who wanted to take a slower paced course chose Chemistry. Although students' course and career choices were as complex as their interests, backgrounds and personalities, the Physics-9 course did one important thing: Physics-9 maintained or improved students' overall views of science and learning science. Students who walked into the ninth-grade science class with science majors or careers in mind did not change their minds; they kept on course with the path they intended taking. All juniors and seniors, regardless of whether they took Honors Chemistry or not, reported wanting to take AP courses, courses that are more similar in to Physics-9 than the sophomore Honors Chemistry course. Overall, since the beginning of the PF curriculum, more students were taking honors and AP courses at the site and had experienced science favorably.

The culture of the school had slowly changed with the beginning of the Physics-9 course. A course that started as an elective in 2007 became a required freshman course in 2014 due to its popularity and effectiveness. At the school, science has become a core part of the curriculum much like English and math, taken all four years by more than 90% of the students. While the school required only three years of science, more than 90% of the students were taking four years, and more than 10% were taking two science courses during their senior year and thus were taking five years of science. Much of this shift in culture was because science was considered a

fun, engaging challenge and was one of the highlights of the students' and alumni's high school experiences.

The results of the study were consistent with Goodman and Etkina (2008), who reported more AP exams were taken and students passed the AP exam at a rate 14 times greater than the average pass rate in the state in which the study took place. All students, whether they passed the AP Exam or not, scored higher on the Trends in International Mathematics and Science Study (TIMSS) and students in the PF courses were taking more science courses overall in high school (Goodman & Etkina, 2008). Larkin (2016) described a case study of three schools in which all three schools reported improvement in mathematics due to the curriculum switch but not all schools reported increased science courses taken after the PF courses. However, schools reported issues for finding trained teachers for the physics course (Larkin, 2016). The site of the study was able to train and mentor teachers and allowed the site the flexibility to offer courses based on student needs.

The main findings of the study indicated that students were enjoying science more in high school, they were finding the projects to be lifelong memories, and they were taking more high school science courses. This culture shift at the school, where a freshman elective science course had become a catalyst for an increase in science courses, had arguably changed the science literacy of the student body at the site. While not all students were matriculating on to major in science, they were becoming scientifically literate citizens. The non-science majors were scientifically literate and pursuing quantitative careers like business, economics and computer science.



Therefore, it can be inferred that Physics-9 can have lifelong implications. Imagine a student who disliked science in middle school because he thought all the labs and worksheets were boring. Now in high school, this student was in a science class where he and his classmates are talking about cars, bikes and skateboards. For the first time in his life, he was engaged by his science class. Through these class experiences, he started to see the world differently. He heard his football coaches' and driving instructors' directions differently as now he understood the rationale behind the instructions during practice and driving lessons. He was perhaps becoming a better athlete and driver because of what he had learned in his physics class. At home, he played online video games and watched DIY YouTube videos. But now, when he turned his devices on, he imagined the inner workings of the electrical circuits making these devices operate. In physics class he could use tools and design and construct products that solve a problem. It is no wonder that the students loved this course; students were able to see their entire world differently because of Physics-9. Physics-9 has the power to change students' lives.

Not only were students understanding the world differently, but they were able to solve problems. The challenges (culminating projects) in Physics-9 required students to achieve a desired outcome given constraints. For the egg cart project, they were given certain materials and they had to make sure their egg could go down the ramp and not break. They were not only proposing solutions to problems, but they were actually building and seeing their ideas come to life. They must ask themselves important questions: Did it work? What needed to change? When we fast forward to the future jobs and careers of these students, whether they are working in a research lab, managing a world class hotel or restaurant, or directing a movie, they all must achieve outcomes and solve problems given certain constraints in materials, time and personnel.

When students had to build an egg cart in a constrained amount of time with a group of three students given limited materials, they were facing similar challenges in a smaller scale as managers, employees and entrepreneurs in all industries. Physics-9 is setting the students up for success in any career they choose to pursue.

Students might not all be thinking about their careers yet, but they were focused on college. Some students had long family legacies at and were expected attend prominent universities. Others may be the first in their families to attend college. Both students in the same physics class wanted to attend college and this class was helping them generate the interest and skills to take AP courses and succeed in their AP courses. Physics-9 is opening doors for all students to further study regardless if they major in science or not.

### **Limitations**

The site had offered the PF curriculum for over 10 years and, therefore, was an appropriate site to study the perceptions of the PF program. The study of future course choices of current students and future course choices and career choices of alumni could be done due to the length of time that the PF curriculum had been offered at the site. The researcher was a teacher and science department chair at the school and had been granted access to students and alumni by the principal of the organization. However, since the school was an all-male school, the exclusion of female students and the school's access to fiscal resources and human capital presented a limitation to the application of the results of the study to other coed and lower socioeconomic contexts.

In addition, other limitations emerged in this qualitative study of the perceptions of the PF curriculum including experimenter bias, self-reported data bias and small sample size. The

interpretation of the qualitative data was subject to personal bias as viewed through the lens of the researcher. Since the data consisted of self-reported qualitative interviews, responses were only as accurate as the reflections of the subjects of the study. Current students and alumni may tend to recall their perceptions of the PF curriculum as extremely positive or negative based on their overall experiences as students at the site.

### **Future Research**

In light of the above limitations, future studies on Physics-9 programs should include sites with varied populations such as a coed environment, and all-female school, or a public school with a low socioeconomic status and diverse demographics. Future studies in coed or all-female environments will not only address a population excluded from this study but will also address the gender gap in science. Studying schools with lower socioeconomic status and diverse demographics will provide some insight into lack of people of color in STEM fields. Many schools do not have PF programs so study of the effectiveness and perceptions of different, non-PF inquiry-based science curriculum would also offer an opportunity for comparison to the PF curriculum. Lastly, the alignment between assessments and course content was a cause for critique by several alumni. With many schools adopting inquiry-based instruction to address the NGSS standards, authentic assessments need to be studied and explored. Inquiry based courses need to align assessments with the instruction.

Recommendations for future studies on PF curriculum, whether qualitative or quantitative, would include populations with female students or populations with students of low SES to compare their perceptions and achievements in a PF program. The accessibility of science courses and underrepresented populations in STEM fields emerges as an important social

justice issue that a course like PF would address since the research indicates more students are taking science after the Physics-9 course. Future studies with inquiry-based instruction with a different course sequence such as inquiry base BCP rather than PCB would be useful in comparing the influence of the course sequence.

Longitudinal study that follows a population from the beginning of PF through college and into their careers would provide evidence about PF and achievement and application of PF concepts and skills into their careers. Interviewing the same population every year would allow data to be obtained about how PF has impacted each year of their life in college, jobs, internships and careers. Interviewing a different set of students every year would generate an immense amount of data about the changes and progressions of the course. This study did not include artifact analysis, extensive classroom observations and teacher interviews. Each of those, artifact analysis, class observations and teacher interviews, could be combined into a single study or constitute separate studies.

### **Implications**

In addition to suggestions for future research including diverse populations and inquiry-based curricula, there are several implications from the current study. Implications for theory, practice and policy emerge from this study of student and alumni perceptions of a PF curriculum.

#### **Theoretical Implications**

This study validated the constructivist views proposed by Vygotsky, Piaget, Papert, Dewey, and countless others. The collaborative learning that occurred in the Physics-9 classroom on a daily basis, whether for an activity or a major project like the egg cart, supported Vygotsky's (1978) view about how social connections between students can promote learning.

Each physics lesson was structured in the activity before concept format which was a part of the 5E model in which students completed the lab activity before they discussed the concepts and problem solving. This allowed students to construct new knowledge from their experiences as Piaget (1963) suggested. The egg cart and house wired for electricity were some of the activities the students and alumni recalled fondly. Student responses indicated that they were engaged during these activities in which they made a product. This was in line with Papert (1991), who described how making a product in inquiry-based discovery learning and problem-solving situations would result in highly engaged students. The 5E instructional model used in inquiry-based physics instruction descended from Herbart's (1901) and Dewey (1938) philosophies of learning. The student voices in this study supported all the constructivist ideas proposed by educational philosophies proposed for decades.

The results of this study clearly demonstrate that students enjoyed their PF experience with an inquiry-based course that was fun, memorable and made science engaging. Students not planning to major in science or pursue a career in science still took four years of science. It is important to notice is that Physics-9 was enjoyable to the students not only because of the inquiry-based instruction, but because it was taught in the sequence that makes the most sense pedagogically. With more students engaged in science, even if not all students pursue STEM fields, there are more students who have increased science literacy and will grow up to be scientifically literate adults. This study added data to and validated claims of the inquiry-oriented educational research done in the past in science. For students to be scientifically literate science must be taught via inquiry. Inquiry-based instruction is imperative to ensure scientifically literate adults.

## **Implications for Practice**

Research about how students best learn pointed to inquiry-based instruction as the most effective. However, for the inquiry to be comprehensible to students, it has to be taught in an order that matches the logical progression of the science course as recommended by the CoT. Thus, these two components—inquiry and Physics First—are the basis of a successful science program. This study adds to evidence that demonstrates that PF works. After the curriculum shift to the required freshman PF course, the percentage of students who took four years of science courses increased from 50% to 90%. Not only were more students taking four years, and sometimes an additional fifth year, of science when only three were required, more students were taking AP courses. The gains and progress made after the curriculum shift to the PF curriculum serves as a model for schools looking to increase their science AP program enrollment numbers or have more students take science.

Students benefited from the PF course sequence because they took more science and an enjoyable first year science course, allowing them to be more prepared to enter STEM fields. Teachers benefited from teaching an effective inquiry-based course aligned with the current standards. Principals and administrators benefited from increased enrollment and gains in AP scores and having a more engaged student body with increased science literacy.

Based on the research performed in this study, it can be concluded that students' first year in high school would benefit by starting with an engaging physics course covering the topics of kinematics, dynamics, momentum, waves, and electricity. The course should follow a 5E model in which each activity should have a connection to real-world application (engagement) which leads into a hands-on inquiry-based activity (explore and explain) followed by homework,

projects and assessments (extend, evaluate). The second-year chemistry course should continue with the topics of atomic theory, stoichiometry, reactions in solutions, thermodynamics, bonding, gases, kinetics, equilibrium, acids and bases and electrochemistry addressed via the same 5E model with activities and projects. The third-year biology course can use the concepts of energy conservation, bonding among others to set the foundation of the study of biochemistry, molecular and cellular biology, evolution and ecology again delivered in the activity and project-based 5E model. This PCB course sequence is an answer to the calls for science reform and consistent with the NGSS.

### **Policy Implications**

Most states have adopted the Next Generation Science Standards (NGSS) and are in the implementation phase, in which the school districts are working to implement K-Eight and high school curriculum aligned with the NGSS. The Physics First course curriculum was aligned with the NGSS and will allow districts a smoother implementation. Schools must consider a Physics First curriculum in order to address the NGSS successfully in their science curricula. The traditional BCP course sequence is inconsistent with over one hundred years of literature about how students best learn science. All schools, public, private, single sex, and co-ed need to flip their curriculum to an inquiry-based PF curriculum.

### **Recommendations**

In the 10 years that the site studied has offered Physics-9, this was the first-time students were asked about the activities that were foundational to their experience. Students should be often surveyed about what is effective in the course to help design and improve existing course curriculum. This is true not just in science, but in all subjects.

The recommendation for the instructors at the site includes alignment of the Physics-9 course content and assessments and alignment and collaboration with other courses. While students and alumni found the Physics-9 activities engaging and memorable, the need for improvement articulated by the students included better alignment of assessments to the course content. After the nationwide implementation of NGSS curriculum, the assessments for the NGSS will be the next area of concern nationally. The work toward aligning assessments with activities and projects will be an important task for all science instructors.

The students interviewed indicated the lack of alignment of Physics-9 with the sophomore Honors Chemistry course. The physics and the chemistry instructors should work to improve the vertical alignment of the courses. Cross-curricular alignment helps students' understanding as it reinforces practice and application. Physics-9 should also be better aligned with freshman math courses (predominantly Geometry), and sophomore year chemistry should be aligned with sophomore math courses (predominately Algebra II). It also seems prudent to consider merging the senior year courses, AP Physics and AP Calculus, into one course taught across a two-period block. Cross-curricular alignment and common projects between courses such as AP Biology and AP Statistics also would be effective. Most importantly, developing arguments using evidence is an important performance expectation of not just the NGSS, but also the Common Core State Standards and the College and Career Life Framework for Social Studies Standards. Aligning English and social studies courses with the science courses for each grade would allow students to improve writing across the curriculum and improve each year for their four years of science. Alignment with four years of English, Math, social studies, and science courses could not have been possible without the Physics-9 course.



## Conclusion

A science course sequence that includes a highly recommended order of topics (PCB) taught in a manner in which students learn best (inquiry-based) improves student achievement and engagement in science education. This study explored the experiences of students in their Physics First course and how the Physics First curriculum influenced students' and alumni future STEM course choices and experiences. The students recalled positive experiences in their Physics-9 course and almost all of the students liked science for the first time because of the Physics-9 course. While Physics-9 did not appear to be an explicit factor in determining all student and alumni course and career choices, the engaging nature of the class appeared to have set participants up for success in science classes as students enrolled in more science classes, including more AP classes.

This study validated research claims made for decades that science should be taught inquiry-based and with physics first. However, the study also brought to light that curriculum changes should be ongoing because student engagement and achievement should be assessed continuously. As student populations change, technology access improves, and college and workforce demand shift, curriculum should keep up with these changes. Student voices are imperative to the curriculum development process. While the site studied as the subject of this qualitative dissertation was also the focus of a quantitative dissertation six years ago, it does not take a dissertation to listen to students and collect data. Formative changes can be made on an ongoing basis by data gathered by instructors, department chairs and administrators.

Fourteen years ago, a science department decided to study science curriculum to find one that best helps students learn. After attending national conferences, visiting schools and poring

through hundreds of pieces of science education literature they voted to go Physics First by adding a Physics-9 elective course. That elective course won the hearts and minds of students, parents, administrators and the principal and became a first-year course for all freshman. This course is changing students' lives, and all students deserve to experience such a science curriculum.

## APPENDIX A

### *Junior (11th Grade) Student Interview Questions*

The following interview questions will be asked to aid in answering the research questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
  - How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
1. Describe your science experience prior to taking Physics-9? Who was your teacher?
  2. Do you remember a favorite science class or project prior to Physics-9? Please describe it in detail.
  3. Did you like science prior to taking Physics-9? Why or why not?
  4. What was your experience in Physics-9? Did you enjoy the course? Why or why not?
  5. What concepts did you find difficult in Physics-9? What concepts did you find easy in Physics-9?
  6. What math class did you take in Grade 9?
  7. Did you find the math computations you had to do difficult in Physics-9? Why?
  8. Do you remember a favorite topic, activity or challenge in Physics-9? Why was that particular topic, activity or challenge memorable?
  9. Which 10th grade high school science classes did you take after Physics-9? Why did you choose that course?
  10. Which 11th grade high school science class did you choose to take? Why did you choose that course? Which 11th grade high school math class did you choose to take? Why did you choose that course? Did Physics-9 influence the course choices for your 10th and 11th grade courses?
  11. Do you plan to take a science course during your senior year? Which one(s)? Why or why not?
  12. Was there a concept or skill you learned in Physics-9 that was helpful in your 10th or 11th grade science courses? How about your math classes?
  13. What are you considering majoring in when you go to college and the career you want to pursue? Have any classes affected these potential choices? Which classes and why?
  14. Is there anything that I did not ask you that you would like to share?

## APPENDIX B

### *Senior (12th Grade) Student Interview Questions*

The following interview questions will be asked to aid in answering the research questions:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
  - How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
1. Describe your science experience prior to taking Physics-9? Who was your teacher?
  2. Do you remember a favorite science class or project prior to Physics-9? Please describe it in detail.
  3. Did you like science prior to taking Physics-9? Why or why not?
  4. What was your experience in Physics-9? Did you enjoy the course? Why or why not?
  5. What concepts did you find difficult in Physics-9? What concepts did you find easy in Physics-9?
  6. What math class did you take in Grade 9?
  7. Did you find the math computations you had to do difficult in Physics-9? Why?
  8. Do you remember a favorite topic, activity or challenge in Physics-9? Why was that particular topic, activity or challenge memorable?
  9. Which 10th grade high school science classes did you take after Physics-9? Why did you choose that course?
  10. Which 11th grade high school science class did you choose to take? Why did you choose that course? Which 11th grade high school math class did you choose to take? Why did you choose that course? Did Physics-9 influence the course choices for your 10th and 11th grade courses?
  11. Which 12th grade high school science class did you choose to take? Why did you choose that course? Which 12th grade high school math class did you choose to take? Why did you choose that course? Did Physics-9 influence the course choices for your 12th-grade courses?
  12. Was there a concept or skill you learned in Physics-9 that was helpful in your 10th-12th science courses? How about your math classes?
  13. What are you considering majoring in when you go to college and the career you want to pursue? Have any classes affected these potential choices? Which classes and why?
  14. Is there anything that I did not ask you that you would like to share?

## APPENDIX C

### *Alumni Interview Questions*

The following interview questions will be asked to aid in answering the research question:

- What were the experiences of students in an all-male private Catholic high school in their Physics First course?
  - How has the Physics First curriculum at an all-male private Catholic high school influenced students' future STEM course choices and experiences?
  - How has the Physics First curriculum influenced alumni career choices?
1. Describe your science experience prior to taking Physics-9? Who was your teacher?
  2. Do you remember a favorite science class or project prior to Physics-9? Please describe it in detail.
  3. Did you like science prior to taking Physics-9? Why or why not?
  4. What was your experience in Physics-9? Did you enjoy the course? Why or why not?
  5. What concepts did you find difficult in Physics-9? What concepts did you find easy in Physics-9?
  6. What math class did you take in Grade 9?
  7. Did you find the math computations you had to do difficult in Physics-9? Why?
  8. Do you remember a favorite topic, activity or challenge in Physics-9? Why was that particular topic, activity or challenge memorable?
  9. Which 10th grade high school science classes did you take after Physics-9? Why did you choose that course?
  10. Which 11th grade high school science class did you choose to take? Why did you choose that course? Which 11th grade high school math class did you choose to take? Why did you choose that course? Did Physics-9 influence the course choices for your 10th and 11th grade courses?
  11. Which 12th grade high school science class did you choose to take? Why did you choose that course? Which 12th grade high school math class did you choose to take? Why did you choose that course? Did Physics-9 influence the course choices for your 12th-grade courses?
  12. Was there a concept or skill you learned in Physics-9 that was helpful in your 10th-12th science courses? How about your math classes?
  13. What is your major at your college/university?
  14. Which science courses did you take in college?
  15. Did you choose to pursue a career in science? If so, which field of science. If not, what do you plan on pursuing?
  16. Did Physics-9 influence your college course choices or career choices? Why or why not?
  17. Is there anything that I did not ask you that you would like to share?

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