A Comparative Case Study of the Characteristics of Science, Technology, Engineering, and Mathematics (STEM) Focused High Schools

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DEDICATION

This dissertation is dedicated to my husband, Randy, for being by best friend and supporting me throughout the years of my PhD. He has been a source of encouragement, patiently listening to my ideas while taking on additional household responsibilities for me to write this dissertation. This is also for our children Caleb, Stephanie, and Jared who have brought love and joy into my life and helped me understand education from the perspective of the next generation. I would also like to thank my mother, and father, in-law, Raymond and Deloris Scott, who have always supported me and been there to love and care for our children. I would like to thank my mom who has always valued education and instilled in me the importance of following through with commitments that I made. And finally, I would like to thank my dad for encouraging me to pursue mathematics education. Although he is not here to share in this accomplishment, he would have been proud and would have taken the time to read this dissertation. I could not have done this without all of my family's support.

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LIST OF ABBREVIATIONS

AAAS.. American Association for the Advancement of Science
ACT.. American College Test
AIMS...Academic Investment in Math and Science Program
AP ....Advanced Placement
AYP...Adequate Yearly Progress
CMST..Computational Math, Science and Technology Institute
CTE ....Career-Technical Education
CRS .... Congressional Research Services
EHR...Education and Human Resource
ESEA.. Elementary and Secondary Education Act
GAO ....Government Accountability Office
HSA...High School Assessment
IB...International Baccalaureate
IEP .... Individualized Education Program
LCD...Liquid Crystal Display
LITEE .... Laboratory for Innovative Technology and Engineering Education
MSP.. Math Science Partnership
NAEP ....National Assessment of Educational Progress
NCLB...No Child Left Behind Act
NCTM.. …National Council of Teachers of Mathematics
NRC .... National Research Council
NSF .... …National Science Foundation
STEM...Science, Technology, Engineering, Mathematics
TIMMS ....…Trends in International Mathematics and Science Study

ABSTRACT

A COMPARATIVE CASE STUDY OF THE CHARACTERISTICS OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) FOCUSED HIGH SCHOOLS.

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This study examined the characteristics of 10 science, technology, engineering, and mathematics (STEM) focused high schools. A comparative case designed was used to identify key components of STEM school designs. Schools were selected from various regions across the United States. Data collected included websites, national statistics database, standardized test scores, interviews and published articles.

Results from this study indicate that there is a variety of STEM high school programs designed to increase students' ability to pursue college degrees in STEM fields. The school mission statements influence the overall school design. Students at STEM schools must submit an application to be admitted to STEM high schools. Half of the STEM high schools used a lottery system to select students. STEM high schools have a higher population of black students and a lower population of white and Hispanic students than most schools in the United States. They serve about the same number of

economically disadvantaged students. The academic programs at STEM high schools are more rigorous with electives focused on STEM content. In addition to coursework requirements, students must also complete internships and/or a capstone project. Teachers who teach in STEM schools are provided regularly scheduled professional development activities that focus on STEM content and pedagogy. Teachers provide leadership in the development and delivery of the professional development activities.

1. Introduction

Introduction

The term *STEM* has been used by the National Science Foundation (NSF) to indicate "Science, Technology, Engineering and Mathematics" and generally refers to education in these areas (Vanderbilt University, 2006). The decline in the number of undergraduate degrees earned in STEM fields since 2000 has caused concern about the ability of the United States to remain competitive in the world (Library of Congress, 2006; 2008). "The number of students attaining STEM postsecondary degrees in the U.S. more than doubled between 1960 and 2000; however, as a proportion of degrees in all fields, STEM degree awards have stagnated. In the 2002-2003 academic year, fewer than 16% of all degrees conferred were in STEM fields. The total number of STEM degrees collectively was roughly equivalent to the number awarded in business" (Library of Congress, 2006, p. 11; Library of Congress, 2008, p. 10).

According to Atkinson, Hugo, Lundgren, Shapiro, and Thomas (2007), the United States faces a new and pressing competitiveness challenge as a growing number of nations seek to gain a global market share in technology-based economic activities. They write, "Ensuring an adequate supply of talented scientists and engineers is one key step in addressing this challenge" (p. 1). To compete in the present global economy, it is essential to develop a workforce that is literate in STEM areas. As Lawrenz, Huffman, and Thomas (2006) noted, “It is important for all students, including those who have not traditionally been able to participate in STEM fields, to have opportunities to learn the knowledge and skills they will need in a technologically oriented future” (p. 105).

In *Rising Above the Gathering Storm* (2006) presented four principle recommendations: 1) increase America’s talent pool by vastly improving K-12 science and mathematics education; 2) sustain and strengthen the long-term commitment to basic research; 3) make the United States the most attractive environment in which to study and perform research; and 4) ensure that the United States is the premier place in the world for innovation and investment in manufacturing and marketing (Vanderbilt University, 2006). Of these recommendations, the common thread is education in the STEM disciplines.

Background of the Problem

The Report of the Academic Competitiveness Council (2007) outlined three goals for K-12 education. First, prepare all students with science, technology, engineering, and mathematics (STEM) skills needed to succeed in the 21st century technological economy. Second, recruit and retain teachers with majors or minors in STEM fields and increase the content knowledge of current K-12 STEM teachers. Third, increase students’ engagement in STEM and their perception of its value to their lives (U. S. Department of Education, 2007).

Many educational leaders from across the country have tried to address the first goal: to prepare all students with STEM skills needed to succeed in the 21st century. Chapter 2 describes programs that universities and school systems have designed to support and prepare students who are pursuing degrees in STEM-related fields. Most of the STEM high school programs were designed with one of the following goals: to integrate science, mathematics, and technology curricula; to blend academic coursework with career-technical education (CTE); to apply concepts and ideas from STEM courses into other disciplines such as language arts and social studies; to provide a well-rounded education with outstanding science and mathematics instruction integrating technology across the curriculum; and to improve STEM education through increased teacher knowledge and student processing. Chapter 2 contains more detailed descriptions of these programs.

Statement of the Problem

The decline in STEM graduates in the United States has stimulated interest in creating and implementing STEM programs. In the revised CRS Report for Congress (Library of Congress, 2008), the Government Accountability Office (GAO) reported that there were 207 federal education programs in 2004 designed to increase the number of students studying in STEM fields and/or improve the quality of STEM education. About $2.8 billion was appropriated for these programs. These programs provided financial support for students or scholars, institutional support to improve educational quality, support for teacher and faculty development, and institutional physical infrastructure support. Of the 207 programs, 53 of them were targeted toward high schools.

School systems continue to develop and implement strategies that have potential to improve science, technology, engineering, and mathematics education, yet little is known about what strategies have been implemented in existing STEM programs. There is a lack of research documenting STEM school program structure, course requirements, and the technology used to teach STEM content. The problem is further compounded by what the NSF identified as a shortage of reliable indicators for assessing the quality of STEM education projects and programs. As it noted, “There is a serious lack of instruments of demonstrated validity and reliability to measure important outcomes of STEM education interventions, including teacher knowledge and skills, classroom practice, and student conceptual understanding in mathematics and science” (Katzenmeyer & Lawrenz, 2006, p. 7) .

In an effort to respond to the current status of STEM education in the nation, several STEM high schools have already been designed and are currently operational, and even more are in the design phase. While this is a fruitful direction to take, the problem is a lack of available research documenting the design and effectiveness of existing STEM programs toward changing the nation’s profile. As such, there is a need to gather information from current STEM programs so it can be shared with other school districts considering the development and implementation of a STEM program. Information that would be helpful regarding program design includes: the type of courses offered, population served, how they perform on achievement tests, the schools’ vision statements, highlights of unique academic programs, and entrance requirements. Educational leaders desiring to begin a STEM programs would benefit from research that documents current STEM school models. This study provides school leaders with a design guide including detailed descriptions of 10 STEM high schools across the county.

Educational leaders can use the results from this study to generate ideas that could be implemented in their own school setting.

Research Questions

The following questions guided this study: What are the characteristics of STEM-focused high schools?

The following sub-questions focused on specific characteristics of STEM schools.

RQ1: What content in the schools' missions influenced the establishment of the schools?

RQ2: How are students selected to attend the STEM schools?

RQ3: What student populations do the STEM schools serve?

RQ4: What are the academic programs provided? What are the requirements for graduation?

RQ5: What professional development activities do STEM school faculty members participate in?

Research Goals

The goal of this comparative case study research project was to gain an in-depth understanding of current STEM high schools. A comparative case study method was selected because it provided the most comprehensive answers to questions about STEM high school programs and resulted in a descriptive portrait of different STEM school designs. A secondary goal was to learn what selection criteria was used to admit students into STEM schools and what types of students were being served. The final goal of this study was to contribute to the body of knowledge regarding STEM high schools by providing intensive descriptions and analysis of courses offered, graduation requirements, and student performance on standardized tests. Insights gleaned from this case study can be used to influence new STEM programs and future research in STEM education.

This study is important because it provides schools systems, administrators, teachers, and community members desiring to start STEM programs with examples of existing programs. An analysis of the data gathered from documents and interviews with STEM school principals provided information needed to write a holistic description of instructional programs at ten STEM high schools.

Definition of Terms

For the purpose of this paper, the following definitions will be used:

1) STEM Schools − are schools designed to prepare students with diverse backgrounds to pursue careers in science, technology, engineering, and mathematics related fields. The purpose of these schools is to increase student achievement by engaging and exposing students to innovative science and mathematics instruction while simultaneously providing real-life applications.
2) Public schools − are institutions that get their financing from local, state, and federal government tax-generated funds. In most cases, they must admit all students who live within the borders of their district. Charter schools and magnet schools are two relatively new kinds of public schools.
3) Charter Schools − are institutions of choice. "Some are specifically designed to provide an alternative for parents who desire a learning environment different

from that of the regular public school available to them" (National Center for Educational Statistics, 2006, p. 4). They are public schools operated independently of the local school board, often with a curriculum and educational philosophy different from the other schools in the system.

4) Magnet Schools − are public schools offering a specialized curriculum, often with high academic standards, to a student body representing a cross section of the community. These schools offer special programs and instruction that are not available elsewhere in a school district and that are specially designed to draw students from throughout a district. Most magnet schools have specific academic or audition entrance requirements.
5) Private schools − rely on tuition payments and funds from nonpublic sources such as religious organizations, endowments, grants, and charitable donations. These schools select from among students who apply for admission. About 25% of the elementary and secondary schools in the United States are private.
6) Independent schools − are private, nonprofit schools governed by elected boards of trustees. This category includes such famous private schools as Andover and Exeter. Independent schools draw their funds from tuition payments, charitable contributions, and endowments rather than from taxes or church funds. They may be affiliated with a religious institution but cannot receive funds or governance from them.
7) Parochial schools − are church-related schools, most commonly owned and operated by Catholic parishes or dioceses but also by Protestant denominations.

Hebrew schools may also be termed parochial. The majority of the private schools in the United States are parochial schools.

8) Proprietary schools − are private schools that are run for profit. This is a relatively new category of school. They do not answer to any board of trustees or elected officials. Because of this, they claim to be able to respond quickly to the demands of the market.

9) Pedagogy − by definition, pedagogy is the art or science of teaching. On a more practical level, pedagogy refers to the approaches and strategies that guide instruction.

10) E-learning or electronic learning − a type of education where the medium of instruction is computer technology.

11) Curriculum − “This study defines curriculum as a specific set of instructional materials that order content and are used to support PK-12 classroom instruction, what is often called the available curriculum” (Clements, 2007, p. 36).

2. Review of Literature

Introduction

According to the Partnership for 21st Century Skills (2007), education is changing, competition is changing, international and workplace jobs and skill demands are changing. Innovations are continuously being created and events occur that impact the skills that current students will need in order to be productive contributors in the work force. Our ability to provide children with the skills needed to adapt to a changing environment will determine the success or failure of our current education system. Wankat (2002) stated, “Because technology is changing very rapidly, engineering and technology graduates will have to be proficient at transfer” (p. 5). Transfer will allow students to take information or skills that are known and use them in a new environment. Problem solving is a critical skill for students to learn in order to adapt to a changing world. The National Council of Teachers of Mathematics (NCTM) defined problem solving as “engaging in a task for which the solution method is not known in advance,” and suggest that “solving problems is not only a goal of learning mathematics but also a major means of doing so” (NCTM, 2000, p. 52).

Literature identifying skills that students need to succeed is abundant but documented research on current models of STEM high schools and how these skills are being developed in school settings is lacking. This study is informed by three fields of knowledge: government policies influencing STEM education; research on science, technology, engineering, and mathematics education; and research on current and future needs of K-16 education.

Procedures for Obtaining Relevant Literature

This literature review began with a search of relevant databases, which included, PsychINFO, ERIC, Education Research Complete, Wilson Web, EBSCO, and digital dissertations. Key search words included STEM schools, Science, Technology, Engineering and Mathematics Education, school case studies, and STEM school design and evaluation. Articles relevant to this study were printed then sorted by common themes: history of STEM education, policies and publications influencing STEM, current progress toward STEM Goals, STEM pedagogy, challenges facing the implementation of STEM, and current/future needs of K-16 education. A hand search of relevant journals was conducted and an ancestry search was done on key articles. In addition to journals, a search for books using the George Mason library catalog was conducted and comparative design qualitative case study books were secured.

Conceptual Framework

This section is an overview of concepts developed by other researchers and policy makers that influenced the design of this study. Concepts influencing this study include research identifying a national education problem; reports documenting a shortage of students in the fields of science, technology, engineering and mathematics; actions taken by the U.S. government; and programs designed to solve the problem.

According to the CRS Report for Congress (Library of Congress, 2006, 2008) "there is growing concern that the United States is not preparing a sufficient number of students in the areas of science, technology, engineering, and mathematics" (p. 1). According to the U.S. Department of Education (2007), students need better preparation in K-12 to successfully complete university degrees in STEM fields.

In recent years, several pieces of legislation have been passed by Congress and signed into law. The National Aeronautics and Space Administration Authorization Act of 2005 expanded outreach programs in science and space for elementary and secondary schools; the National Defense Authorization Act of 2006 made permanent the Science, Mathematics and Research Program to address deficiencies of scientists and engineers in the national security workforce; the Deficit Reduction Act of 2005 established the Academic Competitiveness Grants for students studying mathematics, technology, engineering, critical foreign languages, and physical, life, and computer sciences; the America Competes Act of 2007 expands existing STEM education programs and establishes several new programs (Library of Congress, 2006, 2008). A more detailed description of government policies are in the policies and publications section of this paper.

In addition to the research identifying the shortage of STEM degrees granted in the United States and suggested solutions, a body of research also identifies successful strategies for increasing student's success. Many of the studies focused on teachers. To better prepare K-12 students, teachers need training in best practices in STEM pedagogy. According to Wilkins and Brand (2004), teacher training has been successful in changing teacher's attitudes and beliefs about reformed teaching methodologies. They found that mathematics methods courses are successful in changing teacher beliefs and attitudes to be consistent with the underlying philosophy of the National Council of Teachers of Mathematics (NCTM) and mathematics reform. This confirms the need to support teachers with specific STEM education training. Wankat (2002) acknowledged a lack of preparation that many university faculty have in teaching pedagogy. He stated, "Excellent teachers are made, not born," (p. 6) in reference to new professors needing to take courses or workshops on teaching pedagogy.

More than 150 studies focus on specific programs designed for K-16 students. Most studies focused on programs for teachers or students although Wankat (2002), studied the interchange between teacher and student. He emphasized the role of motivation in student's success and described the important role teachers' played in motivating students. He suggested using cooperative small groups, useful material, challenges, and deadlines to motivate students and provide them with a sense of efficacy.

Several of the STEM programs began as charter schools. Because this is not typical for most public schools in the United States, further investigation was done to obtain more information about charter schools. Charter schools differ from public schools because they are "public schools of choice" (National Center for Educational Statistics, 2006).

> Charter schools are free from a range of state laws and district policies stipulating what and how they teach, where they can spend their money, and who they can hire and fire. In return, they are held accountable for their academic and financial

performance. Basically they are free to experiment. With this kind of autonomy, making them available tuition free to students, proponents hope that this environment will provide students stronger learning programs that will stimulate improvements to the existing public education system. No charter school is permanent. It must be renewed or revoked at regular intervals. Funding is tied to student enrollment and educational results. Parents choosing to enroll their children in charter schools, usually enter a lottery selection when schools are oversubscribed (NCES, 2006, p.1).

An extensive study was conducted by the U.S. Department of Education (National Center for Educational Statistics, 2006), which compared 150 charter schools to 6,764 public non-charter schools. When comparing mathematics and reading NAEP assessment scores for fourth and eighth graders, they found that "the average charter school mean was 5.8 points lower than the average public non-charter school mean" (p. 4). The author of this study also found no significant differences in the mathematics achievement scores of students attending charter schools that were affiliated with a public school district. NCES authors made it clear that there was selection bias due to the fact that the length of time a student was in the charter school, possible attraction of parents to charter schools, and amount of parental support was not accounted for. Characteristics of the charter school such as policies from which the school had waivers or exemptions, student population served, and program content also were not accounted for in this study (NCES, 2006). Charter schools, often working with lower performing children in urban areas, have obvious differences in student populations that impact student achievement scores. All charter schools selected for this study are clearly identified.

The following diagram is an overview of the concepts that shaped this study. The highlighted box in Figure 1 illustrates where this study would fit into the current body of literature.

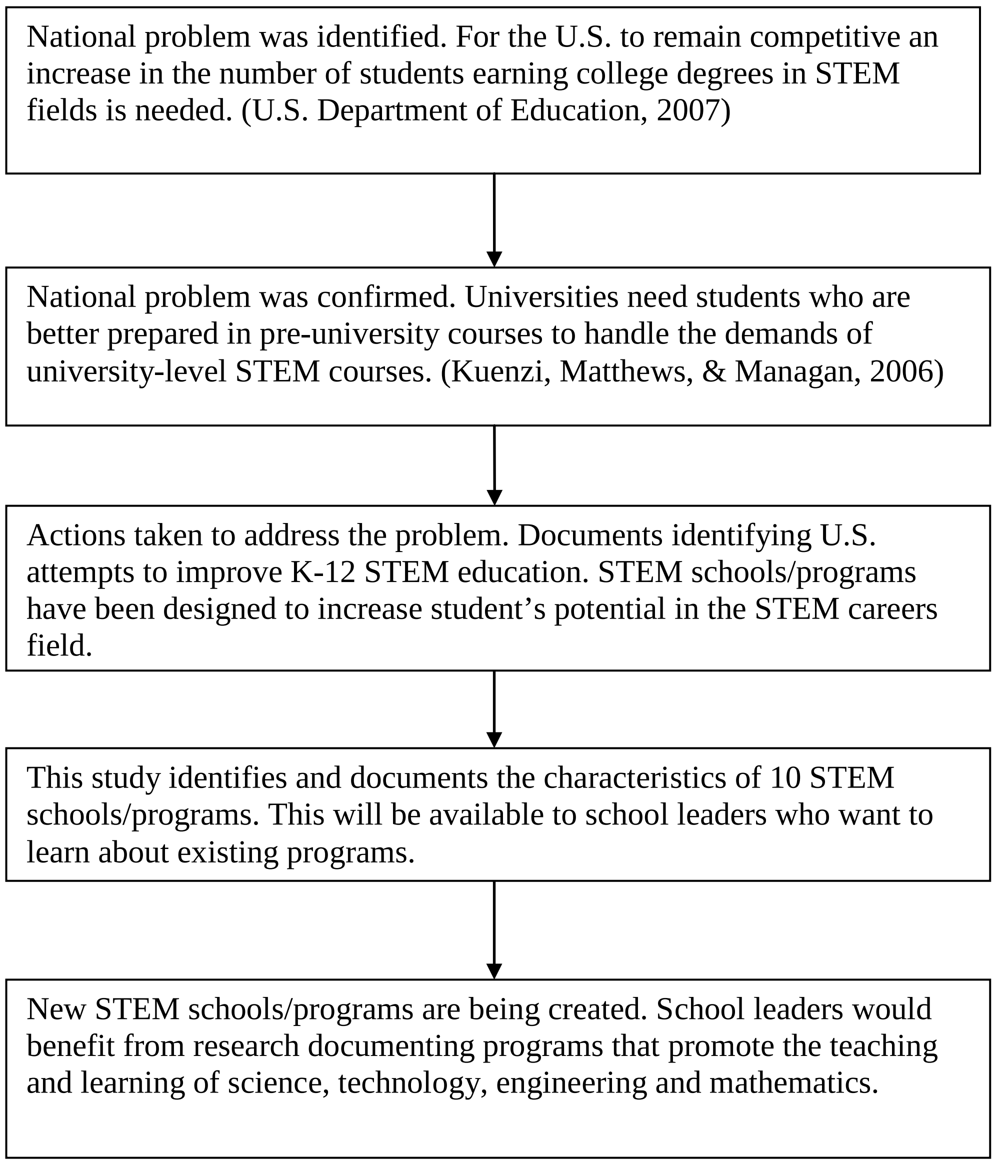

Figure 1. Researcher’s conceptual framework.

Definition of STEM Education

STEM education is complicated to define because many individuals interpret it in different ways. Examples of what STEM education is and how it is implemented in the classroom differ. Ways to improve STEM education are still emerging. After reading descriptions of STEM education programs in schools systems, several interpretations of STEM education emerged as it applies to K-16 educational settings in the United States. From the literature that was reviewed, descriptions of STEM education fell into four categories: (1) STEM education is integrating science and mathematics content while implementing technology into the curricula, (2) STEM education is blending academic coursework with career-technical education (CTE), (3) STEM education is applying concepts and ideas from STEM courses into other disciplines such as Language Arts and Social Studies, and (4) STEM education is a well-rounded education with outstanding science and mathematics instruction with technology integrated across the curriculum.

The first interpretation of STEM education involves the integration of science, technology, engineering, and mathematics concepts in the curriculum. This seems like common sense and has gained in popularity; however, Czernik, Weber, Sandmann, and Ahern (1999), warned that "Many educators provide testimonials about the effectiveness of units they teach. However, few empirical studies exist to support the notion that an integrated curriculum is any better than a well-designed traditional curriculum" (p. 1).

The second interpretation of STEM education is blending academic coursework with career-technical education (CTE) courses with the goal of making college an option for greater numbers of high school students. Stern and Stearns (2006) documented the potential benefits and barriers to integrating academic and vocational education. Attempts to obtain clear-cut research results have been difficult because most studies have not been able to determine whether apparent effects are due to particular programs or to selection of students in those programs. Vocational education has traditionally been defined as a pathway that does not lead to a bachelor's or advanced degree. Career-technical educators pointed out that, as of March 2004, only about 30% of 25 to 34 year olds had completed bachelor's or advanced degrees (Stern & Stearns, 2006). Several studies have found that students who combine academic coursework with CTE perform better in high school, but there is no evidence to show that this blended curriculum improves the chances of college enrollment or completion (Stern & Stearns, 2006).

The third interpretation of STEM education comes from the Ohio Department of Education, describing STEM education as:

> A movement sweeping across Ohio and the nation to grow and nurture students who are problem solvers, innovators, inventors, logical thinkers, and strong communicators, both oral and written. Rooted in an active inquiry and design process, STEM education spans the entire K-16 education continuum. It allows students to make sense of the world around them by applying concepts and ideas from STEM as well as other disciplines such as Language Arts and Social Studies. (Ohio STEM Learning Network, 2007, p. 1)

The fourth interpretation comes from the Texas initiative called T-STEM, which defines STEM education as "programs and schools are based on the following principles: provide a rigorous, well rounded education, establish a personalized, college-and work-ready culture, and provide teacher and leadership development" (Texas Education Agency, 2007, p. 1).

The Massachusetts Department of Education has been collaborating with partners across the state to strengthen the STEM education pipeline over which the department has the most influence: teacher knowledge and skills, and student proficiency. Massachusetts has opted to address the STEM problem with teacher training and testing rather than curriculum or school based programs. Some of the activities designed to increase student proficiency include requiring students in the class of 2010 and beyond to pass a high-school level examination in biology, chemistry, physics, or technology/engineering in order to graduate from high school, raising the score required to pass the state's annual mathematics student assessment, and recommending a program of studies for college and career readiness. To strengthen the mathematics knowledge required of elementary and special education teachers, teachers will be required to pass the mathematics section of the teacher licensure exam. Programs will be provided for teachers that focus on improving teacher content knowledge and support in STEM. To track the progress of their students the commonwealth of Massachusetts will be participating in the Trends in International Mathematics and Science Study (TIMSS) and in the development of a national end-of-course optional Algebra II exam. They will be working with the Board of Higher Education to develop a school-to-college database that will allow the state to track public high school graduates into the state's public colleges and assess the relationship between high school performance and college outcomes (Massachusetts Department of Education, 2007).

History of STEM Education

The history of STEM education as it applies to grades K-12 has been a story of mixed successes and failures (Chedid, 2005). The United States has a long history of disagreements about how to educate our nation's children. There have been widespread disagreements regarding content and pedagogy (Klein, 2003). During the mid 1990s mathematics teaching became the subject of heated controversies known as "The Mathematics Wars" (Schoenfeld, 2004). The immediate origins of the conflicts were described as a "vociferous national argument over traditional curricula and pedagogy and new approaches needed for the computer age" (Steen, 2003, p. 1). The basic ideas of integrating content in a problem-centered environment came from a variety of sources, some which predate the 20^{th} century. During the 1920s, John Dewey introduced his view of education, putting greater emphasis on the broadening of intellect and the development of problem-solving and critical-thinking skills, rather than simply on the memorization of lessons. John Dewey viewed the public school's relationship to society much like "a repair organ to the organism of society" (1897, p. 78).

The efforts of these and other early groups received little attention until the USSR launched *Sputnik*, the first space satellite in the fall of 1957. The American press treated *Sputnik* as a major humiliation and called attention to the low quality of mathematics and science instruction in the public schools. Congress responded by passing the 1958 National Defense Education Act to increase the number of science, math, and foreign language majors, and to contribute to school construction (Klein, 2003). Eventually some of the momentum was lost, and a new set of skills and abilities became necessary (Chedid, 2005).

During the last two decades, major examinations of K-12 curriculum and instruction were undertaken. A number of alarms have been sounded regarding the quality of mathematics and science taught in K-12 education. Several publications such as the *Report of the Academic Competitiveness Council* (2007) and *Before It's Too Late* (2000), have had a large impact on the attention given to educating children in the United States. These documents aid in understanding the historical progression of education in the United States and are described in detail in the Government and Policies section of this paper.

Dr. Loutfallah Chedid (2005), of Harvard University suggested a national awareness campaign to establish guidelines addressing teacher issues and a Dewey-style instruction strategy as a solution. He estimated that measureable change would take 16 or more years and suggested a sustained long-term commitment.

Our nation has thrived on competition whether it is in sports, innovation, industry or education. With this in mind President Bush signed into law a popular, bipartisan bill intended to ensure that the United States maintains a global leadership position in science, technology, and innovation. The bill, H.R. 2272, is known as the "America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act," or simply the "America Competes Act" (United States Congress, 2007). The STEM Education Coalition is an organization comprised of advocates from more than 40 diverse groups representing all sectors of the technological workforce. The coalition works to support STEM programs for teachers and students and is supported by the U.S. Department of Education, the National Science Foundation, and other agencies that offer STEM-related programs. This organization has influenced legislature and federal funding that impacts STEM education.

A lack of mathematics skills could lead to a further drop in students pursuing degrees in STEM and this in turn could lead to a continuing decline in appropriately skilled mathematics teachers. The assessment of the role of mathematics cannot be understated in the future success of students pursuing university degrees in science, technology, and engineering. Plato described mathematics as “the mother and mistress of the sciences.” Gordon stated “Many sciences including computer science depend on knowledge of mathematics, which is seen as one of the major constraints on students” (2004, p. 30). Like the United States, England has experienced a decline in the number of students pursuing university degrees in STEM fields. Gordon (2004) attributed the main problems in the UK with student’s weakness in the fundamental concepts of mathematics. There is a perceived decline in the mathematical preparedness of students entering higher education.

Policies and Publications Influencing STEM

This section highlights governmental policies and reports that have impacted public education in the United States. State and federal initiatives and funding are essential to quality education for all American children. From a national perspective, providing a quality education to a large and diverse group of students is a monumental task, which requires a strong commitment from many people including politicians, educators, parents, and corporations. The following are some key reports that have impacted educational reform in the United States.

Government Reports and Publications

In 1983, *A Nation at Risk* stimulated interest in academics through an international comparison of student achievement. This report cited a decline in standardized test scores and an increase in remedial mathematics courses in public four-year colleges. Several recommendations were made to increase high school graduation requirements, including a more rigorous and measureable standard for performance and conduct, more time to learn the New Basics, improved preparation of teachers, and leadership and fiscal support for school systems (Gardner, 1983). Steen (2003) reviewed and criticized the efforts made to improve education in the United States over the past 20 years. She cited the poor results on the National Assessment of Educational Progress (NAEP) test as an indication that these efforts have had minimal impact. Between 1983 and 2000, there was an absence of significant governmental policies targeted at K-16 education reform.

In September 2000, the National Commission of Mathematics and Science Teaching for the 21st Century released a report entitled *Before It's Too Late* (Glenn, 2000). This report identified student's performance in mathematics and science as unacceptable and stated three goals for improvement, namely:

> Establish an ongoing system to improve the quality of mathematics and science teaching in grades K-12; Increase significantly the number of mathematics and science teachers, improve the quality of their preparation, improve the working

environment, and make the teaching profession more attractive for K-12 mathematics and science teachers (pp. 8-9).

The No Child Left Behind Act (NCLB) of 2001 (U. S. Department of Education) is a United States federal law that was originally proposed by President George W. Bush on January 23, 2001. NCLB is the latest federal legislation that enacts the theories of standards-based education reform, formerly known as outcome-based education, which is based on the belief that setting high standards and establishing measurable goals can improve individual outcomes in education. The act requires states to develop assessments in basic skills to be given to all students in certain grades, if those states are to receive federal funding for schools (U. S. Department of Education, 2001). This piece of legislature does not specifically target STEM education but has had a significant impact on students and teachers in the United States.

The shortage of qualified mathematics and science teachers was brought into focus in the report titles *A Nation at Risk* (Gardner, 1983) and again by the National Association of State Boards of Education report (United States Department of Education, 2007). The reports pointed out that one third of all fourth, eighth, and twelfth graders performed at the lowest level on the NAEP mathematics assessment.

In 2001, the Bureau of Labor Statistics predicted that from 2000 to 2010 employment in science and engineering occupations will increase about three times faster than the growth rate for all occupations (Bureau of Labor Statistics, 2001). “While there seems to be a great demand for STEM workers, there is a fundamental problem with STEM education in the United States. The percentage of bachelor’s degrees earned in

STEM fields has steadily declined" (Yasar, Little, Tuzan, Rajasethupathy, Maliekal, & Tahar, 2006, p. 170).

In July 2005, the Education Commission of the States released a report identifying five strategies to improve mathematics and science education and suggested that this needs to be a top policy agenda for our country to be globally competitive. The strategies included strengthening mathematics and science assessments; ensuring that teachers have adequate knowledge and skills; giving the neediest students the best teachers; and enlisting the entire university in the effort to improve teacher education and engaging the public (Coble & Allen, 2005).

In May 2006, the Council of Chief State School Officers President Valerie Woodruff and the Board of Directors commissioned the creation of a mathematics and science education task force to address a common set of concerns regarding mathematics and science education in the United States. A common set of concerns to be addressed included U.S. students' performance on international assessments, high school graduates lack of preparation for college, decline in the number of mathematics and science advanced degrees, and the number of mathematics and science students coming from other countries (Jeffrey & Wright, 2006).

In its "Innovation America" report (2007), the National Governors Association has been charged to lead efforts in their states by aligning state K-12 STEM standards and assessments with postsecondary and workforce expectations for what high school graduates know and can do. They should examine and increase the state's internal capacity to improve teaching and learning and should identify best practice in STEM education and bring them to scale.

All of the reports described above were designed to bring attention to the need for improving K-16 education for students in the United States. Suggestions for improvement focused on different aspects of education: teacher preparation, student performance; outcomes based standards, increasing the number of university degrees earned in STEM fields, and workforce development. Some of these suggestions have resulted in the establishment of new programs, which are described in the Implementation of STEM education programs section of this paper.

Labor Needs

According to the *Industry Study* (National Defense University, 2006), the United States' ability to be competitive in the international job market remains relatively healthy. However, indicators show that not all elements of our public school system are producing an adequately educated work force while our global competitors continue to improve. The nation must implement strategic educational reforms to provide a well-educated populace.

Business and Government Initiatives

Many businesses have joined in the challenge of improving student's preparation for a career in the STEM fields. Some have created education programs while others have donated money for scholarships or classroom equipment. The STEM Accelerator Initiative is an alliance of business, education, and public policy leaders working for comprehensive systematic change to improve STEM education for all students. They support only programs that can provide clear evidence of their effectiveness and are intended to provide sustainable programs (McMurtray, 2006).

President Bush's proposed budget for fiscal year 2007 included substantial increases in the physical sciences and engineering programs as well as alternative energy research and development. The White House plan included teacher training for Advanced Placement and International Baccalaureate classes in math, science and foreign language, adjunct Teacher Corps to train professionals to serve as part-time science and mathematics teachers, scholarships to students majoring in STEM fields or who are preparing to teach these subjects at the K-12 level, and grants to encourage university STEM departments to partner with the department of education to train future teachers (Advancing Service Serving Society, 2006).

Current Progress Toward STEM Goals

Research Influencing STEM

The Education and Human Resources (EHR) Directorate at the National Science Foundation has examined its role in supporting the development of new approaches to science, technology, engineering, and mathematics education (Ramaley, Olds, & Earle, 2005). The NSF is looking to fund projects that will provide a national perspective, with insights that will advance our ability to educate. Projects should involve collaboration across fields and across institutions as well as between and amongst them. The NSF is focused on mathematics and science projects developed for middle and high school related to knowledge accumulation. Results from these research projects will be made available to the public and could impact how we teach and design STEM programs.

A report published by the U.S. Department of Energy (Chedid, 2005) projected the United States' energy needs in the year 2025. The paper identified education as a contributor to solving future energy problems. The importance of energy needs is evident in our homes, manufacturing, agriculture, transportation, and the financial markets. The huge increase in energy need that is expected within the next 20 years requires changes in the way we produce and consume energy. Education is a key factor for technology development including technology for efficient clean and economical energy generation, transportation, storage, and use.

The following section of the literature review contains a summary of documented research on programs that were designed to improve STEM education. Table 1 is an overview of the studies conducted and results found by the researchers. Many of the projects designed showed signs of success but were not sustainable due to a lack funding. A description of the individual projects follows the table.

Table 1

Research on STEM Education Programs

Participants	Topic	Number of Studies	Results
University Students	Using small groups/Team learning	4	Increased academic achievement Favorable student attitudes Increased STEM course enrollment
University Students	Integration of course content: Writing & Physics	4	Reduced Physics Dropout Rate Increased Content

	Mathematics & Science Chemistry & Math Pre-Service Science & Engineering		Knowledge Increase in Content knowledge and Pedagogy
University Faculty and Students	Technology use	2	Hands-on experiences with technology had a positive effect in decreasing faculty and student resistance to technology use.
University & In-Service Teacher Collaboration	Teacher professional development	Summary of 123 studies.	Increase in students' mathematics proficiency. Increase in teacher content & pedagogy knowledge.
Elementary Students/Teachers	After school science/mathematics clubs	3	Increase in physics knowledge. Program success was measured by number of participants.
Elementary Students/Teachers	Use of robotics equipment	3	Increase in the number of participants and request for demonstrations.
High School	Texas High School Project	1	Increased high school graduation rate.
High School	Technology education	1	Change in Technology Education courses from industrial arts to architectural drawing, graphic communication requiring computers and software.
Secondary School	Problem/Project-Based Learning: Hands-on Activity Problem solving. Community focused	3	Improved attitude toward science. Increase in complexity of student project designs. Increase in student

	projects		ownership of learning.
University (Undergrad students)	Project-based course Scholars program incorporating STEM-based activities	2	Increased ability to apply STEM concepts. Increased number of STEM graduates

University Initiatives

In 1997, the NSF asked a working group to examine undergraduate education programs in the United States. The findings in this report laid the foundation for education reform at the undergraduate level. The recommendations made by the committee can be grouped into five areas: systematic reform of curricula and institutions; high-quality instruction by faculty; education research, materials, and methods; emphasis on meeting the needs of diverse student populations; and student support (Fortenberry, 2000).

Seymour (2001) described the changes at the University of Colorado to improve both quality and access to STEM undergraduate education. This study was influenced by Project 2061's approach, which grows out of the recognition that science, mathematics, and technology are major influences in the lives of all citizens, no matter what their roles in society may be (American Association for the Advancement of Science, 1989). Changes began with the discovery of under-representation of certain populations in STEM majors. Several debates over the causes of under-representation and how to address the issue were documented. The debate caused a shift in mindset from "Science-for-a-few" to "Science-for-all" followed by a change in emphasis from teaching to learning. This shift has lead to refocusing classroom practice on student understanding, reasoning, application, and learning retention, clarifying goals and redesigning assessments to engage students (Seymour, 2001).

Cooper and Robinson (1998) and Springer, Stanne and Donovan (1999) analyzed the effects of small group learning. They both reported that small group instruction has a positive effect on student outcomes in STEM classes. This method of instruction works particularly well for women and minority students and is effective in promoting greater academic achievement, more favorable attitudes toward learning, and increased persistence through STEM courses and programs. Team work and communication are identified as the top skills needed by graduates at the U.S. Military Academy (Massie & Massie, 2006) and Rowan University (Newell & Cleary, 2004). Students at Rowan University were placed in multidisciplinary teams to analyze and solve problems. Professors developed a document to assist students as they organized themselves for the project and then executed the design with limited resources. Students learned that by combining their unique knowledge and skills, the multidisciplinary team was able to resolve problems that they could not have solved independently. Faculty members noticed improvement in team-building skills when students were given training prior to the beginning of the project.

Roskowski, Felder, and Bullard (2001) and Raju, Sankar, Halpin, and Halpin (2002) studied the comfort level and use of technology by students and faculty members. The results indicated that students and faculty members are resistant to use instructional technology. The Laboratory for Innovative Technology and Engineering Education

(LITEE) at Auburn University developed innovative instructional materials that brought real-world issues into the engineering classroom. A workshop provided faculty with an opportunity to gain hands-on experience with multimedia case studies. Feedback from these workshops showed an increase in the comfort level of people using instructional technology (Raju et al., 2002). These studies were published in 2001-2002. Due to the changes in technology and the availability of the Internet, an update of these studies would be helpful.

Four studies integrated course content at the university level. Typically universities separate courses, making it difficult for students to understand the connections between mathematics and its application to other disciplines. Crumbaugh, Vellom, Kline, and Tsang (2004) described the collaboration between pre-service science education students and engineering students, Larkin-Hein (2001) combined writing with physics course, Holmes (2006) integrated mathematics and science while Blum and Irish (1998) studied the integration of chemistry and math. In each case, students benefited from the integration of the courses. This method of instruction forced science education students to think about their content knowledge as well as their pedagogical content knowledge while novice engineers benefited from leaning about redesign in product development. Integrating writing with physics instruction at the university showed strong results in lowering dropout rates in entry level physics courses, increasing understanding of course concepts, make connections between mathematics and science concepts, and developing problem-solving skills (Holmes, 2006).

The challenge with integration of curriculum occurs when deciding what curriculum to integrate with what other curriculum. Lehman (1994) found that, although teachers have positive perceptions about integrated curriculum, these perceptions do not carry over into practice. Teachers believed that they did not have time to add integrated ideas into an already overcrowded curriculum, and they were not aware of available integrated resources.

In order to replicate successful models of integrated course content, teachers will need training in integrated curriculum and problem-based approaches. Pre-service and in-service STEM education for K-12 is a major challenge for institutions of higher education. Institutions that train pre-service teachers will have to blend STEM knowledge with pedagogical methods and effective practices. STEM faculty in higher education institutions have the content knowledge, but many lack the methods for conveying that content in a usable knowledge format for future K-12 teachers (Chedid, 2005). Universities strive to implement successful education ideas in their course content, defined by Czernik, et al. (1999) as strategies that can be successfully implemented in a "real" classroom with "real" students within the structure of a "real" school.

Collaboration Between K-12 and Universities

An analysis of 123 schools participating in the National Science Foundation (NSF) Mathematics and Science Partnership (MSP) program showed improvements in student proficiency in mathematics and science at elementary, middle, and high school levels over a three year period (National Science Foundation, 2007). During this time elementary mathematics students showed the greatest gains.

The Computational Math, Science and Technology Institute (CMST) is a NSF-funded project designed to build a partnership between higher education and school districts. They recognize that colleges demand better prepared students while school districts demand better teachers. This project provided training to more than 265 teachers, which included summer workshops and bimonthly meetings for all faculty, teachers, and coaches. Teachers received laptops, graphing calculus, view screens, smart boards, and LCD projectors. Project evaluators found a correlation between the number of CMST teachers in a school and improvement in student achievement. A strong correlation was found between the amount of teacher training and student achievement (Yasar et al., 2006).

The NSF has funded several projects encouraging universities to work with local school systems to improve mathematics and science education. For example, researchers at State University of New York designed an institute for middle and high school teachers in Rochester City and Brighton Central School Districts where 148 teachers received summer training. The training exposed teachers to an integrated approach to teaching science, technology, engineering and mathematics. Results showed an increase in student achievement of students taught by teachers trained in integrated STEM pedagogy (Yasar et al., 2006).

Implementation of STEM in K-12

The Bayer Corporation has published a report identifying successful K-12 STEM Education programs. This study focused on various programs including summer and afterschool informal education initiatives. The key criteria for evaluating these programs were challenging content/curriculum; an inquiry learning environment; defined outcomes/assessment, and a sustained commitment with community support. The report included a brief overview of each program including targeted population, community partnerships, type of leaning environment, program highlights, and opportunities for replication (Molnar, 2006).

Elementary programs. Several studies have been done on afterschool and summer elementary programs that promote math, science, technology, and engineering. Raju, Sankar, and Cook (2004) worked with teachers and volunteers to develop a physics unit for 4-H students in Alabama. Rhodes, Walden, and Winter (2004) worked with parents and community members to provide an afterschool science club for K-5 students while Perrin (2004) used inquiry-based learning activities to teach basic engineering to K-4 students. The students used hands-on experimentation and technology tools, such as photos and slides, to learn physics concepts. Students were encouraged to assume the role of a scientist where they engaged in trial-and-error investigations. The results from a pre-post –test indicated that these were successful projects. A lack of funding prevented the development of more programs.

One means of creating interest in math, science, engineering, and technology is through the use of robots. Matson, Deloach, and Pauly (2004) designed a road show for elementary students. Students were asked to draw robots, compare the intelligence of humans to robots, view a NASA movie, and participate in a robot demonstration. Rogers and Portsmore (2004) and Whitman and Witherspoon (2003) trained teachers to use LEGO robotics equipment to teach engineering to elementary school students. They found that making significant changes in curriculum requires an extensive time commitment and a large effort on the part of the teachers. To assist with teacher preparation, Mataric, Koeng, and Feil-Seifer (2007) produced a workbook that contains instruction and labs for teachers and students. Challenges encountered when using robotics equipment included dead batteries, computer crashes, and erased programs. One of the barriers to making robotics accessible to all students and teachers is lack of teacher preparation and funds to purchase robotics equipment (Mataric, Koenig, & Feil-Seifer, 2007). For robotics units to be successful, careful consideration needs to go into preparing and assigning groups. The robotics programs were successful when measuring number of participants and number of requests for demonstrations.

Secondary programs. The Texas High School Project is a $261 million public-private initiative dedicated to increase high school graduation rates. The key strategies include rigorous curriculum, effective teachers, building leadership, and multiple pathways. Thirteen schools were selected and challenged to develop a school-wide plan to align curriculum, technology, and professional development. An evaluation was done using document reviews, site visits, and school staff surveys. Schools were rated according to their implementation levels. Some challenges to implementing the new design included staff turnover, limited resources, and lack of involvement of school staff members in the development of redesign plans. The high-level implementation schools allocated the largest portions of their grant funds to professional salaries. The period of time for this report was too short to measure a significant change in pedagogy. Teachers thought it was too early to see much change in student achievement but were positive about the changes in relationships and climate (Texas Education Agency, 2007).

This section of the literature review highlighted some of the research and programs that were implemented at the K-12 grade level and universities across the United States. Many of the programs described had good results but lacked funding to continue. The challenge is not only finding programs that are successful, but also understanding how to implement them with a broader audience.

Challenges Facing STEM Education

For the United States to be successful in increasing the number of students earning degrees in STEM fields, it must be aware of several challenges that educators face − declining student interest, a mobile population, and rapidly changing technology.

Declining Student Interest

American College Test (ACT) research has indicated that there has been a steady decline in ACT-tested students who said they were interested in majoring in engineering from 7.6% to 4.9%. Over the past five years, the percentage of students who said they were interested in majoring in computer and information science has dropped from 4.5% to 2.9% (American College Test, 2006).

Mobile Population

In 1999, Kelly, Suzuki, and Gaillard (1999) identified the need for additional research, collaboration between the university, K-12 and business to respond to the deficiencies in American science and mathematics education. Since then, the NSF has issues partnership grants to several universities challenging them to improve mathematics and science education through teacher preparation. Significant progress has been made in the areas of instructional materials and teacher preparation through partnerships formed between universities and K-12 institutions. One issue that was identified as a threat to American education is the mobility rate of students. Kelly, Suzuki, and Gaillard (1999) stated that "one in three students change schools more than once between grades 1 and 8" (p. 1). Due to this high mobility rate, the researchers who conducted this study thought that it was essential that curricular content be coordinated on a national level.

Short Life Span of Technology

One of the challenges facing educators is the ability to stay current with new technologies. Instructional technology faculty members have to deal with the challenges of new software, hardware, and networking along with new course materials. Businesses expect graduates to be well prepared for the work force. Professors at Bentley College encouraged collaboration with practitioners and students (Fedorowicz & Gogan, 2002). To compound the problem, "the amount of new knowledge is doubling every year and it is a challenge to manage the information created every year" (Yasar et al., 2006). In addition to the challenges described in this section, additional challenges facing STEM education include teacher training and financial support as previously mentioned in this literature review. This study attempts to describe how STEM high schools have addressed these challenges.

Current and Future Needs of K-16 Education

Teacher Training, Equipment, Curriculum

"Research has clearly shown that a good teacher is the single most important factor affecting student learning" (Geringer, 2003, p. 373). Payne (2004) attributed the lack of science skills in the United States to poor elementary school teacher preparation. Elementary teachers identify science as the curriculum they are least comfortable with teaching. "This is the time when students, if taught science in a hands-on, inquiry-based manner, being to develop important lifelong science literacy skills, such as problem solving, critical thinking, and working in teams" (Payne, 2004, p. 2).

Many pre-service teachers have a narrow view of mathematics and its application to the real world. Lloyd (2006) suggested using K-12 standards-based curriculum to train preservice teachers. She suggested selecting activities that are mathematically challenging, illustrate connections among concepts, and emphasized where misconceptions usually occur or real-world contexts. Teachers become aware that the materials and mathematics content is different from textbooks they learned from.

Models of teacher preparation are needed to prepare teachers to integrate curriculum. For integration of curriculum to be successful on a larger scale, standards for individual disciplines need to be integrated at the national level (Czernik, Weber, Sandmann, & Ahern, 1999). Czerniak et al. challenged proponents of STEM education who believe these goals can be accomplished by integrating STEM concepts in the curriculum. They also pointed out that the structure of the school day and departmental standards are obstacles to enacting integrated units in a real classroom. For example, the

National Science Education Standards and the National Mathematics Standards would need serious collaboration and revision.

One example of teacher training is described by Dennis J. Kulonda (2003) who documented his experiences at a workshop designed for educating engineers. The focus of the workshop was to address how the engineering curricula should be taught, who should teach the courses, and how to prepare faculty to teach. The goal of the workshop instructor was to illustrate the expanding roles of engineers. Like K-12 educators, engineers are faced with the challenges of a broad range of new materials and software while operating in a multifunction team that requires them to be sensitive to other cultures while learning new knowledge. Participants were put in teams and worked together to cope with a critical situation. Participants were not lectured using the case method they were immersed in a problem-solving situation (Kulonda, 2003).

Facilities

As a result of research that has been conducted over the past 10 years, educators have come to a deeper understanding of the kinds of programs that stimulate student interest and convey a useful understanding. Now they face another challenge of inadequate facilities. Many colleges and universities were designed with large lecture halls and small laboratory spaces. Undergraduate students learn best when learning is experiential and investigative. Students are most successful when they make connections to other fields of inquiry with practical applications. One critical barrier to continued reform is the design and quality of classrooms and laboratory space (Narum, 1996).

Improved Teacher Preparation

In their report for evaluating and improving undergraduate teaching, the National Academy of Sciences (Fox & Hackman, 2003) made several recommendations for postsecondary faculty. The first recommendation suggested that effective teaching in science, mathematics, and technology should be available to all students. Second, design of curricula and evaluation of teaching should be a collective responsibility of faculty, and finally scholarly activities should focus on improving teaching effectiveness and learning, faculty should be given support and mentoring in teaching throughout their careers.

Changes to Current National Standards

In order to make any significant changes to include STEM education for all students' specific changes need to be made to the current national standards. Chedid (2005) recommended including the following expected student outcomes: Students have the ability to apply knowledge of mathematics and science to solve real-life problems or to conduct an intelligent inquiry; the ability to design and conduct experiments in a variety of STEM disciplines as well as to analyze and interpret data; the ability to function on a multidisciplinary team; and the ability to use the techniques, skills, and modern technology tools necessary to succeed in the 21st century (Chedid, 2005).

A National Database (Library)

As e-learning or electronic learning, a type of education where the medium of instruction is computer technology, has gained in momentum, so has the number of digital resources on the web. Some of this information is useful while some has no value to educators. Accessing this information can be a frustrating, time-consuming task for students and teachers. Dong and Agogino (2001) and Zia (2004) suggested creating a digital library containing a search engine categorizing materials by subject matter. The advantage of a central website is that teachers and students can access materials in math, science, engineering, and technology at one place. The materials are labeled including a description of the content, author, and identify any fees involved. This site is located at http://www.smete.org/. Ongoing support for this project will be needed to maintain this site.

Additional Research

The National Science Foundation acknowledges the need for STEM educational program evaluation. NSF program evaluation faces several contextual challenges. To make evaluations more relevant, there needs to be more extensive stakeholder involvement. To guarantee that NSF evaluations are of high quality, the planners of the evaluations must be conversant with cutting-edge theory and research in STEM evaluation and must understand how to conduct evaluations competently. To increase STEM evaluation capacity, larger project grant evaluations will be asked to incorporate graduate students or novice evaluators. This will entail broader feedback from a diverse set of evaluators (Katzenmeyer & Lawrenz, 2006).

Henry Kelly (2005) described current federal research in education as “small and fragmented” (p. 1). He described the many challenges that face the American public education system. He suggested using technology as a vehicle for tutoring students but does not identify a particular piece of software that has been successful in the classroom.

He described the progress that business has made by implementing technology to accommodate customers and to improve employee work performance and how the military has successfully used technology to train pilots and surgeons. Public education has made progress in providing Internet access and computers to most students but still falls behind in using technology for meaningful instruction.

Teacher Collaboration

Teachers need time to plan lessons and collaborate with their colleagues. U.S. teachers spend most of their day instructing students with only one period per day to prepare. Chinese teachers spend approximately 40% of their day with students and the remainder of their time is spent studying and preparing for instruction (Newton, 2007).

Summary

Much work has been done at the federal, state, and local levels to increase student's interest and skills in the STEM fields. Communities and businesses have partnered with local schools to provide resources that stimulate interest in STEM-related occupations. To make a more significant difference, additional work needs to be done analyzing the impact and sustainability of these programs. Once successful programs and practices have been identified, resources need to be provided to implement the successful programs to a broader audience.

The literature documented in this chapter provides the background for this study. The literature indicated that many programs have been implemented with groups of students and teachers, but little research has been done on their long-term impact and sustainability. In order to measure the success of STEM programs, schools need to keep records of students pursing and completing college degrees in STEM fields.

Educators working with students in the classroom need to think more broadly about their teaching and where it fits into the world. They need to think about how to prepare students to be lifelong learners. They need time to communicate with others outside their own content area and be willing to make changes in their classrooms. Classroom teachers need a broad knowledge base. They need to know the content for the current course they are teaching, as well as content knowledge students learned in the past will need to know in the future. They need to understand how their subject matter is relevant in the real world.

Educational leaders at the state and local level need to model these same concepts by exposing themselves to those in the workforce who can articulate the skills necessary to perform in a changing world. Educational leaders need to set the same example by collaborating with state and local leaders to come up with the best content and teaching strategies for all children. They need to share their knowledge and learn from each other. Collaboration between states as well as universities can be an efficient way to make education relevant for all students and teachers.

3. Methods

Overview of Methods

This chapter describes the methodology used to conduct a comparative design qualitative case study that documents 10 STEM high school program designs. The purpose of this study was to gain an understanding of what STEM high schools are. A comparative case study method was used because it provided the most comprehensive answers to questions about STEM high school programs. Case studies offer a means of "investigating complex social units consisting of multiple variables" (Merriam, 1998, p. 41). The comparative case study method provided for a holistic description of each STEM school including the school vision, entrance requirements, academic programs, and students served at the selected schools.

Research Questions

The following questions guided this study: What are the characteristics of STEM focused high schools?

The following subquestions focused on specific characteristics of STEM schools.

RQ1: What content in the schools' missions influenced the establishment of the schools?

RQ2: How are students selected to attend the STEM schools?

RQ3: What student populations do the STEM schools serve?

RQ4: What are the academic programs provided? What are the requirements for graduation?

RQ5: What professional development activities do STEM school faculty members participate in?

Study Design Framework

In order to investigate the characteristics of STEM high schools such as entrance requirements, student demographics, performance on standardized tests and course requirements, and a diagram was created to clarify the interaction between key components of this study. The study design illustrated in Figure 2 depicts the flow of information between the data collected and school site comparisons. Data that were collected is highlighted in the large rectangular boxes at the top of the diagram.

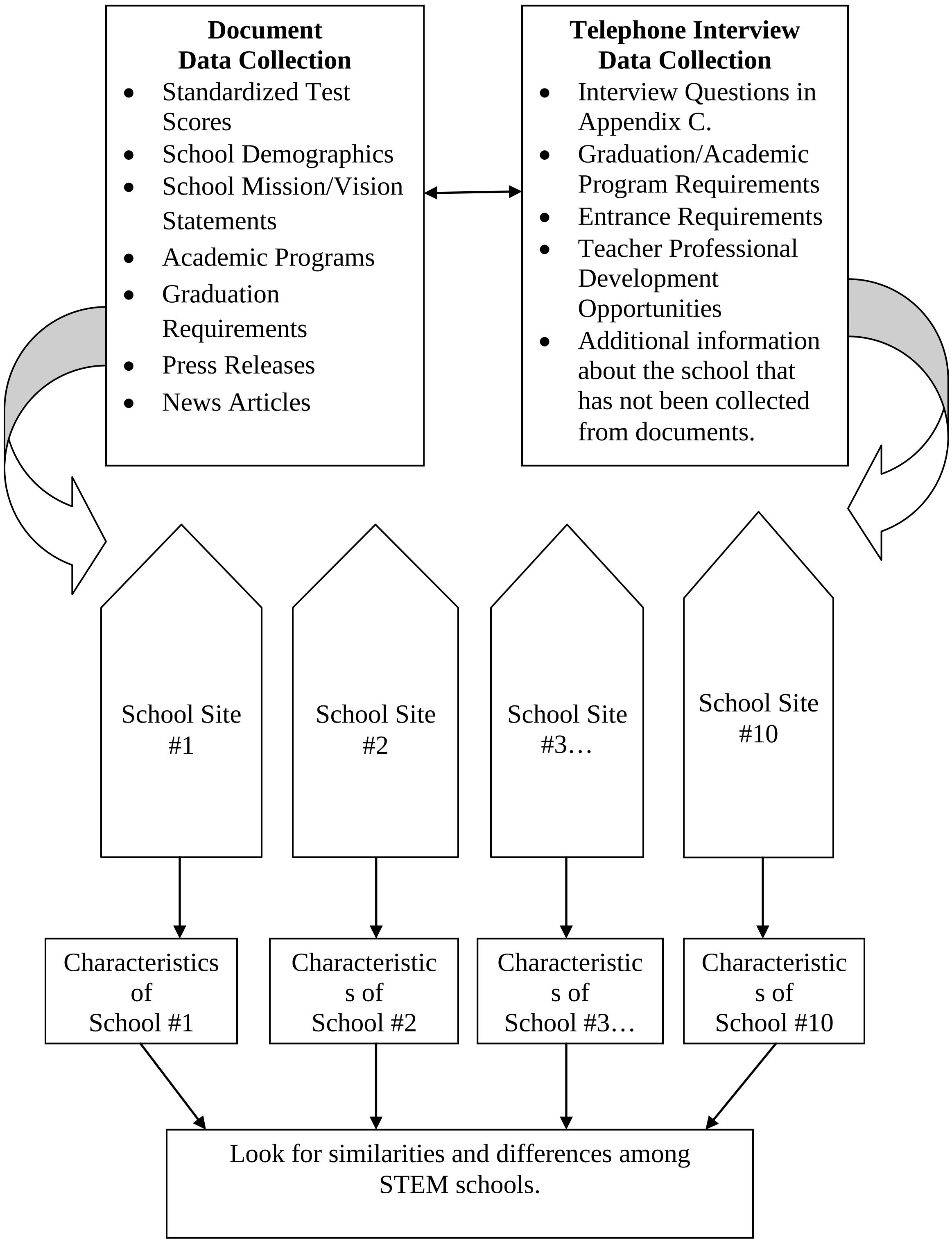

Figure 2. *Study design framework.*

Comparative Case Design

A comparative case study design was selected because it provides insights into different types of STEM school designs by making comparisons among the selected schools. Yin (2003) advised,

> When you have the choice, multiple-case designs may be preferred over single-case design. Your chances of doing a good case study will be better than using a single-case design. Single-case designs are vulnerable if you have to put all your eggs in one basket. More important, the analytic benefits from having more cases may be substantial. (p. 53)

One advantage of a multiple-case study is “the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust” (p. 46). Yin suggested conducting 6 to 10 case studies within the multiple-case study design. “The logic underlying the use of multiple case studies is that each case will either predict similar results or contrasting results but for a predictable reason” (p. 47). According to Yin (2003),

> Case studies have not always been considered to be a method in the logical positivist tradition. His approach has been to place case study research within the framework of the scientific method to develop a hypothesis, collect empirical data, and develop conclusions based on such data. The result is not claimed to be science, but the emulation of the scientific method. (p. 164)

This study emulates the approach suggested by Yin, with the hypothesis being: STEM high schools have unique characteristics that are different from non-STEM high schools.

After selecting school sites, various types of data were collected from each school and used to develop the conclusions. Combinations of data were used to describe each school fully. A comparison between all 10 schools was conducted to find commonalities and differences, which revealed answers to the research questions.

Research Site Selection Process

For this study a criterion-based selection was used to choose the site and participants to be studied. The following describes the criteria used for site selection. The initial site selection began with a national search of STEM secondary schools. The initial criterion for site selection was schools in the United States that were specifically designed as STEM schools. According to Atkinson et al. (2007), more than 100 high schools are designed with a mathematics, science, and technology focus. Many of these schools were designed as magnet programs using a school-within-a-school concept. Some of them have strict entrance requirements and are often regarded as “elite” schools that drain financial support from the general population of students (Atkinson et al., 2007).

After identifying the STEM schools, the second criterion for selecting a school site was the school’s mission statement. This study focused on schools that were designed specifically to enhance all students understanding of science, mathematics, engineering and technology as opposed to programs that were designed primarily for the advanced or gifted students only. Therefore, STEM schools that have statements on their website that indicate that their goal is to provide opportunities for all students, including underrepresented student populations, were selected for further study.

The preliminary search for schools using the first two criteria yielded several school sites. An initial Internet search was conducted using the Google search engine. The following key words were used: STEM schools, STEM programs, STEM academy, Science, technology, engineering, and mathematics, focused schools. This search yielded several websites that identified STEM schools. The Ohio STEM learning network website (2007) identified five schools. This search also yielded news briefs, editorials, and published articles that identified additional schools. Several news briefs announced partnerships and grants awarded to begin STEM programs. For example, an article written by Trotter (2008) in *Education Week* highlighted an urban school in Baltimore. An article written by Goldman (2008) in the *Journal of New England Technology* identified a STEM program in Maine. A summary of the schools identified are presented in Table 2. From more than 100 STEM-focused schools in the United States, 10 schools met these criteria.

Table 2

STEM School Overview

Pseudonym	Location	Grade Level	Year Established	Locale	Charter/ Magnet	Title I	Student Enrollment
Archimedes HS	South East	9-11	2004	Large City	N/N	Y	876
Boyle HS	West	9-12	2000	Large Suburb	Y/N	N	527
Priestly HS	South West	9-12	2002	Large Suburb	N/N	Y	892
Pythagoras HS	West	9-10	2004	Large City	Y/N	N	450
Einstein HS	Mid West	9-12	2006	Large	N/N	N	300

				City			
Galileo HS	North East	9-12	1997	Large City	N/N	N	1,344
Plato HS	South East	9	2008	Small City	Y/N	N	86
Marconi HS	Mid West	9	2008	Large City	N/N	Y	100
Euclid HS	North East	9-12	2008	Rural	N/N	N	1683
Pascal HS	South East	9-12	2007	Small City	N/N	N	1335

Note. Data collected January 2009 from National Center for Education Statistics, 2008.

Participant Selection

One participant from each school was selected to participate in a telephone interview. An email (Appendix A) was sent to each potential school site requesting an interview with the principal. If the principal was new to the school, his/her most trusted and informed staff member was selected to participate.

Data Sources

The data collected during this project included documents in print and digital format, telephone interviews, and email communication. These sources were used to provide and confirm information needed in order to answer each research question. In order to maintain the anonymity of the participants in this study, the name of the school, state where they reside, and URL where documents were retrieved have been given pseudonyms. Appendix B contains a list of data sources used in this study.

Documents

Digital and print documents and websites gave important details about the school’s mission, entrance requirements, graduation requirements, school profile, and achievement test scores. Documents collected from multiple sources included school websites, State Department of Education archived test score databases, and applications for admissions instruction sheets. Merriam (1998) identified the greatest advantages in using documentary material is its stability and objectivity. She wrote “Unlike interviewing and observation the presence of the investigator does not alter what is being studied” (p. 126).

Standardized test scores. For each school, standardized test scores were used to compare the STEM school with other schools in their district. These data were collected from individual state department of education websites. Three years of test scores from two content areas were used when available. The content areas and grade level for test data varied due to differences in individual state requirements.

School demographics. Information on student demographics was collected from the National Center for Educational Statistics website http://nces.ed.gov/ for each school. Data collected from this website included enrollment, race/ethnicity, gender, number of students receiving free or reduced lunch, and school classifications such as magnet and/or Title I identification. Website data were verified by school report card documents and interview transcripts.

School websites and publications. Information about the school profile, mission statement, entrance requirements, and graduation requirements was collected from the school websites. The combination of these data sources provided information for an overall description of general characteristics of each school program. These documents provided information about programs for students, internships, research projects, mentorships, required courses and electives, summer opportunities, and design competitions.

Telephone Interviews

A telephone interview, follow-up telephone call, and email communication were used to communicate with the principal or his/her designee for each site selected. Each interview took approximately 45 minutes and was conducted after the initial digital documents were collected and analyzed. The first telephone interview consisted of a standard set of structured questions for all school sites. Interviews were documented via speaker phone and taped recordings. Appendix C contains a sample of the initial interview questions. The questions for the follow-up telephone call were designed after the documents and first interview questions were analyzed. The questions for the follow-up call were specific to the individual site and designed to fill in missing information from the first interview.

Data Collection Procedures

Yin (2003) suggested identifying field procedure before beginning the research. Field procedures for this study included a plan for access to interviewees, obtaining sufficient resources and supplies, having an experienced researcher to call when you need help, and making a clear schedule for data collection activities, which provided for unanticipated events (Yin, 2003). As suggested by Yin, several databases were created to organize significant activities and to track information collected. Table 3 is an example of the database used to organize contact information for each site in this study.

Table 3

School Contact Information and Demographics

Pseudonym	School	Princip al	School Web Site	Phone	Locatio n	Grade Level	Year Establ ished	Local e	Charter/ Magnet	Title I
Archimedes										
Boyle										
Priestly										
Pythagoras										
Einstein										
Galileo										
Plato										
Marconi										
Euclid										
Pascal										

According to Maxwell (2005) and Merriam (1998) a common problem in multi-case studies is the management of the data. Merriam (1998) stated "the researcher probably has considerably more raw information and must find ways to handle it without becoming overwhelmed" (p. 195). To keep track of the data being collected, two spreadsheets were created. Table 4 was used to track the document data collected, and Table 5 was used to track the communication with principals.

Table 4

Document Data Collection Dates and Sources

School Pseudonym	*Demographics*	*Standardized Test Scores*	*School Web Docs*
Archimedes	Date: Source:	Date: Source:	Date: Source:
Boyle			
Priestly			
Pythagoras			
Einstein			
Galileo			
Plato			
Marconi			
Euclid			
Pascal			

Table 5

Interview Data Collection Dates

School Pseudonym	*Initial Contact with School Principal*	*Telephone Interview*	*Transcribed Data*	*Follow Up Interview*	*Draft to Principal for Review*	*Principal Approval*
Archimedes	Date: Email: Phone:	Date scheduled: Date completed:	Date completed:	Date completed:	Date sent:	Date approved:
Boyle						
Priestly						
Pythagoras						
Einstein						
Galileo						
Plato						
Marconi						
Euclid						
Pascal						

Maxwell (2005) warned that "letting your notes and transcripts pile up makes the task of analysis much more difficult and discouraging" (p. 95). To avoid this problem I began transcribing data immediately after the first interview and continued to analyze the data throughout the duration of this project.

Data Analysis

In order to identify characteristics of STEM focused high schools several questions were asked. Table 6 provides an overview of the question, data sources used to collect information, and analysis technique used for answering the questions.

Table 6

Data Analysis Overview

Research Question	Data Sources	Data Analysis
What content in the schools mission influenced the establishment of the schools?	School Web Site	Document Analysis
	Telephone Interview	Transcript Analysis
	Published Documents (i.e., handbooks, press releases)	Descriptive Analysis
How are students selected to attend the STEM schools?	School Web Site	Document Analysis
	Telephone Interview	Transcript Analysis
	Published Documents (i.e., application procedures)	Descriptive Analysis
What student populations do the STEM schools serve?	National Statistics Web Site	Document Analysis
	School Report Card	Descriptive Analysis
	State Web Site	Descriptive Analysis
	Standardized Test Scores	Descriptive Analysis
What are the academic programs provided? What are the requirements for graduation?	State Web Site School Web Site	Document Analysis
	Telephone Interview	Transcript Analysis

What professional development activities do STEM school faculty members participate in?	School Web Site Telephone Interview	Document Analysis Transcript Analysis

Data Analysis Procedures

Strategies for analyzing data followed suggestions in publications written by experienced researchers. Maxwell (2005) identified three main options for analyzing data: memos, categorizing strategies, and connecting strategies. For this study a categorizing strategy was used. According to Maxwell (2005),

> An important set of distinctions in planning your categorizing analysis is among what I call “organizational,” “substantive,” and “theoretical” categories. Organizational categories are broad areas or issues that are established prior to your interviews…these categories function primarily as bins for sorting the data. (p. 97)

As Maxwell suggested, the data in this study were initially arranged by organizational categories that were established by the research questions. Categories used in this study were: mission statements, admissions requirements, student population, academic programs, and teacher professional development.

> The next task requires substantive or theoretical categories, ones that provide some insight into what’s going on. These categories can often be seen as subcategories or the organizational ones…they make some sort of claim about the topic being studied. (Maxwell, p. 97)

A cross-case synthesis technique was used to analyze the data in this study. Yin (2003) suggested treating each individual case as a separate study then aggregating findings across a series of individual cases. He recommended "creating a word table to display the data from the individual cases according to a uniform framework" (p. 134). Following these suggestions, the contents of the interview and document data collected were coded and organized in a matrix.

Formal analysis of the interview data began by listening to the interviews, then transcribing them, then listening and reading them at the same time. Transcript data were entered into a digital database. Variables were identified then coded, to identify emergent themes, patterns, and questions. Coding and matrices were used for comparison across interviews and interview summaries to retain the context of the data. During the analysis phase, patterns were identified, and explanations as well as rival explanations were highlighted.

The document analysis was compared to the telephone interviews to verify accuracy of the information. Multiple sources of data allowed me to triangulate the data to strengthen the study by reducing potential threats to validity. Three sources for cross-checking the data collected were used: document data, interview data, and a draft description of each STEM school that was sent to each principal for verification.

The final step in the analysis of this study was making a logical connection between the research questions, data collected, and data analyzed. Maxwell (2005) recommended "constructing a matrix including columns for research questions, selection decisions, data collection methods, and kinds of analysis. Then write a brief narrative justifying the choices you made in the matrix” (p. 103). This method was helpful in organizing and connecting data from all 10 schools and was used for each of the questions in this study. The results are described in chapter 4.

Validity

The following methods were implemented to avoid validity threats to conclusions and bias in the selections of participants.

Triangulation Methods

A triangulation method was used to verify the accuracy of the data collected. For example, after interviewing the principals, the data were compared to the document data that were collected from various sources. Any discrepancies between the interview transcripts and document data were noted and clarified during the follow-up telephone call. The statements made by each principal were accepted as true unless I encountered discrepant evidence. Once a description of the characteristics of each school was completed, it was emailed to the principal for verification of the accuracy of the data. Appendix D contains a copy of the email sent to each of the principals.

Reactivity

To deal with reactivity, I emphasized to participants that this was strictly a research project and the results would not contain any identifying information that would point back to them. An effort was made to phrase each question in a way that would not prime participants for responses. Interview questions were tested on a colleague and revised to clarify the wording.

4. Results

In order to identify characteristics of STEM-focused high schools, multiple documents were collected and telephone interviews were conducted with school principals. The data in this study is confidential. In order to maintain the anonymity of the participants in this study, the administrators, school names, and locations were given pseudonyms. The school website references where data was collected were given generic references.

Introduction to the STEM Schools

The following is a description of the 10 schools included in this study. Schools were located in various regions across the United States including; two in the North East, three in the South East, two in the Mid West, one in the South West, and two in the Western region of the United States. None of the schools in this study were classified as magnet schools, and three qualified for Title I status. Table 7 lists the schools included in this study.

Table 7

STEM School Overview

Pseudonym	Location	Grade Level	Year Established	Locale	Charter/ Magnet	Title I	Student Enrollment
Archimedes HS	South East	9-11	2004	Large City	N/N	Y	876
Boyle HS	West	9-12	2000	Large Suburb	Y/N	N	527
Priestly HS	South West	9-12	2002	Large Suburb	N/N	Y	892
Pythagoras HS	West	9-10	2004	Large City	Y/N	N	450
Einstein HS	Mid West	9-12	2006	Large City	N/N	N	300
Galileo HS	North East	9-12	1997	Large City	N/N	N	1,344
Plato HS	South East	9	2008	Small City	Y/N	N	86
Marconi HS	Mid West	9	2008	Large City	N/N	Y	100
Euclid HS	North East	9-12	2008	Rural	N/N	N	1683
Pascal HS	South East	9-12	2007	Small City	N/N	N	1335

Note. Data collected January 2009 from National Center for Education Statistics, 2008.

Half of the schools in this study were located in large cities. Ninety percent were located in high population areas while only one was located in a rural setting. A large city has a population greater than or equal to 250,000, a small city has a population less than 250,000 and is located in a metropolitan region, a large suburb has a population greater than or equal to 25,000 and is located outside of a metropolitan area, and a rural region has a population less than 25,000. Figure 3 shows the distribution of school locales.

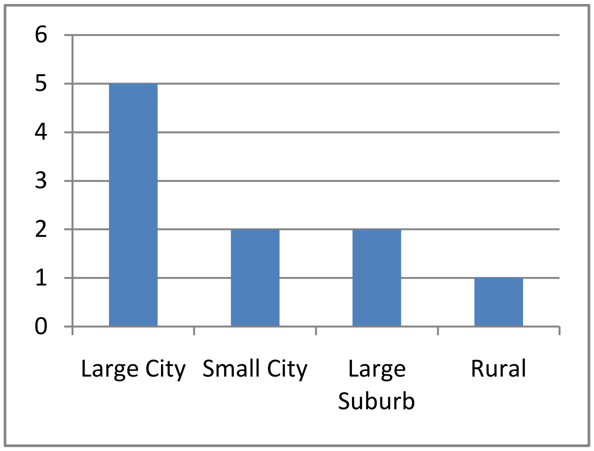

Figure 3. *Number of schools in each locale.*

Several schools in this study were new schools that did not exist prior to the start of the STEM program implementation. These schools began with a new building and new faculty and staff members. Four schools were already in existence but were redesigned to change the academic emphasis to science, technology, engineering, and mathematics. Most of the schools had traditional school facilities while two of the new schools were located in business or commercial settings. Three schools were classified as charter schools. All of the charter schools fall in the new school category.

Figure 4 shows the number of students enrolled in STEM schools, which varied from 86 to 1,683 students. Three of the schools with enrollments greater than 1000 students were the redesigned school models. The enrollment at Plato and Marconi High schools was less than 100 students because they are new schools that opened in fall 2008 and currently enroll 9th graders. The population of these schools is expected to grow to approximately 500 students. Enrollment at STEM high schools is very similar to other high schools in the United States. Average enrollment for STEM schools in this study is

756 students, which is almost the same as the average size high school in the United States, 752 students (NCES, 2008).

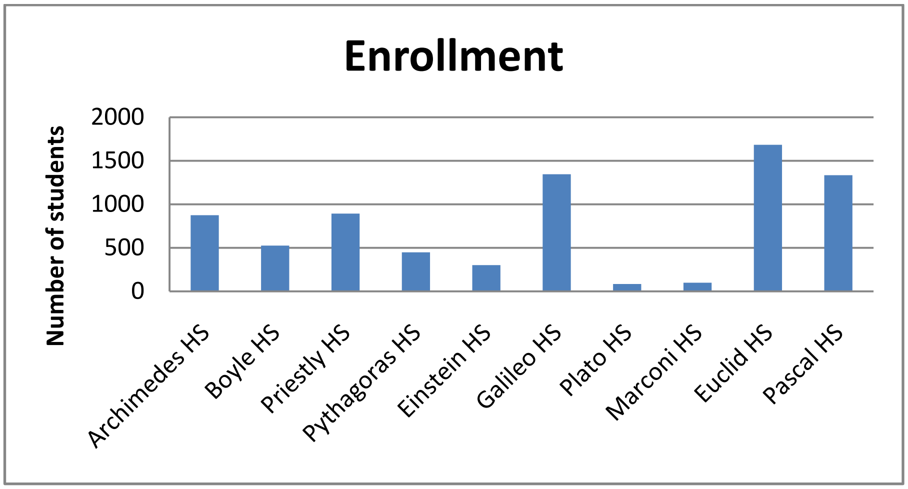

Figure 4. *Number of Students enrolled in the STEM High Schools.*

Students in the schools in this study took different state assessments, these data provide an indication of how STEM schools performed on their own state assessments. Data in Figure 5 represent the percentage of students who passed last year's state standardized tests in English and math. Plato and Marconi are new schools which opened in the fall of 2008 so these schools did not have any test data reported. Most students who passed math also passed the English tests with the exception of Pythagoras High School. This school had unusually low math scores for the year reported. The low scores were similar for other schools in this school district.

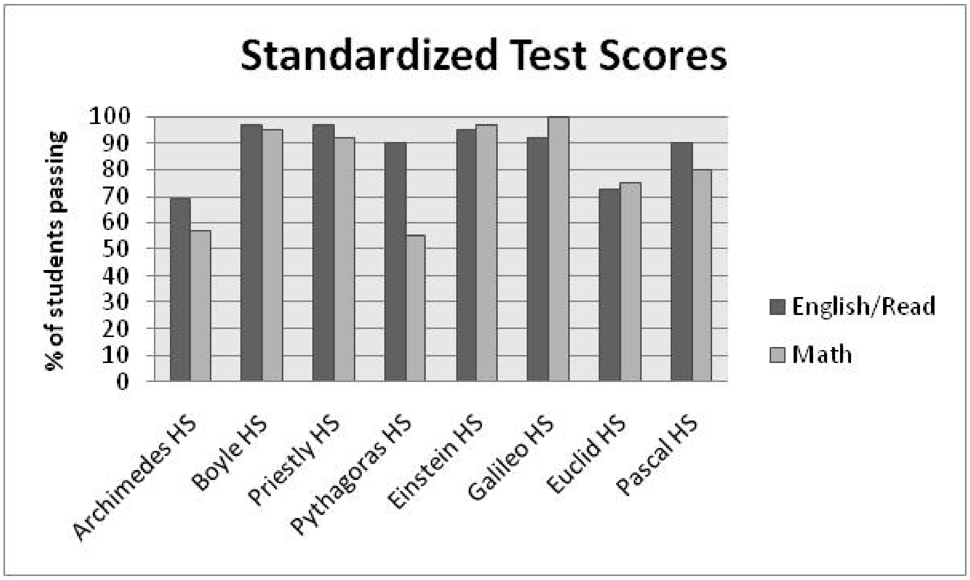

Figure 5. *Percentage of students passing state assessments.*

When comparing the percentage of students who passed the state administered standardized tests in STEM schools compared to the overall passing rate for the state, STEM schools in this study had approximately 14% more students pass the English and 17% more pass the mathematics exam. Of the eight schools who participated in statewide testing, all performed the same or higher than the state average. Euclid and Pascal High Schools had the lowest scores and were also new STEM programs beginning in the fall of 2008 and 2007 respectively.

Table 8

Comparison between STEM School Pass Rate and the State Pass Rate

	Reading/ English	State AVG Eng/Read	% Difference Eng/Read	Math	State AVG Math	% Difference Math
Archimedes	69	42	+27	57	41	+16
Boyle	97	79	+18	95	78	+17
Priestly	97	90	+7	92	79	+13
Pythagoras	90	66	+24	55	30	+25
Einstein	95	85	+10	97	79	+18
Galileo	92	71	+21	100	64	+36
Euclid	73	71	+2	75	64	+11
Pascal	90	88	+2	80	80	0
AVG			+13.88			+17

STEM School Models

This section contains detailed descriptions of each of the 10 STEM high schools.

#1 Archimedes High School

School Background

In 1997, Archimedes High School (AHS) closed its doors. The school was physically run down and there was a need to retool. The school remained closed until 2002 when it resurged as the first “technology” school in the district. School leaders worked diligently to build a competent and excited faculty, challenging curricula, and a comprehensive program. In 2004, AHS opened its doors as a city-wide comprehensive high school to 9th and 10th grade students. Students were exposed to a liberal-arts and career and technical education. Partnerships were enhanced to make the learning relevant with connections to the National Institutes of Health, XM Radio, Carnegie Institute of

Science, and many colleges and universities. The results of this program led to impressive student achievement. In each of the next three years, this school made Adequate Yearly Progress (AYP) and grew in math and literacy achievement (Archimedes school website, 2008).

Last year this school was one of 7 schools in the United States that was awarded $100,000 for its innovative educational programs. This money is being used to provide students with the first technology mobile-unit in the world. Students will use this unit to give back to the community by sharing their technological skills with community members using the technology mobile-unit to travel to schools, retirement centers, and libraries (Archimedes school website, 2008).

This school is actively involved in the STEM education coalition, which works to support STEM programs for teachers and students at the U.S. Department of Education, the National Science Foundation, and other agencies that offer STEM-related programs (STEM Education Coalition, 2008).

School Population and Standardized Testing

Archimedes High School serves an African American population with 36% receiving free or reduced lunch. It has a higher percentage of black students and a lower percentage of economically disadvantaged students than other schools in its district. Table 9 contains statistics documenting the student population.

Table 9

Archimedes High School Demographics

Characteristic	School Data	District Data
Enrollment	876	56,776
Charter	No	-
Locale	Large City	Large City
Ethnicity	White: 1% Black: 97% Hispanic: 2% Asian: 1%	White: 10% Black: 83% Hispanic: 5% Asian: 2%
Magnet	No	-
Title I	Yes	-
Free/Reduced Lunch	36%	53%

Note. Data collected January 2009 from National Center for Education Statistics, 2008.

Testing in this state has become increasingly important in measuring student achievement. In 2006-2008 this state administered the State Comprehensive Exams (SCE) to measure student achievement in grades 3 through 8 and 10 in reading and mathematics. Students are rated at one of four levels: below basic, basic, proficient, and advanced (No Child Left Behind Data Reports, 2008). Test results in Table 10 show that there is a very large range in scores between the highest and lowest performing schools in this district. In 2008, there was an 85% difference is math scores and 76% difference in reading. No test data were available for AHS in 2006. In 2008, tenth-grade students at AHS ranked third out of 15 schools in its district on the math exam and fourth in reading.

The only schools that scored higher than AHS were magnet schools which have strict academic entrance requirements. Most schools in this district made significant improvements in test scores over the past three years. Although it is difficult to compare school test scores without controlling for differences in population, I was able to confirm that many students enrolled at AHS have mastered the state required content. Overall AHS has made improvements in both mathematics and reading over the past year.

Table 10

10th Grade SCE Results

School	Reading (2008)	Reading (2007)	Reading (2006)	Mathematics (2008)	Mathematics (2007)	Mathematics (2006)
School A[a]	97	95	91	98	91	87
School B[a]	93	90	92	93	87	77
Archimedes	72	69	-	63	57	-
School C	62	57	57	60	51	58
School D	53	37	42	60	39	46
School E[a]	76	64	58	52	48	40
School F	29	24	15	51	23	17
School G	35	32	22	39	21	14
School H	22	18	18	26	26	11
School I	24	14	17	26	17	15
School J	18	6	10	22	8	7
School K	22	24	30	19	20	27
School L	29	12	17	18	11	13

School M	19	19	9	17	18	4
School N	21	6	12	13	5	6

Note. Scale: % at or above proficiency on SCI exams. Data collected from the State website, 2006-2008
[a]Magnet School

Influence of the Mission Statement

Archimedes High School's mission is to be a professional learning community accountable for increasing student achievement. This school strives to become the highest performing high school in the nation through the integration of a rigorous college preparatory and STEM curricula taught by master teachers that prepares students for the challenges of an ever-changing and competitive global market. To implement this mission, this school offers a learning environment that utilizes technology to support academic achievement. Teachers and students engage in a project-based curriculum that has the rigor of a first-class liberal arts education and the job skills development of a technical program. According to the principal, "We are the only school in the world that teaches students how to use Virtools, a computer simulation and video game design program and we are the only school with a motion capture studio for video game design" (personal communication, February 6, 2009). Archimedes High School provides students with opportunities to pursue an intense focus in biomedical technology, information technology, or broadcast technology (Archimedes school website, 2008).

Student Selection Process

Student selection process is based upon a student application, grade point averages, school attendance, a student questionnaire, teacher recommendations, a personal interview, proof of residency, and a parent statement. Once students are selected they must attend an orientation meeting, sign a contract, and attend a summer institute (Archimedes school website, 2008).

Academic Programs and Graduation Requirements

Archimedes High school offers a learning environment that is digitally enhanced to support academic achievement. Technology is available to all students and staff members who are provided with personal computing devices, wireless and broadband infrastructure, digital video, and biochemical technologies designed to improve educational delivery (Archimedes school website, 2008). The school provides students the opportunity to pursue an intense focus in biomedical technology, information technology, or broadcast technology. Specific program concentrations are in computer networks, interactive media, computer programming, radio, TV/video production, and molecular and plant genetics. The curriculum is structured to challenge students to be prepared for both future academic study and a world of technology-based employment. Unique features of academic programs at this school include:

- An integration of technological skills into content disciples
- Interdisciplinary blocks of time
- Real-world problem solving tied to community needs
- Internship and apprenticeship opportunities
- Project-based curriculum (individual and group long-term projects)
- Rigorous liberal arts education combined with job skill development

Students are required to master a more rigorous foundation curriculum than other students in this district including:

- four years of English composition and literature
- four years of mathematics and science (instead of three)
- U.S., state, and world history
- biology, chemistry, physics
- three years of foreign language (instead of two)
- performing arts and physical education
- four credits of selected career technical education courses

(Archimedes school website, 2008).

"Engineering, Mass Media and Communications, Biotechnology, and Information Technology are the key areas of technology specialization" (personal communication, February 6, 2009). In the ninth and tenth grades, students acquire basic technology skills in these three focus areas and others by embedding the skills in the core content. In the 11th and 12th grades, students choose specific technology disciplines for advanced study and internship opportunities. Community professionals assist in project development and the assessment of student project performance. In addition, AHS offers traditional Advanced Placement (AP) academic courses and dual credit options for students who desire to begin their postsecondary education while still in high school (Archimedes school website, 2008).

Archimedes High School plans to add rigor to their program by adding an intensive STEM-focused program for students beginning in the 2009-2010 school year.

This STEM certificate will require 30.5 credits and “every student must take at least two AP courses to graduate, one must be in science or math, the other in economics and global perspectives” (personal communication, February 6, 2009). STEM students will complete an internship and senior project. Students are provided Internet course options including a large selection of AP courses.

The Career and Technical Education Program at AHS allows students to take technical courses in addition to their core coursework. One area where students can take extra coursework is in Interactive Media, where students gain a mix of experience in 3-dimensional modeling, 3-D animation, and programming, using professional software.

> Our goal for this program is to motivate and prepare students for a college program in computer science or another technical field inspiring them to pursue traditional command line computer science courses. To be successful in this program, students have to be creative problem-solvers who understand not only computer programming but also complex math, physics, and even design. (personal communication, February 6, 2009)

Students at AHS are involved in Saturday after school program, the Institute of Urban Game Design, which is now expanding to five schools in this city (game website, 2008). In addition to the academic programs, AHS offers a full range of competitive athletics and afterschool activities.

Professional Development Activities

Teachers at this school have regularly scheduled professional development workshops provided by instructional coaches in a variety of topics, including classroom as a learning lab, creating master lesson plans, classroom management that works, executing a master lesson, using grading to move student engagement, reading strategies, assessments and accountability, key principles of learning, master teaching rubric and goals, pedagogy, rigor in the classroom, differentiating instruction, making powerful presentations, create purposeful movement, and encouraging critical thinking (Teacher professional development website, 2008).

In addition to onsite instructional coaches, educators at AHS are provided a virtual mentor network (Educators Virtual Mentor, 2008). This resource provides a unique, online video staff development. Teacher can watch master teachers demonstrate techniques that work in real classrooms. AHS has developed an instructional partnership with a charter school with the purpose of building a professional learning community that observes and analyzes effective instruction (Teacher professional development website, 2008).

#2 Boyle High School

School Background

Boyle High School (BHS) was originally conceived by a group of about 40 civic and industry leaders and was launched by an industry and educator coalition. It was designed to immerse students in rigorous learning environments that engage and interest students in fields of math, science, and engineering. BHS is a small diverse learning community with a current enrollment of 535 students (school report card, December 5, 2008). It began in September of 2000 as a single charter high school and has evolved into a school development organization with a growing number of innovative charter schools spanning grades K-12. It now has seven schools; four high schools, two middle schools, and one elementary (BHS website, 2008). The Gates Foundation awarded a grant to support new STEM-focused schools in this state in 2006. In 2007, the State Board of Education awarded several other grants to schools following this design.

Boyle High School creates personalized, project-based learning environments where all students are known and challenged to meet high expectations. The BHS model emphasizes small school size, small classes, real-world immersion, and performance-based assessment. Because of the focus on personalized learning environments and hands-on work, this school has classrooms and labs that provide students with a dedicated computer workstation for half of each day. The facilities include teaching clusters, seminar rooms, studio areas, shared teacher offices, gallery spaces, specialty labs, and outdoor learning spaces (BHS website, 2008).

School Population and Standardized Testing

Boyle High School serves a multicultural population with 10% of its students receiving free or reduced lunch. It has a higher percentage of white students and a lower percentage of Hispanic students compared to other schools in its district. It also has a lower percentage of economically disadvantaged students. Table 11 contains statistics describing BHS student population.

Table 11

Boyle High School Demographics

Characteristic	School Data	District Data
Enrollment	527	132,482
Charter	Yes	-
Locale	Large City	Large City
Ethnicity	White: 51% Black: 12% Hispanic: 19% Asian: 17%	White: 25% Black: 13% Hispanic: 45% Asian: 16% Native American: 0.5%
Magnet	No	-
Title I	No	-
Free/Reduced Lunch	10%	59%

Note. Data collected January 2009 from National Center for Education Statistics, 2008.

In 2006-2008 the state administered the High School Exit Exam (HSEE) to test high school students' skills in English, language arts, and mathematics. This test is particularly important to high school students because they must pass the test in order to graduate. Table 12 focuses on the HSEE test because this exam is taken by all high school students regardless of the course in which they are enrolled. Alternative and special education schools were not included.

There are 39 high schools in the school district including several charter schools making it the largest of the school systems involved in this study. There is a very large range in scores between the highest and lowest performing schools in this district. In 2007, there was 64% difference mathematics and a 61% difference in English. From 2006 to 2008, test scores were fairly consistent. High performing schools continued to do well while low performing school maintained. In 2008, BHS was the second highest performing school in English and fifth highest in mathematics. Although it is difficult to compare school test scores without controlling for differences in population, we can confirm from the test scores that students enrolled at BHS have mastered the state required content. Students at BHS scored 17% higher in English and 16% higher in mathematics than the state average (State Department of Education website, 2008).

Table 12
HSEE Test Results

School	Public/ Charter	English (2008)	English (2007)	English (2006)	Mathematics (2008)	Mathematics (2007)	Mathmatics (2006)
School A	Charter	100	100	100	100	100	100
Boyle HS	Charter	96	97	-	94	95	-
School B	Public	96	86	65	87	90	78
School C	Public	95	90	91	93	91	91
School D	Public	94	97	95	94	96	96
School E	Charter	94	93	-	87	91	-
School F	Public	92	88	92	96	93	92
School G	Public	90	90	90	91	90	91
School H	Charter	90	94	-	87	84	-
School I	Public	88	90	85	95	91	89
School J	Public	88	86	90	92	87	92
School K	Public	88	90	91	89	90	89
School L	Public	87	79	82	85	76	79
School M	Public	87	91	87	82	78	77
School N	Charter	85	73	73	70	70	61
School O	Charter	84	72	73	74	65	58
School P	Public	82	91	83	73	79	80
School Q	Public	81	78	72	78	76	77

School R	Public	81	78	83	78	75	76
School S	Public	80	80	83	78	76	78
School T	Public	78	74	79	66	63	67
School U	Public	77	71	71	74	71	75
School V	Public	76	68	89	82	74	84
School W	Public	76	61	67	82	70	70
School X	Public	75	74	64	71	82	67
School Y	Public	73	73	74	68	67	73
School Z	Public	67	62	63	70	67	54
School AA	Public	67	73	87	66	67	85
School BB	Public	67	53	66	51	44	43
School CC	Public	65	57	64	59	56	66
School DD	Charter	62	72	74	63	43	65
School EE	Public	59	45	47	48	41	34
School FF	Public	56	47	69	61	70	72
School GG	Public	53	57	55	56	57	57
School HH	Public	50	55	66	50	67	68
School II	Public	49	61	51	50	54	57
School JJ	Public	47	62	55	58	68	66
School KK	Public	33	31	28	45	55	46
School LL	Public	-	39	46	-	36	51

Note. Scale % passing. Data collected from the State Department of Education website, 2008.

Influence of the Mission Statement

The mission of BHS is to serve a student body that mirrors the ethnic and socioeconomic-diversity of the local community, integrate technical and academic education, prepare students for postsecondary education and for leadership in the high technology industry increase the number of educationally disadvantaged students in math and engineering who succeed in high school and postsecondary education and graduate students who will be thoughtful, engaged citizens who are prepared to take on the difficult leadership challenges of the 21st century. BHS strives to provide students with rigorous and relevant academic and workplace skills, preparing its graduates for success in an increasingly technological society (school report card, December 5, 2008).

The school educational philosophy is derived from the New Urban High School Project, a 1996 study commissioned by the U.S. Department of Education to identify the strategies that had been successfully used as a lever for whole-school reform. Their philosophy is that the best learning occurs when the educational program is based on three key educational principles: Personalization, Adult World Connections and a Common Intellectual Mission. Personalization will cultivate academic excellence by encouraging each student to personally invest in his/her education. Innovative features include performance-based assessment, daily shared planning time for staff, state-of-the-art technical facilities for project-based learning, internships for students, and close links to the high tech workplace. Each student has an individual staff advisor who will visit the home of each new student. This may occur on or off campus.

Students pursue their particular interests through projects and prepare personal digital portfolios to document achievements. The adult world connection allows students to engage in real-world projects that enable students to learn while working on problems of interest and concern to adults in the community. Common intellectual mission includes curriculum that is rigorous and engaging with performance-based assessment and addition to traditional letter grades and standardized test assessments (school report card, December 5, 2008).

Student Selection Process

Boyle High School endeavors to accommodate all students who apply. However, when applications for admissions exceed the number of spaces available, BHS employs a computerized lottery generated by zip codes to determine admissions. In order to ensure that the student body represents the socio-economic and cultural diversity of the county within which it operates, a separate lottery is held by grade level for each zip code in the county. Spaces are allocated to a zip code area based on enrollment data provided to the site by the county office of education. If additional openings remain after this first series of zip code-based lotteries is performed, remaining students are aggregated into a single applicant pool for a second random lottery. If admissions spots are available in a particular zip code then those spots are filled with sibling applicants. Applications are due at the beginning of March and notification of admissions decision is released in early April (BHS website, 2008). Criteria for admission include state residence, matriculation from the current grade, and interest in attending the school.

Academic Programs and Graduation Requirements

Academic internships provide students with workplace skills through project-based learning in a real-world environment. All students are required to have an academic internship to graduate. Students are required to put together a project surrounding their internship, write journals, and communicate with their employers, mentors, and the school internship coordinator. Students work at their semester long internships on Tuesday and Thursdays from approximately 1:00-4:30 p.m. The internship experience is academic in nature. Interns can only be paid after internship hours are completed.

Transportation is provided by a school shuttle, mass transit, parents, or student cars (school report card, December 5, 2008).

Unlike many traditional high schools, BHS requires production of real-work products, solving problems, and making oral and written presentation. Teachers, industry experts, community members, parents, and peers review these efforts. BHS institutes a “Transitional Presentations of Learning (POL)” at the end of each grade to ensure that all students make adequate yearly progress before moving on to the next grade level. A Presentation of Learning is a formal presentation given by a student to a panel at the end of the first semester each year. Prior to the presentation, students practice in their advisory and core classes. Each presentation must incorporate a reflective piece regarding the learning goals. For the second semester, teaching teams conduct transitional POLs to determine whether students are ready to advance to the next grade. The requirements for the POL is grade-level specific, but include an oral presentation, use of the student’s digital portfolio, artifacts from standards-bearing project work in the humanities, math and science, and elective courses. Each grade level uses a common rubric to evaluate POLs. Students who attempt but do not pass the OPL are given additional opportunities to present once they have revised their work based on input for the review panel (school report card, December 5, 2008).

The BHS curriculum supports state stands and students are required to pass state standardized tests. In addition, student are expected to achieve competency in six learning areas: (1) collaboration; (2) technology; (3) communication, both oral and written; (4) art and design; (5) ethics and responsibility, and (6) critical thinking. All students use technology to research, produce, and present across academic disciplines. BHS is an inquiry-based liberal arts school where the lines between "technical" and 'academic" are deliberately blurred. Students with interest in math and science are encouraged to apply while similar excitement and quality can be found in the humanities and arts (BHS website, 2008).

Students can take community college courses in addition to the high school program but not in replacement of high school courses. AP courses are not central to this school's design. This school is designed to emphasize deep project-based work rather than content tested on the AP exams. Students receive report cards at the end of every semester. Although much of the work at BHS is nontraditional, students receive traditional-looking grades for colleges to understand (BHS website, 2008).

Students are scheduled for "Student Interest Groups" or x-block three times per week. School day goes from 8:30 a.m. to 3:30 p.m. including x-block. All x-blocks have a fitness focus, such as soccer, dance, rock climbing, cross country, Tai Kwan Do, etc. Once a week students attend clubs such as student government, tutoring, yearbook, United Nations, art, coking, chess, etc. Traditional sports teams are limited in number due to lack of facilities. Sports currently offered are volleyball, basketball, rowing, cross country, flag football, fencing, and soccer (BHS website, 2008).

Professional Development Activities

Teachers are positioned for success by working in teams that deal with the same cohort of students. They come to school an hour before the students each day to plan, discuss student work, and engage in professional development activities (BHS website, 2008). This school offers learning opportunities for practitioners including teacher residencies and institutes. It provides resources for educators including guides to project-based learning, curriculum integration, internship program development, teaching to diverse learners, student advisory, college advising, facilities development, technology infrastructure, and policies and management.

Faculty members at BHS participate in ongoing professional development. This includes 45 minutes per day without students for collaboration and program development. Student/faculty team meetings occur three times per week in addition to a weekly meeting for all staff. There are various day-long development workshops throughout the year and a two-week long teacher preparation session in August prior to the opening of school a one week-long session during the winter break (BHS website, 2008).

The state commission on teacher credentialing has approved BHS to certify teachers in mathematics, science, English, history/social studies, Spanish, Mandarin, and art through hits Teacher Intern Program. The teacher intern program situates teacher professional development in BHS sites where candidates can experience a 21st century context for teaching and learning. The program provides direct, on-the-job training to recent graduates of postsecondary institutions, as well as to mid-career individuals in transition. BHS partners with the state university to provide a 120-hour preservice teacher program and 600 hours of training and practice over two academic years. Interns earn full-time salaries and benefits as teachers in charter school classrooms while working toward their credentials. To be considered for this program, applicants must first apply for a teaching position at BHS. Once hired, interns will participate in the program (BHS website, 2008).

#3 Priestly High School

School Background

Priestly High School (PHS) is nonselective public school located in a large city in the southern part of the United States. It has received numerous recognitions including Early Innovator model school and U.S. World News and Report Bronze medalist school. This school initially received a $300,000 grant from the state to advance their program in science, technology, engineering, and mathematics, to enhance their program's personalization, and to act as a mentor to other schools working on the design and implementation of science, technology, engineering, and mathematics academies (PHS website, 2009).

School Population and Standardized Testing

Priestly High School serves a very diverse population with more than half of its students receiving free or reduced lunch. PHS has more black students and fewer Hispanic students than other schools in this school district. It also has a lower percentage of economically disadvantaged students. Table 13 contains statistics documenting PHS student population.

Table 13

Priestly High School Demographics

Characteristic	School Data	District Data
Enrollment	892	58,093
Charter	No	-
Locale	Large Suburb	Large Suburb
Ethnicity	White: 8% Black: 49% Hispanic: 40% Asian: 3%	White: 5% Black: 32% Hispanic: 61% Asian: 2%
Magnet	No	-
Title I	Yes	-
Free/Reduced Lunch	56%	75%

Note. Data collected January 2009 from National Center for Education Statistics, 2008.

This state uses the Assessment of Knowledge and Skills (AKS) to test students in grades 3-11. Students must pass English, mathematics, science, and social studies in the grade 11 exit level AKS in order to graduate from high school. High school students take AKS tests in English language arts in grades 10 and 11, in mathematics in grades 9-11, in science in grades 10 and 11, and in social studies in grade 11. Results from the English exam do not include the Spanish version. Table 14 contains grade 11 test scores. These were highlighted because they are used as a barrier for graduation. For the past three years, PHS students have consistently outperformed other students in its district. They had the highest performance in both the mathematics and English exams. In 2008, the range in scores between the highest and lowest performing schools in this district was 31% in mathematics and 12% in English. PHS students performed 13% higher than the state average in math and 7% higher in English. Although it is difficult to compare school test scores without controlling for differences in population, I confirm from the test scores that students enrolled at PHS have mastered the state-required content and outperformed other schools in its district and state.

Table 14

11th Grade AKS Results

School	Grade 11 Mathematics (2008)	Grade 11 Mathematics (2007)	Grade 11 Mathematics (2006)	Grade 11 English (2008)	Grade 11 English (2007)	Grade 11 English (2006)
Priestly	92	91	87	97	96	96
School A	86	90	87	95	93	89
School B	82	90	83	93	93	89
School C	71	83	63	92	94	82
School D	75	78	70	92	92	80
School E	61	30	45	85	67	71

Note. Scale % meeting or exceeding standards. Data collected from school report card, 2008.

Influence of the Mission Statement

Priestly High School's mission is to provide students with the academic foundation and individualized support to ensure that each student achieves their own personal vision. Through the Performing Arts, Engineering, and Visual Arts houses these visions become realities. The school's mission is "to ensure students the opportunity to achieve their individual potential and fully participate in the social, economic, and educational opportunities in our global community now and in the future" (PHS website, 2008). To ensure that the school mission is accomplished, students are expected to follow an attendance and dress code policy.

Student Selection Process

Students interested in attending PHS must submit an application by the student's parent or legal guardian by the end of January. The application is one page in length and requests student's demographic information and student program preference. The school uses a lottery system to select students. Applicants are notified at the beginning of March if they are selected (PHS website, 2008).

Academic Programs and Graduation Requirements

This school is part of the state public school system and uses the same curriculum framework as the rest of the state. Students are provided additional support to prepare them for state standardized tests. Every student is provided a free online tutorial program called PLATO, which contains practice assessments. There are mandatory classes scheduled two days per week for students that need extra help on the AKS test. Remediation classes are scheduled as an eighth period and have been attributed to an 11% gain in overall AKS math scores.

Students who attend PHS can select from three programs: Engineering, Visual Arts, and Performing Arts. Students take seven classes within the academic school year including five academic courses and two electives. The two elective courses focus on the program a student enrolls in (PHS website, 2008).

"The engineering program is based on Project Lead the Way, a national curriculum, which focuses on dynamic partnerships with schools that prepare diverse student populations to be successful in fields of engineering and technology" (PHS website, 2008). Within the engineering program, students can focus on architectural, computer, manufacturing, or electrical engineering. Students in this program have the option of obtaining certifications including: A+, MOUS, and networking. Traditional curriculum is combined with engineering applications taught in the engineering course. Elective courses for this program include technology systems, digital electronics, intro to engineering, principles of engineering, computer-integrated manufacturing systems, business computer programming, cabling/design, quality control, and engineering research design and development. Students are permitted to waive physical education requirements to take some of these courses. Graduation requirements within the engineering program include four years of math, four years of science, and a senior project (PHS website, 2008).

The advanced visual arts program is based on studio classroom experiences in design, drawing, painting, printmaking, photography, sculpture, and electronic media. Students rotate through each area and are guided by master teachers. Students are given the opportunity to exhibit their work in professional venues throughout their city. Students in this program have received local, state, and national recognition. Students complete portfolios that are assessed internally and entered in competitions. Elective courses for this program include art, electronic media, painting, drawing, printmaking, sculpture, and photography (PHS website, 2008).

The performing arts include vocal music, instrumental music, dance, and theater. Students are involved in teamwork in order to create performances that best showcase the talent of everyone participating. Individual student productions as well as group performances are held throughout the year. Elective courses for this program include dance, ballet, theater arts, theater production, piano, music history, music theory, and instrumental ensemble. This school has its own dance company (PHS website, 2008).

Advanced Placement (AP) courses that are available to students include Biology, Chemistry, Physics, World History, Psychology, English Language, English Literature, Calculus, Statistics, Spanish Language, and Spanish Literature. Classes offered in the summer include video, photography and broadcast, robotics, CIMS, principles of engineering, and math remediation. Library resources are available to all students including many online databases to help students with research projects. These are available to families as well as students attending this school (PHS website, 2008).

Parents are encouraged to stay actively involved in monitoring their children's progress through an online parent portal. The portal is an online access program that contains daily grades, homework assignments, and attendance. Students are expected to spend one hour per night practicing skills taught. Parents are also encouraged to join the Parent Teacher Organization, which is currently seeking business and community partnerships as well as organizing fundraisers to support student scholarships and incentives for students and staff. This school celebrates academic achievement through reception to recognize the efforts of students who made the academic honor roll and merit roll. This school sent two students to the U.S. First Robotics conference and hosted an engineering fair (PHS website, 2008).

#4 Pythagoras High School

School Background

Pythagoras High School (PHS) is an innovative charter high school serving a highly diverse student body. It began as a cooperative initiative with the Governor and the states Small Schools Initiative along with early funding from the Bill and Melinda Gates Foundation. Construction of the new campus began in 2004 and opened its doors for the first time in August 2004 (PHS website, 2008). The State Commission for High School Improvement calls for smaller schools, fewer courses, but longer hours, more teacher-student interaction and more control for school (newspaper article, February 20, 2005). This is the only high school in its state to earn an “Excellent” performance rating and “Significant Improvement” on the state report card (PHS press release, December 7, 2007).

This school was the first public school in its state that had a wireless network and each student received a laptop. This school has fully equipped physics, biotech, chemistry, and engineering labs and has a variety of classrooms, project rooms, and comfortable work and social areas (PHS website, 2008).

School Population and Standardized Testing

Pythagoras High School serves a very diverse population with more than 40% of this student body receiving free or reduced lunch. When asked to describe his student body, the principal said, “We serve a diverse group, of approximately one-third black, one-third Hispanic, and one-third white. Roughly 45% low income, 45-50% first generation going to college” (personal communication, January 12, 2009). Table 15 contains statistics highlighting the student population. This school has a lower population of Hispanic students, and 22% fewer economically disadvantaged students than other schools in its district.

Table 15

Pythagoras High School Demographics

Characteristic	**School Data**	**District Data**
Enrollment	450	75,269
Charter	Yes	-
Locale	Large City	Large City
Ethnicity	White: 35% Black: 34% Hispanic: 26% Asian: 5%	White: 23% Black: 18% Hispanic: 55% Asian: 3% American Indian: 1%
Magnet	No	-
Title I	No	-
Free/Reduced Lunch	42%	66%

Note. Data collected January 2009 from National Center for Education Statistics, 2008.

The state Student Assessment Program (SAP) is used to test students in reading, writing and mathematics in grades 3 through 10, and in science in grades 5, 8 and 10. The

SAP is a standards-based assessment that tests specific skills defined by the state. This state also requires that all 11th-grade students take the American College Test (ACT), a college entrance exam, though no particular passing score has been established. This state does not currently have a high school exit exam. For this comparison, alternative schools and schools which had 0% pass rate were omitted due to lack of available data.

The school district in which PHS resides has 16 public high schools that participated in the SAP exams in 2008. In 2008, the range in scores between the highest and lowest performing schools in this district was 55% in mathematics and 70% in English. Table 16 indicates that there was little change in SAP test scores between 2006 and 2008. In 2008, students at PHS outperformed all other schools in its district in math and had the second highest scores in reading. Although it is difficult to compare school test scores without controlling for differences in population, I can confirm from the test scores that students enrolled at PHS have mastered the state required content in reading due to the fact that 90% of its students passed the state exam. We can also confirm that PHS was the highest performing school in its district on the math exam. They scored 24% higher in reading and 25% higher in math than the state average.

Table 16

10th Grade SAP Results

School	Charter/ Public	Reading (2008)	Reading (2007)	Reading (2006)	Math (2008)	Math (2007)	Math (2006)
Pythagoras HS	Charter	90	91	86	55	67	64
School A	Public	94	95	89	46	38	48
School B	Public	60	60	60	36	27	29

School C	Public	72	64	68	31	28	32
School D	Public	61	55	68	21	13	22
School E	Charter	67	41	45	17	12	12
School F	Public	60	71	70	16	16	13
School G	Public	36	41	45	11	12	12
School H	Public	47	43	44	11	7	13
School I	Public	21	23	31	6	5	6
School J	Charter	37	42	26	5	5	2
School K	Public	34	20	23	5	3	3
School L	Public	29	27	20	4	4	2
School M	Public	31	30	27	4	3	2
School N	Charter	24	15	28	3	1	1
School O	Charter	24	20	27	0	1	1

Note. Scale % at or above proficiency. Data collected from the State department of education website, 2008.

Influence of the Mission Statement

Pythagoras High School is dedicated to providing a diverse student body with an outstanding liberal arts high school education with a science and technology focus. creating a powerful learning community centered on respect, responsibility, integrity, courage, curiosity, and doing your best. The school rules include a dress code; closed campus; no carbonated, caffeinated, and sugar-laden beverages in the building. The goal of PHS is to increase the number of underrepresented students (women, minorities, and economically disadvantaged) to attain college science and liberal arts degrees. The principal's goals for this school are "to send 100% of our kids to 4-year colleges, to get 100% of our kids to proficiency by 10th-grade on state tests, to develop leaders of the future, and help impact education reform across the country" (personal communication, January 12, 2009).

Student Selection Process

Pythagoras High School is a charter school in a public school district. Each year it admits 140 new 9th-grade students. Any metro area student may apply for the random lottery admissions process. When asked how difficult it is to win the lottery, the principal said, “We have about three applicants for each available slot” (personal communication, January 12, 2009). Pythagoras High School admits 40% low-income students, ensuring an economically and ethnically diverse study body. In order to be eligible for the lottery, interested students must complete an admission application and comply with admissions deadlines. Families are encouraged to attend an open house and schedule a shadowing appointment. The application comprised of five short answer questions asking students why they would like to attend PHS, about their personal interests, and what they are interested in studying.

After students are admitted an extensive support system ensures their success. The principal describes the support system as “extra math and English classes to support what is taught in the classroom, mandatory outside tutoring in addition to teacher tutoring. Students who are doing poorly are required to attend these sessions” (personal communication, January 12, 2009). If a student is not successful in any course(s), they remain in this school and repeat the course(s).

Academic Programs and Graduation Requirements

Students are challenged with a rigorous, college preparatory curriculum. Students are taught a strong liberal arts curriculum with an emphasis on the sciences. Curriculum is aligned with state standards that meet traditional measures of success and reinforce academic principles of rigorous, personalized, and integrated content. Each student receives a laptop or tablet computer to lean with the most available technology. During 9th and 10th-grade curriculum focuses heavily on content and skill development in math, physics, chemistry, Spanish, humanities, world history, world literature, and studio art in 75-minute block setting. At the end of the 10th grade, students are required to create a digital portfolio that demonstrates mastery of core performance skills (PHS website, 2008). "Every student takes the same classes with the exception of senior year essentially. Every freshman takes physics they don't have a choice" (personal communication, January 12, 2009).

In 11th and 12th grades, students progress to more advanced coursework. In order to graduate, students are required to complete an internship project allowing them to synthesize the information and skills developed across the curriculum. Students take courses in math, biology, American literature, American history, government, and advanced science electives in physics, chemistry, and biotechnology. Junior year students complete an internship that requires students to apply academic skills in a professional setting helping them to develop their postsecondary plan. Seniors propose, execute, and present an independent research project in an area of interest. The comprehensive senior project is intended to be an overall illustration of students' knowledge and skills (PHS website, 2008).

The principal described some of the major differences between PHS and other schools in its district "We have a different culture with different sets of expectations. We have a much more focused program in that all students take a required curriculum. Our academic requirements exceed the states in additional coursework requirements, internship, and senior projects. Some of the additional courses include engineering electives" (personal communication, January 12, 2009).

Science and technology elective courses include astrophysics, biotechnology, building bridges, Computer Aided Design (CAD), creative engineering, earth science, engineering models, engineering of sound, environmental biology, crashes and biohazards, genetics, JavaScript programming, medical imaging, neurobiology, and robotics (PHS website, 2008).

In addition to a strong academic program, PHS provides a competitive athletic program that emphasizes teamwork, good sportsmanship, school spirit, character building, and fun. Noncompetitive fitness options include yoga, weight training, kickboxing, ultimate Frisbee, softball, Nike golf, and roller hockey, emphasizing the acquisition of life-long skills. Students can expect about 2.5 hours of homework per night that accompanies demanding coursework (newspaper article, August 29, 2005).

Professional Development Activities

When asked what it takes to teach at PHS, the principal said, "We look at high performing individuals who have demonstrated a capacity to perform at the highest level in all that they have done. We look for people with 3 to 5 years of experience, and those who have experience in urban city schools." Once a teacher is hired at PHS, the school provides in-house training. "The staff meets two to three weeks before school starts. They meet with the director of curriculum and assessment who gives a very clear set of curriculum guidelines. Largely our curriculum is designed in house." Although teachers do not have to be certified by the state to teach at this school, “we have a prescribed training program that is very thorough” (personal communication, January 12, 2009). Teachers use “common assessments across the departments and across the school.” Teachers are union-exempt and serve one-year contracts. Teachers are expected to enforce school policies and model behavior for students (newspaper article, August 29, 2005).

Instructors use technology as a tool to enhance learning and integrate it across disciplines. Technology is used to enable higher-order thinking, learning, and expression. It is used to engender more intense investment and engagement by students. It is used for collaboration, extrapolation, projection, analysis, demonstration, and closer tangible interaction with the subject under study. Technology is used to transport students to places, experiences, and modes of thinking, cultures, and people otherwise impossible to reach for the normal high school student (PHS website, 2008).

School Leadership

When asked to provide advice to new administrators seeking to begin a new STEM school, the principal focused on curriculum and high expectations. He said “Make sure the program contains rigorous academics. There is a focus nationally on exposing students to content and making things relevant for them. This is not enough. They will not be able to get into STEM programs at institutions of higher education. Make sure the program is rigorous and have clear expectations. If students do not have the technical abilities, they can learn. They must have a deep understanding of math and science content.” The principal has high expectation for students and staff members. “When students have to pass pre-calculus, it's not a watered down version of algebra 2" (personal communication, January 12, 2009).

The faculty and staff at PHS have made a lasting difference in the lives of students who attend. The principal states, "We impact students every day in terms of their dreams. Many of our students never thought they would go to college and they are there today" (personal communication, January 12, 2009).

#5 Einstein High School

School Background

Einstein High School (EHS) started in the fall of 2006 with only 100 ninth-grade students and added other grades in the following years. It is currently in its third year of operation and is the result of a unique partnership between a major corporation in this city, the State University and the education council, which is a consortium of 16 school districts in this city. It is a small 100 students per grade, and intellectually vibrant learning community serving grade 9-12 students in this county. It emphasizes college readiness in mathematics, science, engineering, and technology. EHS is operated by the educational council and receives funding for operation from a major corporate sponsor, the state university, and the 16 school districts within this city. Facilities are located in a research park adjacent to the university campus.

School Population and Standardized Testing

Einstein High School serves a very diverse population with 38% receiving free or reduced lunch, which is much lower than the overall district rate of 78%. This school has a higher white and a lower black population than other schools in this district. Table 17 contains statistics documenting the student population.

Table 17

Einstein High School Demographics

Characteristic	School Data	District Data
Enrollment	300	58,961
Charter	No	-
Locale	Large City	Large City
Ethnicity	White: 48% Black: 41% Asian: 6% Multiracial: 5%	White: 28% Black: 62% Asian: 2% Multiracial: 3% Hispanic: 5%
Magnet	No	-
Title I	No	-
Free/Reduced Lunch	38%	78%

Note. Data collected from Einstein school website, 2008 and Newspaper article, July 27, 2008.

In 2007-2008 this state used the State Graduation Test (SGT) to test students in grade 10 in reading, writing, math, science, and social studies. A high school graduation requirement for public schools and chartered private schools, SGT is a standards-based test, which means it measures how well students are mastering specific skills defined by this state. The goal is for all students to score at or above proficient on the test. EHS has the second best passing rate in math, compared with state graduation-test data from the other 16 schools in this district. It currently ranks No. 20 out of 610 schools statewide (Newspaper article, July 27, 2008). Although it is difficult to compare school test scores without controlling for differences in population, we can confirm from the test scores in Table 18 that students enrolled at EHS have mastered the state-required content. Students at this school scored 10% higher in English and 18% higher in math than the state average.

Table 18

Graduation Test Results

School	Reading (2008)	Mathematics (2008)
School A	98	98
Einstein HS	95	97
School B	98	96
School C	96	96
School D	96	95
School E	94	93
School F	91	89
School G	93	88
School H	96	87
School I	90	87
School J	90	86
School K	82	86
School L	88	84
School M	82	78
School N	72	69
School O	81	65
School P	72	58

Note. Scale % passing. Data collected from State Department of Education website, 2008.

Influence of the Mission Statement

Einstein High School's mission is to produce independent thinkers who are intellectually curious and committed to making a difference. This mission is turning college aspirations into reality through person relevance, academic rigor, and transformative relationships. Its mission is to personalize learning so each child can succeed. To fulfill this mission, students are provided long blocks of time in integrated courses of study to allow for deep inquiry and the development of strong student/teacher relationships. Students are provided extensive feedback about what he/she is doing well and given suggestions for improvement. The advisory program assures that each student has an adult who serves as a student advocate. Learning centers across the community during the junior and senior year are selected by the student and are interest driven (Einstein school website, 2008).

Student Selection Process

Students are selected via lottery from the 16 participating school districts. EHS will phase in enrollment with a maximum capacity of 400 students. The number of students attending this school from each of the 16 school districts will be determined on a formula based on district size and student interest. The school is not necessarily for the highest-scoring students. Those with good basic skills and a passion for science and math will be considered the best candidates. Students who want to focus on the STEM disciplines will have the chance to learn in a place designed and overseen by a major university and a world-class science-and-technology research institution. Interested students must complete an application, including an essay explaining why they want to attend EHS, and interview with the staff. Students must complete a questionnaire about themselves, and parents must sign a release of records form. Guidance counselors must forward a transcript of grades, attendance records, achievement tests, health record, and IEP or 504 plans if applicable (Einstein school website, 2008).

Academic Programs and Graduation Requirements

All students engage in a personally relevant and academically rigorous curriculum within a safe and trusting environment. Students participate in an integrated curriculum that fosters critical thinking, creativity, and communication. School hours are from 8:00 a.m. to 2:25 p.m. Students have three career shadowing days in which they spend the day with someone in their potential career path.

The learning experience is divided into two distinct developmental phases: preparation and exploration. During the core preparation phase, 9th and 10th grade students focus on learning that promotes performance. Students demonstrate performance in math, science, social studies, and language arts. Student performance is measured by successful passage of the state graduation tests and performance tasks that show student's ability to work independently and in group environments as they investigate solutions to real-world problems. Students spend long blocks of time in integrated courses of study. The advisory program assures that each student has an adult advocate. Students in the 9th and 10th grade can earn up to five high school credits in mathematics based on mastery performances in Algebra I and II, Advanced Geometry, Statistics, and Trigonometry. Students can earn up to five credits in physical science based on performance in physics, natural resources, systems and engineering, biology, earth and space science, chemistry, and principles of engineering. Student may earn up to five credits in language arts in 9th and 10th grade. Social science coursework begins in the 10th grade. Students take quarter credit courses in research, social, emotional, and physical well being, Students can earn credits in Spanish or Chinese languages and the arts. Freshmen take math, language arts, science, social studies, and foreign language. Math lasts for two hours each day and begins at the Algebra II level (newspaper article, July 27, 2008).

This school is unique in that 11th and 12th graders participate in hands-on, self-directed learning outside the classroom with teachers and mentors from the community. Students participate in mentoring and internship opportunities where they are paired with scientists from the corporate sponsor. The state university uses the school as a research and development site. These experiences are more than traditional internships; students engage in problem solving, critical thinking, and creative innovation. Students create portfolios through their academic career, which demonstrate the evolution of their skills and knowledge. In the 11th and 12th grades students are required to take engineering. They begin their remaining coursework in one of four different environments: state university coursework, high school coursework, and learning centers or field placement. Students are required to demonstrate their service to the community and their individual research as a graduation standard. Curriculum is modeled after the International Baccalaureate (IB) program and students have the option of completing the IB diploma.

Students who attend this school still participate in extracurricular activities at their base school. They have a dual graduation from this program and their base school.

Professional Development Activities

The school serves as a laboratory for developing the best ways to teach science and math. The school is staffed by teachers from the districts, enabling them to take what they've learned back to their home classrooms (newspaper article, January 24, 2006).

Einstein High School provides time for teachers to collaborate, support for instructional improvement, and encouragement to develop as professional. Providing time for teachers to work together is a priority at this school: "teachers have common planning time every morning." They also spend time in professional learning communities: "during this time we examine student work, peer review lessons, and work on collaborative integrated course projects" (personal communication, January 29, 2009). The principal describes the instructional support provided to the teachers: "Coaching is individually tailored to teachers needs. The coach meets with them one-on-one for an hour, then observes, then works on improvements with the teacher based up their improvement plan" (personal communication, January 29, 2009). The school provides substitutes so teachers can work with their coaches. Teachers are encouraged to develop as professionals. The principal says the "full time teachers are working on national board certification" (personal communication, January 29, 2009).

School Leadership

This school is directed by a visionary principal who is confident and committed to making a difference in the lives of students. She suggests,

> "Be flexible and agile as the best opportunities are not yet known. You are charged with preparing students to innovate and design a world that does not

currently exist. Learn and grow with your team and students, it will be the most rewarding experience you have ever had." (personal communication, January 29, 2009)

6 Galileo High School

School Background

Galileo High School (GHS) is a city-wide high school offering college preparatory and advanced college preparatory curricula emphasizing the study of science, mathematics, and engineering. It draws grades 9-12 students from across its city where they take part in independent research projects in science lasting two or three school years including summers. It was around the turn of the 20^{th} century when the city authorities established an engineering school. The first school building opened with 60 students. GHS became the first high school in the city school system to racially integrate its student body. In 1974 young women were admitted and the school became co-ed (Galileo school website, 2008).

In the fall of 1997, the STEM Project was launched. The project aids in supporting students in grades 6-12 by helping them succeed on Advanced Placement tests and in competitions in math, science, technology, and related fields. A research director position is funded by the project and helps students find their research topics and a local scientist to mentor them at an outside facility (newspaper article, March 27, 2008). A TIMMS grant in 2000 provided the opportunity to wire the entire school complex for Internet access.

School Population and Standardized Testing

Galileo High School serves a diverse population with 35% of its students receiving free or reduced lunch. The principal describes the population as unique due to student demographics and the high percentage of students who pursue postsecondary education. "98% of our students go on to college; most of them go for engineering. I think we are probably uniquely positioned [as] we are about 80% African American and 50% female" (personal communication, January 6, 2009). Table 19 contains statistics collected from two web-based databases defining GHS student population. GHS student body is similar in ethnic background, but has a much lower percentage of economically disadvantaged students.

Table 19
Galileo High School Demographics

Characteristic	**School Data**	**District Data**
Enrollment	1344	87,643
Charter	No	-
Locale	Large City	Large City
Ethnicity	White: 20% Black: 75% Hispanic: 2% Asian: 3%	White: 8% Black: 89% Hispanic: 2% Asian: 1%
Magnet	No	-
Title I	No	-
Free/Reduced Lunch	39%	71%

Note. Data collected January 2009 from National Center for Education Statistics, 2008 and State Dept of Ed website, 2008.

In 2006, this state, located in the mid Atlantic, began using the High School Assessments (HSA) in algebra, biology, government, and English at the completion of each course. Beginning with the class of 2009, students must pass the HSA to graduate from high school. Students taking the HSA receive a scaled score for each test they take. The goal is for all students to pass the tests. Table 20 contains the percentage of 10th grade students who passed the algebra and English HSA or mod-HSA. The mod-HSA is an alternative test for students with disabilities who meet specific participation requirements based on their Individualized Education Plans (IEP). Students who do not pass the tests are given additional opportunities to retake the test (State Department of Education website, 2008). The school district in which Galileo resides is very large with more than 35 public high schools who participated in the HSA exams. There is a very large range in scores between the highest and lowest performing schools in this district. In 2008, there was a 100% difference in the algebra scores and 96% difference in English. Several schools in this district have made significant improvements in HSA test scores between 2006 and 2008. In 2008, students at Galileo outperformed all other schools in its district in algebra, and it had the third highest scores in English. Although it is difficult to compare school test scores without controlling for differences in population, we can confirm from the test scores that students enrolled at GHS have mastered the state required content.

Table 20

HSA Test Results

School	Algebra (2008)	Algebra (2007)	Algebra (2006)	English (2008)	English (2007)	English (2006)
Galileo HS	100	86	93	92	98	91
School A	97	66	83	96	90	85
School B	92	63	66	95	91	85
School C	91	71	87	63	40	51
School D	90	72	86	84	91	83
School E	88	32	26	78	54	68
School F	86	40	41	67	68	35
School G	85	65	86	70	75	73
School H	76	44	50	64	61	41
School I	75	33	35	67	57	30
School J	74	23	43	62	52	41
School K	68	31	-	41	65	-
School L	66	21	-	58	42	-
School M	62	12	-	67	30	-
School N	59	27	26	32	30	18
School O	57	16	-	63	46	-
School P	56	24	22	30	33	23
School Q	55	28	40	32	36	29
School R	54	31	26	41	37	23

School S	46	14	18	39	28	23
School T	45	21	25	34	29	18
School U	43	30	-	40	35	-
School V	43	13	32	29	35	14
School W	36	14	54	38	60	40
School X	32	12	-	23	29	-
School Y	31	18	20	31	32	23
School Z	30	9	-	27	28	-
School AA	30	8	-	25	21	-
School BB	28	12	25	33	40	16
School CC	27	11	19	22	23	25
School DD	22	11	12	23	21	25
School EE	0	10	-	-	8	15
School FF	0	10	14	-	23	19
School GG	0	3	4	0	7	11
School HH	-	15	-	-	33	-
School II	-	5	6	-	14	3
School JJ	-	2	-	-	26	-

Note. Scale % of student scoring at or above proficiency level. Data collected from the State department of education website, 2008.

Influence of the Mission Statement

The Galileo High School mission is “to create the next generation of world leaders.” In order to accomplish this, “leaders should understand many things including science, technology, engineering, and math” (personal communication, January 6, 2009). All GHS staff and community members understand this and it is embedded in the entire school culture.

> We live and breathe STEM it’s not just a program. It’s what we do, we’re known as the science and engineering and math school, so our students traditionally have gone on to become engineers, scientist, mathematicians. (personal communication, January 6, 2009)

To support this goal GHS has implemented the STEM Project, which is focused on preparing highly capable and motivated secondary students to achieve at nationally competitive levels in mathematics, science, research, and technology. The expectation is that STEM students will take AP courses during high school, work with scientist mentors to develop independent research projects, and submit their work to national competitions. One of the competitions that students at GHS participate in is the Intel science competition, which is America’s oldest and most highly regarded pre-college science competition, consisting of original research projects resulting from inquiry-based learning demonstrating how math and science skills are crucial to making sense of today’s technological world (Society for Science and the Public, 2008). GHS students have been successful in this highly competitive competition. “We are the only urban public school to have a student in the top 10 for three consecutive years" (personal communication, January 6, 2009).

Student Selection Process

GHS is a selective public high school with admissions based on criteria favoring good grades and recommendations by their middle school teachers and counselors. "We look for students who have shown aptitude in math and a love for science; also, students who are serious about school" as reflected in good attendance in middle school (newspaper article, March 27, 2008). Students residing in this city and surrounding counties are eligible to apply. Selection is based on the completed application and the composite score. Application documents consist of teacher recommendations from science and math teachers, one community person, and a principal or guidance counselor recommendation. All qualified applicants are invited to take the admissions test, which is held in January (Galileo school website, 2008). Applicants to the STEM program must meet the following criteria to be eligible for the admissions test. Requirements for admissions include: Overall average of 80% or better, 80% average in both math and English, rank of 65th percentile or better in math and English on standardized tests, 90% or better attendance rate (Galileo school website, 2008). Students are given a composite score by combining, math, science, Terra Nova, and attendance scores.

Galileo High School has more applicants than it can accommodate.

> Every year we have about 320 students on a waiting list. This year we've accepted 525 students. They meet eligibility requirements but we do not have enough space to admit them…students who are close to the cut off are encouraged

> to keep their grades up at their current school and are encouraged to reapply in the 10th grade. (personal communication, January 6, 2009)

Academic Programs and Graduation Requirements

Once students enroll in GHS academic expectations are high when it comes to content area knowledge “we do not assume that they know it [algebra I]. We test them when they get here. Even though they may have earned a high school algebra credit in middle school, unless they pass an in-house test they are not given a credit” (personal communication, January 6, 2009).

Distinguishing characteristics of the GHS academic program include accelerated math courses. Students must complete Algebra I before entering the 9th grade. During their 9th-grade year students take algebra 2 and biology. They also take a yearlong course on the Foundations of Technology. This course gets students to consider technology as more than iPods or flat-screen TVs; they study the history of technology and explore its relationship to engineering, as well as to science and math (newspaper article, March 27, 2008). Every freshman learns how to fly an airplane.

> We have is an aerodynamics and flight simulation lab where every freshman learns all of the physics involved in flying. That’s a lot for freshmen; first of all they don’t expect to learn how to fly an airplane. If you want to capture the mind, you have to create things that are exciting. You have to come up with creative ways to create these labs. (personal communication, January 6, 2009)

Other academic program features:

- Double periods for science courses to accommodate lab/research sessions;

- research under the direction of mentor scientists;
- SAT IIs at the completion of each science course;
- AP courses;
- Math competitions including state mathematics league, American invitational;
- mathematics exam, university mathematics competition, and others;
- Science Competitions including Intel Science talent search, Siemens Westinghouse Science and Technology competition; university science fair;
- Computer lab open during lunch and after school;
- Additional assistance for individual students as needed.

(Galileo school website, 2008)

GHS gives students a chance to explore a wide range of subjects in grades 9 and 10. By junior year students must select one of two tracks, science or engineering. Table 21 lists the two options available to juniors and seniors. The science track includes the opportunity to conduct research under the mentorship of a professional scientist in the local area. Both tracts aim to mold students to think scientifically, put things in perspective, and to solve problems (newspaper article, March 27, 2008).

Table 21

GHS Course Options for Science and Engineering Tracks

Science Course Options	Engineering Course Options
Chemistry, Organic Chemistry, AP Chemistry, Marine Biology, Biology, AP	Engineering Practicum, Electricity/Mechanics, Surveying,

Biology, Physics, AP Physics, Electricity, Environmental Science, Genetics, Anatomy/Physiology, Earth Systems or Science Research	Architectural Drawing, CAD, and Environmental Science, AP Chemistry, AP Physics

Note. Data collected from Galileo school website, 2008.

Successful students report that most nights average three hours of homework, 30 minutes per class. However, projects and research assignments often require additional time. The school day begins at 8:15 a.m. and ends at 3:05 p.m. Students are expected to attain an 80% average or above in all coursework. Students not showing consistent effort to meet the standards will be asked to have a meeting with their parents and school personnel. Students who are continually unable to meet the demands of the program will not reenter the subsequent year (GHS website, 2008).

Each June of the students' high school career, their academic records are reviewed. Students who demonstrate success are invited to remain. Any student who accumulates three or more credits of failures is automatically reassigned to another high school. Students receiving failures in one or two courses are provided remediation in order to remain in the program. Programs at this school exceed state requirements (GHS website, 2008).

There is a cohesive academic plan, and teachers work together to design and assess student progress. Deliberate effort is made to control the quality of the material students receive. "We have academic freedom, teachers are free to follow their syllabus, and that is a social contract. Teachers must follow the syllabus and meet the norms of their department. They have departmental expectations that no matter which class a student takes, if it's the same class taught by different teachers, everyone should be able to pass the same exam. Although teaching styles are different; expectation is that students will master content is the same" (personal communication, January 6, 2009).

Professional Development Activities

Hiring and training teachers in STEM content areas has been a challenge for many schools systems. The principal describes faculty as a key component to the success of this school. "It starts with quality teachers. One of our hindrances to growth is finding teachers who truly understand rigor; we search the country for teachers" (personal communication, January 6, 2009). Once teachers are hired, GHS provides support to new faculty members,

> We have a new teacher orientation, and that's a three-day orientation. We pair the teachers up with buddies or mentors. We also encourage the teachers to visit other teacher's classrooms, both within their disciplines and outside disciplines. So it would not be unusually for a math teacher to visit an art class or computer animation class just to see how creativity and rigor work in another content area, and to see how some of the same students who they may be challenged with are excelling in other classes. (personal communication, January 6, 2009).

School Leadership

When asked to provide advice to new administrators seeking to begin a new STEM school, the principal focused on three things: competent staffing, innovative academic programs, and a belief in students. He advised new administrators to "hire competent and confident teachers then give them autonomy; empower them to do their thing, to really excel in their fields, and pass it on to the next generation" (personal communication, January 6, 2009). He explains how new and innovative academic program ideas are born.

> I personally visit colleges and universities that I respect to see what students really want to do. I find that students who are in engineering programs are in the fine arts buildings where you may have computer graphics and animation, different software packages than are in the engineering department. I am able to create a lot of interdisciplinary labs by visiting schools like Carnegie Mellon, Georgia Tech, and MIT. We have created a "ROB-ART" lab combining robotics and art, where the art will push technology and technology will push the art. Look at how curriculum comes together. Our latest focus is to create the next generation of world leaders who understand the linkages between business and engineering or business and math so we are creating a group called "GI" (G-Inc.) encouraging students to become entrepreneurs by thinking it, creating it, and shaping it. (personal communication, January 6, 2009)

He identified the constraints of designing new and innovative programs "No one has the budget to do this" and challenged new administrators to,

> Go out and find the means to get it done. Principals who want a creative environment cannot live within their means. You have to go way beyond it. Imagine it, and then make it happen. The same principles we teach in engineering

> are the same business principles that are needed to run an effective school. (personal communication, January 6, 2009)

The principal at GHS is passionate about students. He states,

> The students love when you love them. When you believe in them and you tell them that they look brilliant, they walk brilliant, they walk like they are going somewhere. They will perform higher. So we certainly created an environment where the students know we care about them. (personal communication, January 6, 2009)

He contributes his schools success to faculty who “are truly committed to developing the next generation of leaders.”

#7 Plato High School

School Background

Plato High School (PHS) is a new school located in a small city in the southern region of the Unites States. It is a nonprofit charter school management organization dedicated to improving public education. In July of 2008, the school management organization opened the public charter elementary, middle, and high school under a five-year charter granted by the state board of education. All three schools are open enrollment, publicly financed schools, meaning any school-aged child in this state is eligible to attend. As public schools, the public charter school is tuition-free (PHS website, 2008). Twenty public charter schools were operating in this state during the 2007-2008 school year. Ten of these charter schools were “conversion” charters that continue to enroll only students in their surrounding neighborhood. The other 10 schools were “open enrollment” charters authorized to admit students from anywhere in the state. (Costrell & Wolf, 2009)

Plato High School is located in a historic building. It has retained all of its architectural beauty outside, but inside it has been transformed into a state-of-the-art school. Many believe the school will offer a more advanced education than the traditional public school (news article, July 14, 2009). Parents are responsible for transporting their children to and from school. However, PHS will pay for a monthly bus pass for students using the city transit bus system (PHS website, 2008). PHS is a community-supported school, and each family is expected to either perform 10 hours of credible service during the school year or contribute $100 to the school.

School Population and Standardized Testing

Plato High School, currently in its first year of operation, has 86 ninth-grade students in the high school. Students will continually be admitted throughout the first year so reliable demographic data were not available. This school is located in a city that has a high percentage of minority and economically disadvantaged students. Table 22 contains statistics documenting PHS student population.

Table 22

Plato High School Demographics

Characteristic	**School Data**	**District Data**
Enrollment	86	26,757
Charter	Yes	-
Locale	Small City	Small City
Ethnicity	*	White: 24% Black: 69% Hispanic: 5% Asian: 2%
Free/Reduced Lunch	40%	58%

Note. Data collected January 2009 from PHS website, 2008.
*New school opening, data was not available.

Students in grades 3 through 8 take the state benchmark exams in March of each year. Also in March, students enrolled in Algebra I, Geometry, and Biology take the Arkansas End of Course exams. PHS administers standardized reading, language, and math tests four times annually. The results of the assessments enable PHS teachers and parents to compare their student's score with the scores of students in the same class and grade level, and with students nationally who took the same test. These assessments provide teachers with information to effectively design instruction to meet particular student needs and demonstrate student academic achievement (PHS website, 2008). PHS is currently in its first year of operation. Currently no standardized test data is available for this school.

Influence of the Mission Statement

The mission at PHS is to provide students with 21st century skills in the study of economics as it relates to the fields of science, technology, engineering, and mathematics. "Maintaining scientific and technological leadership is essential to the future of our region and our country" (PHS website, 2008). The goal of PHS school is to produce high school graduates who are STEM literate and capable of keeping pace with foreign competition (PHS website, 2008). "Student achievement is the focus of everything we do." To accomplish this mission, teachers are focused on individual student academic growth. An ongoing assessment program enables teachers to evaluate a student's progress. Every teacher teaching a core curriculum subject is certified by the state to teach that subject. This school is focused on providing a safe and orderly school environment and has a strict dress code and expects good student behavior. The school enjoys strong academic leadership focused on student achievement without the burden of a large, expensive bureaucracy (PHS website, 2008).

Student Selection Process

Plato High School is currently offering seats to students who are in the 9th-grade only. In the 2009-2010 school year, PHS plans to add a 10th-grade class and continue every year until it reaches the 12th grade in the 2011-2012 school year. This first year, PHS has welcomed 856 students in grades 1 through 9. More than 2,200 students applied for spots, and more than 1,000 are still on a waiting list (news publication, July 14, 2008).

Parents applying for student admission for the 2009-2010 school year must submit a preliminary application by February 2009. Students are assigned to 10th-grade seats one of two ways: Students already on the 9th-grade waiting list will be transferred automatically to the 10th-grade waiting list. The student's position on the 2009-2010 waiting list remain the same as the student's position on the waiting list on the final day of the 2008-2009 school year. A student who is not on the waiting list will have the opportunity to submit a preliminary application for any available seat in 10th grade for the 2009-2010 school year (PHS website, 2008).

PHS admits students of any race, gender, age, sexual orientation, religion, national origin, and disability or handicap to its educational program. Unlike other public schools, a charter school is populated by students who have freely chosen to attend that school. Students who choose to accept the academic program of a charter school also assume the obligation imposed by the policies of the school (PHS website, 2008).

Academic Programs and Graduation Requirements

"[There is a] very focused curriculum that deals with science, technology, engineering, and mathematics. For example we'll be using Singapore math, which is a very focused mathematical model," said Mittiga (newspaper article, July 14, 2008). Students at PHS attend school for 198 days, which is 20 days longer than the traditional school year that the state of Arkansas requires that all students attend. Additionally, students have the opportunity to receive instructional support during the extended day period which runs from 3:30 to 5:00 p.m. each day. Teachers are available to work with students to ensure that they are able to ask questions and obtain clarification on concepts before they go home each day (PHS website, 2008).

The academic program at PHS is a rigorous, college preparatory program that is focused on preparing all graduates to become leaders. “While specific focus is placed on the areas of mathematics, science, and technology, our curriculum is broad and includes a strong emphasis on the liberal arts including foreign languages (Spanish and Mandarin Chinese), fine arts, and history ” (PHS website, 2008). All students at PHS are exposed to real-world economics through a specific progression of courses that will enable students to better understand the way the world works from both a state/local level and from a global perspective.

Students at PHS receive instruction from a highly qualified, dynamic team of educators. One of the unique features of this program is the extended time students are given to master the concepts being taught. Students must successfully complete 30 units in order to receive a diploma from our school. The PHS charter specifies that students will complete the Smart Core curriculum (as defined by the State Department of Education), as well as five additional electives chosen from the areas of mathematics, science, technology, and engineering.

Specific requirements for graduation include the following:

- English - 4 units
- Mathematics - 4 units (must include Algebra 1, Geometry, Algebra 2, and an additional higher-level course)
- Science - 3 units (must include Physics, Biology, and Chemistry)
- Social Studies - 3 units (must include Civics/Govt, World History, and United States History)

- Foreign Language - 4 units
- Economics - 1 unit Engineering - 1 unit Rhetoric - 1 unit Technology - 1 unit
- Physical Education/Health - 1 unit Fine Arts - 1 unit
- Service Learning - 1/2 unit
- Capstone - 1/2 unit
- Electives chosen from Science, Engineering, Technology, Mathematics,
- Economics - 5 units

(PHS website, 2008).

For a student to graduate from PHS, the student must have earned a total of 30 credits as prescribed in school board policies (PHS student handbook, 2008). A student must earn a grade of C or higher to satisfactorily pass a class. If student skills are below grade level, the student may require remedial instruction and will be required to participate in the Prime Time/Enrichment period at the end of the day.

Community service is a critical component of PHS experience. Students are encouraged to participate in service through a variety of clubs and organizations (PHS student handbook, 2008).

Professional Development Activities

PHS rewards teachers for productivity through a merit pay system. The plan, developed with faculty members at the state university, bases teacher bonuses largely on their students' test-score gains. School-wide test scores and evaluations by principals are additional components in the calculation of the year-end bonuses (news article, January 9, 2009). PHS classroom teachers are eligible for bonuses of up to $10,000 on top of salaries that start at $32,486 for those with bachelor's degrees and $37,359 for those with master's degrees. Specialists, such as art and music teachers, can earn up to $6,000, and support staff members are eligible for $1,000 bonuses (news article, January 9, 2009).

School Leadership

According to the principal and executive director of PHS,

> Three factors contribute to the culture of the school. The first is the use of technology in all subjects as a vehicle for learning. Technology is a tool for instruction. Every classroom has a media retrieval system, a projector, and document cameras. We have Smart Boards on every floor, we have writing tablets ... there is so much technology in this building for teachers to use as instruction and also for students to use as a tool for learning. (news article, September 1, 2008)

The principal also points out that the students' daily schedule is just as important as the wide array of technological tools available. Each day students in grades 5-8 go through a core curriculum that includes math, science, English, and social studies for one-hour periods. The remainder of instructional time is spent in elective subjects: art, technology, visual and performing arts, and foreign language.

The instructional school day lasts from 8 a.m. to 3:30 p.m., and an enrichment period extends the school day until 5 p.m. During this time, students can receive extra help with academics or participate in a variety of clubs and organizations. The location of the school is the final ingredient to the academic success of its students. "We have an incredible learning lab right here in downtown [name of city]," principal says. "From here it's a walking field trip in just about any direction for some incredible educational opportunities. The location, for sure, is really going to be something that sets this school apart." And the location, in combination with an academic day that mirrors a traditional work day, provides parents working downtown with a convenient schedule while their children are in school (news article, September 1, 2008).

#8 Marconi High School

School Background

In the 2008-2009 academic year a mid-western school district opened the first incubator STEM school housed on a STEM industry corporate campus. This innovative institution provides students with a dynamic real-world learning environment with a foundation of rigorous STEM based academic principles. Marconi High School (MHS) is a public-private partnership between the metropolitan school district, other school districts, colleges and universities, corporations, and industry partners. More than 55 partners came together to form a creative innovative teaching and learning opportunity for all students across the region. The overall goal of this program is to prepare students to be competitive in today's global economy. Start up funding support came from business community member, Metropolitan Foundation, a private foundation, and the State Department of Education (newspaper article, September 20, 2008).

Unique features of this school include:

- The school is located within an industry campus, which provides students access to internships and apprenticeship opportunities. Students gain firsthand experience in specific professions to assist with career planning decisions (school district website, 2008).

- The school utilizes a year-round academic calendar that more closely resemble a typical business calendar. Students work for 10 weeks then have three weeks off. This facilitates a more productive learning environment and prepares students for what they can expect from "work life" (Marconi school website, 2008).
- The school is partnering with institutions of higher education allowing seniors to take their senior year course load on a college campus while simultaneously earning college credits towards their freshman year. This unique opportunity provides for a seamless transition from high school to college or the workforce (Marconi school website, 2008).

School Population and Standardized Testing

Marconi High School serves a diverse population with 100% receiving free or reduced lunch. Table 23 contains statistics documenting MHS student population. School demographics closely resemble the district demographics. There are no standardized test scores available for this school at this time.

Table 23

Marconi High School Demographics

Characteristic	School Data	District Data
Enrollment	100 (9th grade only), 150 new freshmen will be admitted. Maximum enrollment will be 550 students.	52,769
Charter	No	-
Locale	Large City	Large City
Ethnicity	White: 15% Black: 72% Hispanic: 8 % Asian: 0% Multiracial: 5%	White: 16% Black: 67% Hispanic: 15 % Asian: 0.6% Multiracial: 2%
Magnet	No	-
Title I	Yes	-
Free/Reduced Lunch	100%	100%

Note. Data collected January 2009 from the school district website, 2008.

Influence of the Mission Statement

The design principles that provide the backbone for this school's design and operation are: Ensure opportunities for all students to be academically challenged while appropriately supported; use multiple metrics to measure success and assess the demonstration of mastery; provide an instructional program that reflects the need for all STEM education to be transdisciplinary; deliver an instructional program that is highly differentiated (i.e., discover, collaborative learning, content integration, workforce relevant and problem-based learning); hire and train a diverse faculty including industry partners, professionals from institutions of higher education and from the skilled trades, and pre K-12 education instructors; engage the community and promote citizenship (school proposal document, January 18, 2008).

The design principles of this school are reflected in the core operating principles for students: Own your own potential, master your own path, make a difference, recognize that problems are sources for innovation, and accept that it is your responsibility to take on issues of sustainability. These principles are reflected in the school environment through student expectations. Students are expected to dress as professionals. This is interpreted as a polo style shirt, khaki pants, and closed-toed shoes (school district website, 2008).

Student Selection Process

Enrollment is opened to anyone interested. Although "testing in" is not required, consideration is given to students who show an aptitude and significant interest in the STEM disciplines. As a regional high school, 25% of the student seats are available to students living outside of this city. Applications are available online. Students are required to submit and online application consisting of basic information and a student questionnaire, i.e., Why would you like to attend MHS? How would your classmates describe you? What accomplishments are you most proud of and why? There is a section for parents to complete asking what they would like the school to know about their child. Students/parents must sign a waiver to release school records (school district website, 2008).

Academic Programs and Graduation Requirements

MHS is not your typical high school campus. Students attend school from 9 a.m. to 4 p.m., but move out of the classroom and into a corporate work environment. During the first three years, students attend classes in the mornings and participate in internships and fellowships in the afternoon. In the afternoon, students are paired in one-to-one internship experiences with members of the corporate workforce, providing mentoring for students and direct access to STEM-related fields and professionals. The sophomore year will be housed on a different STEM corporate campus and continue the 10-week internships. The junior year will be hosted in a downtown facility, with in-depth fellowship experiences hosted by multiple STEM companies throughout downtown, allowing smaller and specialized companies to participate. Each partner company will host a small number of fellows and provide a stipend to each student. The senior year partnership is planned to be near a university to serve as a commuter campus center for students as they begin a full dual enrollment experience for their senior year (school proposal document, January 18, 2008).

The MHS curriculum is developed by a diverse team with members from industry, higher education, and PK-12 education. It is the responsibility of this team to ensure that a rigorous, interdisciplinary, and meaningful curriculum is created that is aligned to the academic content standards and connects to higher education courses (school proposal, January 18, 2008). Curriculum is designed to provide students with an integrated core curriculum that includes field experiences, fellowships, and apprenticeships in STEM fields (school proposal document, January 18, 2008).

In addition to the state standardized tests, students are required to exhibit their learning through multiple formats including: portfolios, exhibitions, experimentation, and performances. Students are exposed to rigorous and challenging college preparatory curriculum. Students are supported by an advisor who communicates with families and works with student on developing leadership skills while monitoring student academic and socio-emotional growth. Scheduled time for advising is devoted to work on portfolios, exhibitions, whole group, and small group activities. Major pieces of student work are assessed with rubrics based on the core operating principles. Rubrics are provided to students before they begin work. Students are required to perform at a 90% success level or greater. Any pieces of work graded lower than 90% is considered a work-in-progress (Marconi school website, 2008).

Professional Development Activities

Regular professional development is focused on cross-training experiences through development of trans-disciplinary instructional units, and systemic strategies for knowledge sharing amongst the STEM disciplines (school proposal document, January 18, 2008).

The professional development plan at MHS includes three significant characteristics: quarterly faculty institutes; daily common collaborative time; and embedded industry internship experiences. A revised teacher workday allows for quarterly one-week STEM development institutes in which STEM partners will engage in the study, evaluation, and integration of relevant and current best practices and research. Specific time is built into the work day for collaborative faculty work sessions. MHS faculty have opportunities during the first year of operation and every four years thereafter to acquire, enhance, and refine their own STEM-related skills in four, individualized 10-week faculty internships (school proposal document, January 18, 2008).

School Leadership

Marconi High School is lead by an innovative leader who is committed to doing whats best for students. He advises, “Explore other schools that have an environment similar to what you are tying to create and network with those schools. Spend the time necessary to ensure that you hire the right people for your school….and always do whats best for kids” (personal communication, January 29, 2009).

9 Euclid High School

School Background

Euclid High School (EHS) is the only school in this study that is located in a rural area. In 2002, the district where EHS is located was designated as a technology corridor. The number of technology companies in this community had grown by 90% increasing the need for employees with technical skills. This stimulated an interest in designing a program for students in this school system to develop skills needed to pursue university degrees in science, technology, engineering, and mathematics. Afterwards college students would return to the community and enter the regional workforce. This school system has developed a rigorous and unique program of study emphasizing the core areas of mathematics and science with an infusion of technology and engineering.

The STEM program at this high school began in the fall of 2007 with grades 4 through 9 with a systematic and accelerated focus on science, technology, engineering and mathematics. Bus transportation is provided at designated hubs for all students enrolled at the STEM school. An advisory group comprising community partners and school system personnel will provide ongoing counsel to the STEM consortium leadership. Their input will be sought for student selection, curriculum refinement, and classroom construction. Funding for this project includes: $1,500,000 local funding, planning grant $25,000 in 2008, state implementation grant of $350,000 in 2008, and an Earmark grant of $487,000 in 2009 (EHS website, 2008).

School Population and Standardized Testing

Euclid High School serves a diverse population with 33% of its student body receiving free or reduced lunch. The principal explains, “In the high school STEM program we have students with learning disabilities. This is not a deterrent for being accepted in the program” (personal communication, January 15, 2009). Table 24 contains statistics documenting student population. This school has a higher minority population than other schools in its district.

Table 24

Euclid High School Demographics

Characteristic	**School Data**	**District Data**
Enrollment	1,683	16,665
Charter	No	-
Locale	Rural/Distant Town	Rural/Distant Town
Ethnicity	White: 51% Black: 40% Hispanic: 4% Asian: 5%	White: 75% Black: 19% Hispanic: 3% Asian: 3%
Magnet	No	-
Title I	No	-
Free/Reduced Lunch	33%	32%
Special Education	13%	13%
Limited English Proficiency	0.7%	0.6%

Note. Data collected January 2009 from National Center for Education Statistics, 2008 and the State Department of Education, 2008.

In 2006, this state began using the High School Assessments (HSA) in algebra, biology, government, and English at the completion of each course. Beginning with the class of 2009, students must pass the HSA to graduate from high school. Students taking the HSA receive a scaled score for each test they take. The goal is for all students to pass the tests. The following table shows the percentage of students who passed each exam. Students who do not past the tests are given additional opportunities to retake the test.

There is a small range is test scores between the highest and lowest performing schools in this district. Table 25 shows the range of scores in algebra is 9% and 12% in English.

The current test score data for this school does not reflect courses taught in the STEM program because data were collected prior to the new STEM course implementation. Although it is difficult to compare school test scores without controlling for differences in population, we can confirm from the test scores that 79% of students enrolled at EHS have mastered the state required content in algebra. This school has made significant improvements in algebra and English. Test scores in algebra have increased by 21% over the past two years. Students scored 15% higher in algebra and 2% higher in English than the state average.

Table 25

HSA Test Results for Euclid High School

School	Algebra (2008)	Algebra (2007)	Algebra (2006)	English (2008)	English (2007)	English (2006)
School A	88	74	62	85	86	77
School B	84	87	74	76	77	63
Euclid HS	79	72	58	73	72	61

Note. Scale % of student scoring at or above proficiency level. Data collected from the State Department of education website, 2008.

Influence of the Mission Statement

The school mission is to provide a continuous pathway of education through opportunity that creates STEM-literate graduates ready to accept the challenges of advanced education and the needs of tomorrow's workforce. This STEM program began in 2007 with grades 4 and 9. The plan is to build the program one year at a time, "so this year we have grades 4, 5, 7, 9 and 10. Next year these students matriculate. By August 2010 our STEM program will be a pipeline system that feeds students from grade 4 all the way through grade 12 designed to accommodate STEM careers" (personal communication, January 15, 2009).

Student Selection Process

Any student in the appropriate grade level can apply for this program. Students wishing to enroll in this program will complete an application packet by February each year. Applications are reviewed by an admissions team comprising educators, administrators and foundation members. Candidates are evaluated based on academic performance, dedication to advanced learning, and desire to pursue STEM careers. Application content includes: state assessment scores, percentile ranking on the State assessments, OLSAT SAI score, report card grades (GPA), participation in competitions and fairs, an essay, student self-assessment, parent recommendation, and an interview (EHS website, 2008).

Academic Programs and Graduation Requirements

Euclid High School offers unique courses in English, science, technology, engineering, and mathematics, giving students extraordinary knowledge and skills, as well as career exploration in numerous science and engineering pathways. The curriculum includes dedicated research classes founded upon the application of mastered material, integrated contemporary technologies, and extensive problem-solving experience. EHS will serve ninth-grade students with teamed mathematics and science teachers offering comprehensive coursework focused on the interrelationships of science, technology, engineering, and mathematics. An inquiry approach to discovering science and engineering concepts through experimentation, modeling, testing, and observation will provide a context for all STEM instruction. Project-based units will provide engineering challenges that require students to apply science and engineering concepts. Mathematics will be used in the analysis of data related to results of experiments and testing of engineering projects. A focus on reading scientific literature and technical writing will enhance students' skills in these areas. Students will be provided access to 21st century learning through infused, interactive technology. Technology will be incorporated through the use of personal computers, probe-ware and data collection instruments, simulation software, and various Internet and multimedia resources (EHS website, 2008).

Students in grades 10-12 will have the opportunity to take several AP courses. Students will develop research skills that will culminate in a capstone project. The daily schedule is similar to existing high school schedules. The significant difference is the daily, rigorous, above-level content and emphasis on interrelated science and mathematics opportunities. In 9th grade students will take a 90-minute block of a co-taught Algebra 2 and Chemistry class; 10th-grade Pre-Calculus and Physics block, and an additional course in Biology and STEM Engineering. Students in 11th and 12th grade will select AP courses from AP Physics, AP Biology, AP Environment Science, AP Chemistry, AP Calculus, AP Statistics, AP English, AP World History, AP U.S. History

(EHS website, 2008). “Students are provided one elective freshman year, one sophomore, one junior, and two senior year. They are pretty booked” (personal communication, January 15, 2009).

Experts at the Naval Air Station assist with projects involving lab work. The culminating senior project will identify a unique problem to study with a comprehensive mentorship with a local science or engineering professional. Successful completion of this program includes 100 hours of independent work, a multimedia presentation, a written summation, and panel discussion. A key feature of this STEM school program is the involvement of local business and industry individuals from science, mathematics, and engineering career fields. Mentors will assist students with coursework offering academic and technical expertise as appropriate, and they provide direction for specific senior project work. Mentors will also visit classrooms and present on selected topics in mathematics, science, and engineering to enhance the instructional program. Mentors may also provide access to their workplace and other sites within their industry or business (EHS website, 2008).

Local business and industry representatives may offer paid or nonpaid internship experience for junior and seniors based on student interest aligned with career pathways in STEM. These experiences will be coordinated by the school system and appropriate businesses. Every effort is made to link the internship with the particular work addressed by the student’s senior project or other research conducted in required or elective courses. Students will strive to identify summer internship experiences that offer authentic work in science, technology, and engineering (EHS website, 2008).

Professional Development Activities

The principal identifies the teaching staff as a key component in this program. "We select the best teachers into this program. Then we get our training on the technology that we are using. There is collaborative training for teachers throughout the year and in the summer. We emphasize a team atmosphere" (personal communication, January 15, 2009). Teachers are responsible for selecting curriculum, developing and delivering integrated lessons, and assessing students: "we have core learning goals for the state that we must accomplish but after that teachers have been granted permission to enhance the program as appropriate" (personal communication, January 15, 2009). There is a coordinated effort at the county level to monitor student progress with common midterm and final exams,

> The STEM students take the same mid-term and final exam as the rest of the student population, so we have data to compare their performance to other students. This is a county-wide initiative. All students within the county take the same assessments for mid-terms and finals in academic courses. (personal communication, January 15, 2009)

The administration organized the master schedule to support teacher collaboration and student academic coursework,

> The STEM portion of the master schedule was the first thing that we nailed down last summer, and we set it up so students move together and put their daily schedule together in a way that we knew would work. Also the other part for teachers was common planning time. We keep STEM students together with the

> same instructors. For nonscience and math classes, students are integrated into the school population. (personal communication, January 15, 2009)

School Leadership

When asked to provide advice to new administrators seeking to begin a new STEM school, the principal focused on the value of teamwork, communication, and the importance of teacher planning time. She advised new principals to have regular communication with school and central office staff. “The vision for the program needs to be clear to everyone, and all of the responsibilities have to be clearly designated. Everyone needs to be familiar with the chain of command. Identify who is responsible for which contribution of the program” (personal communication, January 15, 2009). She also emphasizes the importance of knowing and appreciating the skills of a large team of individuals who are involved in making the program successful: “Be very organized and mindful that a lot of different people are going to have their hands in this project. The principal is not the only person contributing really great ideas.” You will need a diverse team of individuals to make a program like this a success,

> Transportation logistics were huge for us. Not only the expense, the logistics of it. How are we going to get all of these students from three different high schools to one school by 8 a.m.? The poor guy from transportation has to find a way to get this all to work. A large part of our budget goes to transportation. We find that most of our STEM students are very involved in afterschool activities. (personal communication, January 15, 2009)

Teachers need to have some designated time of the day when they can plan and collaborate, “This is critical because the idea that they are going to teach lessons together, i.e., chemistry and Algebra 2, plan talk about things, assessments. That’s the piece that is the most important one of all. Give them time to be creative, collaborate, and plan together” (personal communication, January 15, 2009).

The principal and staff at EHS value the school community, work tirelessly to give back to it, and are committed to providing the best possible preparation for their students. “We are hoping that some of our students will stay within the county. Go get the appropriate degrees and training then return here to work for the Navy or medical community” (personal communication, January 15, 2009).

#10 Pascal High School

School Background

Pascal High School (PHS) is located in the Southeastern part of the United States and is a collaborative program involving the county school district, a university center for automotive research, a college of health, education and human development, and a college of engineering and sciences. The purpose of this partnership is to develop an education program that serves as a national model for effectively educating PK-12th grade students in science, mathematics, and pre-engineering; training preservice teachers in mathematics, sciences, and pre-engineering; and providing in-service training for existing teachers in science, mathematics, and pre-engineering. This initiative is divided into three phases. Phase I focuses on creating evidence-based curriculum, Phase II is an expansion of the program to other schools in this district, and Phase III is the development of an elementary and middle school program (community report, August 6, 2006).

Pascal High School has received numerous awards including JROTC, parent involvement, school website, a Red carpet school award, and a character building award. They have received an excellent overall rating in school performance for the past five years. Ratings are determined by: graduation rates, passing standardized test scores, advance placement participation, advance placement success, student and teacher attendance rate, student drop-out rate, teachers with advanced degrees, and students enrolled in career and technology courses (PHS website, 2008).

School Population and Standardized Testing

Pascal High School serves a diverse population with 24% receiving free or reduced lunch. Table 26 contains statistics documenting the student population. Demographics at this school are similar to other schools in its district with the exception of economically disadvantaged students.

Table 26

Pascal High School Demographics

Characteristic	**School Data**	**District Data**
Enrollment	1,335	67,551
Charter	No	No
Locale	Small City	Small City
Ethnicity	White: 58 % Black: 35%	White: 62% Black: 28%

	Hispanic: 5% Asian: 2%	Hispanic: 8% Asian: 2%
Magnet	No	-
Title I	No	-
Free/Reduced Lunch	25%	39%

Note. Data collected January 2009 from National Center for Education Statistics, 2008. and School Data Direct, 2007.

The High School Assessment Program (HSAP) was given to students in grade 10 in English/language arts and math. High school students must pass the HSAP in order to receive a diploma. High school students taking the HSAP are assigned one of four achievement levels: 1, 2, 3 or 4. Students must receive a score of 2 or higher in each subject in order to meet standards and pass the test. This state also administered the End-Of-Course Examination Program (EOCEP) in algebra 1/math for the technologies 2, English 1, physical science, and U.S. history and constitution upon completion of each course. The school district in which PHS resides is large with more than 16 public high schools participating in the state exams. In 2007, PHS was the 5th highest scoring school in English and 6th highest in math in this school district. Table 27 indicates that, in 2007, there was a difference of 86% points in students who passed the math exam and 47% in English. In 2007 many schools, including PHS, saw a decline in math scores. Although it is difficult to compare school test scores without controlling for differences in population, I can confirm from the test scores that students enrolled at PHS are mastering the state required content.

Table 27

10th-Grade HSAP Results

School	English (2007)	English (2006)	English (2005)	Math (2007)	Math (2006)	Math (2005)
School A	100	99	98	99	98	98
School B	97	94	98	92	92	92
School C	93	90	92	85	88	84
School D	93	92	93	85	85	85
Pascal HS	90	90	91	80	88	82
School E	90	89	90	77	83	79
School F	89	90	93	81	84	78
School G	89	82	84	81	78	72
School H	88	87	86	79	79	77
School I	87	86	80	76	76	63
School J	85	80	86	70	70	77
School K	83	82	82	71	69	73
School L	80	79	81	67	69	60
School M	79	72	70	56	59	48
School N	76	73	71	63	58	50
School O	53	36	N/A	13	18	N/A

Note. Scale % passing. Data collected from the State Department of Education website, 2008.

Influence of the Mission Statement

The mission of Pascal High School is to provide each student with the opportunity to become lifelong learners by nurturing students' individuality, guiding students' learning, and challenging students to think critically through the shared involvement of teachers, administrators, parents, and the community. Any student at PHS may choose to follow the track that leads to a diploma with magnet distinction. Students attaining this honor are recognized and a special medal to wear at graduation (PHS website, 2008).

Student Selection Process

There is an application process for students who want to attend PHS. The application consists of parent and student demographic information, grades, attendance, a written statement by the applicant, and discipline records. Siblings of magnet students who will return the following school year are given priority in acceptance. They must complete the application and earn the minimum qualifying score, depending on program level. The random lottery is used to determine the order in which students with the same scores are assigned slots. Beginning with those students with the highest score and decreasing to students with the minimum qualifying score, students are accepted into the school's magnet program until all allocations are filled. Students who apply and meet the qualifications for admission are placed on the wait list into first semester of the next school year. Parents of private and out-of-district schools are welcome to apply and must submit all required documents prior to the deadline. Transportation is currently available for magnet students who indicate their request while completing the application (PHS website, 2008).

Academic Programs and Graduation Requirements

Students pick a cluster of study and set up individual graduation plans. Students can choose from one of the following career clusters: Agriculture, food, and natural resources; architecture and construction; arts, technology and communications; business, management, and administration; educating and training; finance; government, and public administration; health science; hospitality and tourism; human services; information technology; law, public safety, and security; manufacturing; marketing, sales, and service; science, technology, engineering, and mathematics; transportation, distribution, and logistics (PHS website, 2008).

The 24-unit requirement for a Magnet Distinction diploma includes: 4 units of English, 5 units of math (must include at least one AP course in math, or computer science); 7 units of science and technology (must include at least one AP course and 1 semester in programming); 3 units of history/government; 1 unit of PE; 3 units of foreign language, and 1 unit of creative arts. In addition to courses, students must complete a senior project in math, science, or technology (PHS website, 2008).

As part of the Magnet Academy program of study, PHS offers a Senior Project class, which guides the students in preparing and presenting a cumulative project their senior year. This project includes an idea of the student's design and some community involvement with a teacher's guidance. It is not necessary to be in the class or to be in the Magnet Academy program to participate in Senior Project (community report, 2006).

Pascal High School Academy offers an array of AP courses taught by highly qualified instructors. A number of these faculty members hold doctorate degrees and have taught at the college level. Maximum use is made of technology in AP classes, as well as the mathematics courses which are preparatory to AP. In addition to traditional and AP courses, this school offers genetics, microbiology, meteorology, astronomy, geology, environmental science, and marine science. Computers, as well as hand-held technology (graphing calculators and calculator-based laboratories), have become an ever-increasing part of the learning environment at the school (PHS website, 2008). In addition to the academic courses offered, students have many opportunities to participate in sports and extracurricular activities.

Professional Development Activities

Selected educators at this school are members of a curriculum planning committee, which collaborates with university partners. Integrated inquiry experiences are provided at PHS. University engineers will work with the classroom teachers to provide rich real-world experiences and opportunities for students to understand and utilize basic and advanced math and science principles.

Results

The following results answer the question: What are the characteristics of STEM focused high schools?

Research Question 1: What content in the schools' missions influenced the establishment of the schools?

The STEM high schools in this study had a variety of mission statements guiding their programs. The mission statements for each of the schools were different, but there was a clear connection between the mission statement and characteristics of each program designed. Table 28 lists the content in the statement that is connected to specific characteristics implemented in each of the programs. The STEM schools all had one goal in common: they all strived to improve the academic preparation of students in STEM fields. The way they approached this goal was different, and their mission statements emphasized the focus of their efforts, which included increasing STEM skills, providing rigorous academic standards, personalizing learning, creating leaders, and increasing the number of minority and economically disadvantaged students in the STEM workforce pipeline.

Table 28

Distinguishing Characteristics of STEM Programs that Were Influenced by the Mission Statement

School	Content in mission statement	Distinguishing characteristic implemented in the program.
Archimedes	To increase student achievement	• Integrated a rigorous college preparatory and STEM curricula taught by master teachers. • Provided a learning environment that utilized technology to support academic achievement. • Project-based curriculum that is rigorous and has job skill development of a technical program.
Boyle	To serve a student body that mirrors the ethnic and socioeconomic diversity of the community. To provide students with rigorous and relevant academic and workplace skills, preparing its graduates	• Used a computerized lottery generated by zip code to ensure that the student body represents the socio-economic and cultural diversity of the community. • Provided curriculum that is rigorous and engaging with performance-based assessment. • Provided internships for students and

	for success in an increasingly technological society.	close links to the high tech workplace.
Priestly	To ensure that each student achieves their own personal vision.	• Offered a variety of programs students can select from to pursue their own personal vision, including performing arts, engineering, and visual arts.
Pythagoras	To increase the number of women, minorities, and economically disadvantaged to attain college degrees. To provide a diverse student body with an outstanding liberal arts education with science and technology focus.	• Admits 40% low income. • Provided rigorous college prep curriculum. • Provided a laptop or tablet computer. • Academic programs that are focused heavily on content and exceed state requirements.
Einstein	To personalize learning so every child can succeed. To produce independent thinkers who are intellectually curious and committed to making a difference.	• Advisory program assures that each student has an adult who serves as a student advocate. • Students are provided long blocks of time in integrated courses of study to allow for deep inquiry and develop strong student/teacher relationships.
Galileo	To create the next generation of world leaders.	• Focused on achievement at nationally competitive competitions in math, science, research, and technology. • Students are required to take AP courses. • Students work with scientist mentors to conduct independent research projects.
Plato	To provide students with 21st century skills in economics as it relates to the fields of science, technology, engineering, and mathematics.	• Focused on student achievement and individual student academic growth. • Used ongoing assessment to measure growth. • Provided elective courses in economics.
Marconi	To ensure opportunities for all students to be academically challenged while appropriately supported.	• Provided an instructional program that reflects the need for all STEM education to be transdisciplinary. • Delivered an instructional program that is highly differentiated.

		• Used multiple metrics to measure success and assess the demonstration of mastery. • Hired and trained a diverse faculty including industry partners, professionals from institutions of higher education and from the skilled trades.
Euclid	To provide a continuous pathway of education that creates STEM literate graduates.	• Built a STEM pipeline that spans from grades 4-12.
Pascal	To provide students with the opportunity to become lifelong learners by guiding students learning, and challenging students to think critically through the shared involvement of teachers, administrators, parents and the community.	• All students are provided opportunities to follow the diploma with magnet distinction tract. • Students pick a career cluster of study and set up individual graduation plans. • Students are provided challenging curricula including AP courses and complete a senior project involving community members and teacher guidance.

Research Question 2: How are students selected to attend the STEM schools?

A variety of criteria were used to select students to attend each of the STEM high schools. All of the schools in this study had an application form that was required to be considered for admissions. Additional documents requested from students are listed in Table 29. Six out of ten required academic transcripts and attendance records. Only one school required a teacher recommendation while 50% of the schools required a parent recommendation or statement. Eight out of ten schools required a student interest questionnaire or essay. Only three schools required an interview, and three required a proof of residency. Once students submitted the requested documents, the selection process began. Half of the schools in this study admitted students based on a lottery system. Two of the schools were in the first year of operation so were able to accommodate 100% of the applicants.

Galileo was the only school that was specific about the role that grades played in the admissions process. It was the only school that required a placement test. This school required students a grade point average of 80% or higher in academic courses. Five other schools required academic transcripts requirements but did not have any specific grade requirements.

Table 29

School	Applic ation	Acade mic Record	Atten- dance	Teacher Recom- mendation	Inter- view	Proof of residency	Parent recom- mendation	Student interest essay/ question naire	Other
Archimedes	√	√	√	√	√	√	√	√	Required orientation, summer session, sign a contract.
Boyle	√					√		√	Computerized lottery by zip code
Priestly	√					√	√		Lottery system used for selection
Pythagoras	√							√	Random lottery (1/3 chance of acceptance)
Einstein	√	√	√					√	Lottery
Galileo	√	√	√					√	Admissions test required, 65% of applicants are admitted.
Plato	√						√		New school opening, all applicants accepted
Marconi	√	√	√				√	√	
Euclid	√	√	√		√		√	√	
Pascal	√	√	√					√	Random lottery

Research Question 3: What student populations do the STEM schools serve?

STEM high schools serve students from a broad range of backgrounds, from various different ethnic groups. When considering the students served at each of the STEM high schools, the overall average of each ethnic group is as follows: White 32%; Black 50%; Hispanic 12%; Asian 5%; and 1% other. Archimedes and Galileo had the largest number of black students with 97% and 75% respectively. The school with the largest white population was Pascal with 58%. Priestly High School had the largest Hispanic population with 40%. The Asian population was the smallest represented with Boyle HS containing the largest group of 17%. Table 30 contains the percentage of students in each ethnic group.

Table 30

Percentage of Students in Each Ethnic Group

Schools	**White**	**Black**	**Hispanic**	**Asian**	**Multi-racial**
Archimedes HS	0.3	97	1.6	0.8	0.3
Boyle HS	51	12	19	17	1
Priestly HS	8	49	40	3	0
Pythagoras HS	35	34	26	5	0
Einstein HS	48	41	6	5	0
Galileo HS	20	75	2	3	0
Plato HS					

Marconi HS	15	72	8	0	5
Euclid HS	51	40	4	5	0
Pascal HS	58	35	5	2	0
AVG	31.8111	50.5556	12.4	4.53333	0.63

When comparing the demographics of the STEM high schools to all public high schools in the United States, the differences were significant. Table 31 lists the percentage of students in each ethnic group that were enrolled in STEM schools compared to the overall number enrolled in all U.S. high schools during the 2007-2008 academic year (School Data Direct, 2008).

Table 31

Ethnicity of STEM High School Students vs. U.S. Public Schools

	% of students enrolled in STEM HS	% of students enrolled in U.S. public schools	Difference in population
White	32	55	-23
Black	50	17	+33
Hispanic	12	21	-9
Asian	5	5	0
other	1	1	0

The STEM high schools population average for black students was 51%, which is three times the national average of 17%. This over-representation of black students in the STEM high schools may be accounted for by the location. Several STEM high schools were located in urban areas that have higher black populations. The STEM high school population for white students was 32%, which is 23% less than the national average of 55%. Hispanic students were under-represented in STEM high schools by approximately 9%.

The percentage of students receiving free and reduced lunch varied from 10% to 100% with an average of 42%. The national average of all public school students in the United States who are economically disadvantaged is 42% (School Data Direct, 2008). STEM high schools match the population for this characteristic. Figure 6 shows the distribution of students who received free or reduced lunches.

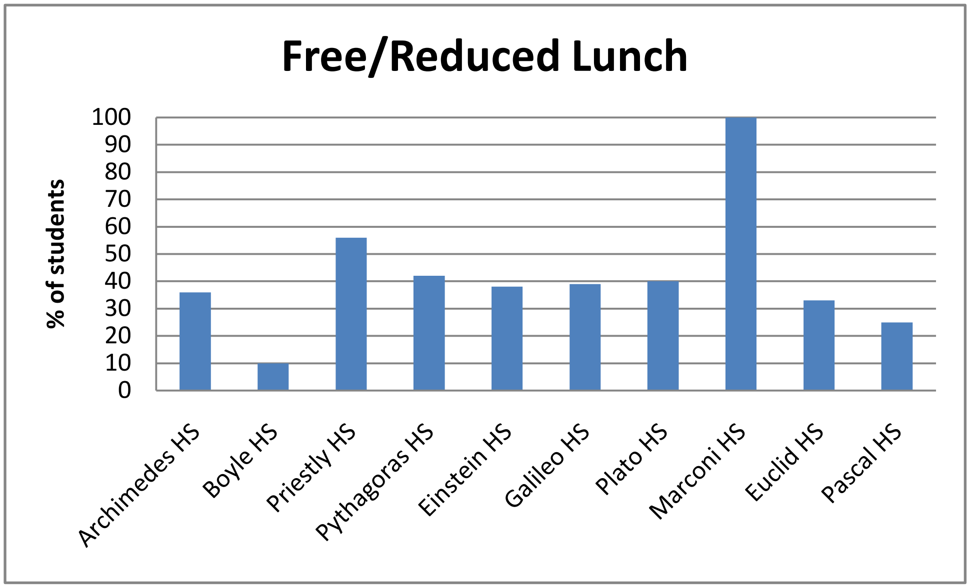

Figure 6. *Number of students receiving free or reduced lunch.*

Research Question 4: What are the academic programs provided? What are the requirements for graduation?

The most unique characteristics of STEM academic programs were the types of electives offered, method of delivering course materials, internship opportunities, and capstone projects. Table 32 lists the key features of the academic programs offered at each of the schools. All 10 of the STEM high schools required a capstone project that reflects learning goals. These were in the form of a digital portfolio, exhibition, or research under the direction of a mentor scientist. Seven out of 10 of the schools required an internship. Internships were designed to provide students with an opportunity to learn from experts in the field in a professional setting. Most internships occurred during students' junior or senior year. Marconi was the only school that had freshman, sophomores, and juniors participating in corporate internships.

Table 32

Key Features of STEM Academic Programs

School	Course delivery	Electives	Internship	Capstone project
Archimedes	Interdisciplinary blocks of time, project-based curriculum	Architectural computer, manufacturing, electrical engineering, networking certification, biomedical technology, information technology, broadcast technology	Yes	Yes
Boyle	Deep project-based work, No AP courses	Inquiry-based liberal arts.	Yes	Yes
Priestly	Traditional curriculum	Technology systems, digital electronics, intro	No	Yes

	combined with engineering applications.	to engineering, computer-integrated manufacturing, computer programming, robotics, principles of engineering, engineering research		
Pythagoras	College readiness, 75-minute blocks	Astrophysics, biotechnology, bridge building, creative engineering, engineering models, engineering of sound, environmental biology, biohazards, genetics, medical imaging, neurobiology, robotics	Yes	Yes
Einstein	Integrated curriculum. 2 hours of math per day.	IB diploma option	Yes	Yes
Galileo	Double periods for science courses. Accelerated math. AP courses	Organic chemistry, marine biology, bioelectricity, environmental science, genetics, engineering practicum, electricity/mechanics, environmental science.	No	Yes
Plato	Rigorous college prep. Attend 20 additional days. Integrated core curriculum.	Need 30 credits to graduate, 5 must be STEM electives	Yes	Yes
Marconi	Rigorous college preparatory courses. Inter-disciplinary curriculum.	Not available	Yes	Yes
Euclid	AP courses, 90-minute teamed math/science (algebra	Research, integrated contemporary technologies, scientific literature, technical	Yes	Yes

	2/chem., pre-calc/physics)	writing.		
Pascal	24 credits plus 2 AP courses	Genetics, microbiology, meteorology, astronomy, geology, environmental science, marine science.	No	Yes

Most schools offered rigorous college preparatory and advanced placement courses in addition to electives focused on STEM content. Marconi High School was the only school that did not offer AP courses. Several of the schools had additional time allocated for math and science instruction, and four schools implemented interdisciplinary curriculum and instruction.

Archimedes High School was the only school that had a Saturday program for students to give back to the community. The school facility was opened to children in the community. The high school students worked with faculty to design a program for teaching the children how to use technology. Marconi was the only school with a year round academic calendar. It is located within an industry campus and students move to different corporate campuses each year.

Students who attend STEM schools use a variety of instructional technology including computers with Internet access, graphing calculators, calculator-based laboratories, probe ware, and data collection instruments. All schools had computer labs available to students. Several schools had staff available in the labs during lunch and after school. Three of the schools issued students and faculty personal laptops for home use. Technology was used to research, produce, and present academic projects and to assist in investigate solutions to inquiry-based lessons. Plato High School encouraged parents to stay actively involved in monitoring their child's progress through an online parent portal.

Research Question 5: What professional development activities do STEM school faculty members participate in?

Professional development opportunities for teachers at STEM high schools in this study are focused on developing teachers as leaders, collaborators, and creators of student learning experiences. Key features of professional development included a dedicated time was set as a priority for teacher training; it was done collaboratively; teachers were leaders in selecting and leading the activities; and topics were focused on curriculum and instruction that pertained to STEM content and pedagogy.

Dedicated time prioritized for teacher training. In the schools studied, teacher professional development is a priority. It is a regular part of the teachers' schedule. Two-thirds of the schools stated that they have a specific time dedicated to teacher education. Archimedes High School has "regularly scheduled professional development workshops throughout the year." The Boyle High School principal stated "training is ongoing; teachers spend 45 minutes per day collaborating with colleagues." At Einstein High, "teachers have common planning time every morning and the school provides substitutes so teachers can meet with coaches." At Euclid High School, "scheduled teacher collaboration is a priority." School principals emphasized that time is needed for teachers to develop. Marconi High provides teachers with a revised workday to accommodate a week-long STEM development institute.

Professional development is done collaboratively. All of the STEM schools reported that teacher training is done collaboratively. Most teachers work with colleagues in their school. "Teachers work together to integrate course projects, develop common assessments and work in teams sharing the same cohort of students." At Galileo, "teachers visit other teacher's classes within content are and out of content area". Half of the schools collaborate with educators outside their school. Teachers at Archimedes partner with another school in their district to create a professional learning community. At Pascal "university engineers collaborate with classroom teachers to provide real-world experiences." Only one school used virtual collaboration − Archimedes "teachers are part of a virtual mentor network where they can access online video resources that model best classroom practices." None of the schools reported having any outside guest lecturers or trainers.

Professional development that encourages teacher leadership. Seven out of 10 schools in this study emphasized teachers being responsible for taking leadership in developing professional development in their own school. At Archimedes, "teachers create master lesson plans and serve as instructional coaches." At Einstein, "teachers come to this school with the understanding that they will rotate back to their base school and will be responsible for teaching other faculty members." At Euclid, "teachers select the curriculum, develop and deliver integrated lessons and assessments, and are responsible for enhancing the academic program." At Boyle, teachers develop integrated curriculum while teachers at Pascal are part of the curriculum planning. Teachers at STEM high schools are actively engaged in professional development training. They are in integral part of the planning and implementation of the professional development activities.

Topics focus on curriculum and instruction relevant to the school mission. The professional development activities at STEM high schools were focused on the following topics: engaging students, rigor in the classroom, project-based learning, curriculum integration, internship program development, college advising, teaching diverse learners, and technology infrastructure. The topics at each school aligned with the school mission statements.

Boyle High School was the only school that had an approved teacher certification program embedded in its program. This school partnered with a university that provides interns that receive a full-time salary while earning their credentials. This school provided the formal training and classroom experience required for teachers' state certification.

Summary

This chapter provides an in-depth summary of each of the 10 STEM high schools. It contains a description of the background of each school including the history, key organizations involved in establishing the school, type of facilities, and funding sources. The test scores and demographic information provide a context for how each school compares to others in their school district. A detailed description of the admission process and academic programs provide insight into the type of students who are admitted, and academic program that student's experience. The professional development activities described highlight the type of support that teachers in STEM school receive. This chapter also contains a cross-case summary of the key features of each of the 10 STEM-focused schools.

5. Discussion

Conclusions

Results from this study show that there are STEM-focused high schools in the United States that are currently implementing programs that fulfill the goal stated in the Academic Competitiveness Council Report (U.S. Department of Education, 2007), "to prepare all students with STEM skills needed to succeed in the 21st century technological economy." STEM high schools in this study indicate that several schools in the United States have responded to the suggestions in the CRS Report from Congress (Library of Congress, 2006; 2008) to strengthen students' knowledge of STEM content by providing rigorous courses in STEM content. The current needs of K-16 schools, identified in the literature as teacher training, curriculum, equipment, and facilities, did not apply to schools in this study. Schools in this study had an adequate supply of resources and had teacher training that was specific to their program.

Results showed that the content in the school's mission statement influenced the establishment of the schools. All schools in this study strived to improve the academic preparation of students in the STEM fields. The way they approached this goal varied but it was clear that the mission statements guided the focus of their efforts. Table 33 contains examples of the connections between the mission statement and program implementation. School mission statements are grouped into four themes: Pathway to university degrees, academics, student population, and student environment. In addition to the alignment between the school mission statement and programs that were implemented, there was also an alignment between topics in the teacher professional development and the school mission statement.

Table 33

Mission Statement Connected to Program Implementation

Focus: Pathway to University STEM Degrees	
School Mission Statement	**Program Implementation**
To provide a continuous pathway of education that creates STEM literate graduates.	Euclid High School is currently building a STEM pipeline that spans from grades 4-12.
Focus: Academics	
School Mission Statement	**Program Implementation**
To increase student achievement.	Archimedes High School integrated a rigorous college preparatory and STEM curricula taught by master teachers. Provided a learning environment that utilized technology to support academic achievement.
To provide students with rigorous and relevant academic and workplace skills.	Boyle High School provided curriculum that is rigorous and engaging with performance based assessment. Provided internships for students to experience the high tech workplace.
To create the next generation of world leaders.	Galileo High School focused on achievement at nationally competitive competitions in math science, research, and technology.
To provide students with 21st century skills in economics as it relates to the fields of STEM.	Plato High School provided elective courses in economics. Embedded economics applications in STEM course content.
To ensure opportunities for all students to be academically challenged while appropriately supported.	Marconi High School delivered an instructional program that is highly differentiated. Used multiple metrics to measure success and assess mastery of content.

To challenge students to think critically through the shared involvement of teachers, administrators, parents and the community.	Pascal High School students were provided challenging curricula including AP courses and completed a senior project that required involvement of community members and teacher guidance.
Focus: Student Population	
School Mission Statement	**Program Implementation**
To serve a student body that mirrors the ethnic and socioeconomic diversity of the community.	Boyle High School used a computerized lottery generated by zip code to ensure that the student body represents the socio-economic and cultural diversity of the community.
To increase the number economically disadvantaged to attain college degrees.	Pythagoras High School admitted a higher percentage of low income students than other schools in its district.
Focus: Student Environment	
School Mission Statement	**Program Implementation**
To ensure that each student achieves their own personal vision.	Priestly High school offered a variety of programs students can select from to pursue their own personal vision including performing arts, engineering and visual arts.
To personalize learning so every child can succeed.	Einstein High School provided an advisory program that assured that each student had an adult who served as a student advocate.

Results from this study show that students who want to attend STEM high schools must go through an application process prior to being admitted. The following criteria were used to select students to attend the STEM high schools.

- 100% required an application form.
- 80% required a student interest questionnaire or essay.
- 60% required academic transcripts and attendance records.
- 50% of the schools required a parent recommendation.
- 50% admitted students based on a lottery system.

- 30% required an interview.
- 20% admitted all applicants.
- One school required a teacher recommendation.
- One school required a placement test.

Results show that there are a higher percentage of minority students served at STEM-focused high schools than other schools in the United States. When comparing the demographics of the STEM high schools to all public high schools in the United States, the differences were significant. Table 34 lists the percentage of students in each ethnic group that were enrolled in STEM schools compared to the overall number enrolled in all U.S. public high schools during the 2007-2008 academic year (School Data Direct, 2008).

Table 34

Ethnicity of STEM HS Students vs. U.S. Public Schools

	% of students enrolled in STEM HS in this study	% of students enrolled in U.S. public schools	Difference in population
White	32	55	-23
Black	50	17	+33
Hispanic	12	21	-9
Asian	5	5	0
Other	1	1	0

The STEM high school population for black students was three times the national average. This over-representation of black students in the STEM high schools may be accounted for by the location. Several STEM high schools were located in urban areas, which have higher black populations. The STEM high school population for white students was 23% lower than the national average. Hispanic students were under represented in STEM high schools by approximately 9%. The average percentage of economically disadvantaged students attending STEM schools was 42%, which is same the national average (School Data Direct, 2008).

An important learning characteristic that emerged from this study was a difference in academic programs and graduation requirements at STEM high schools. The most unique characteristics of STEM academic programs were: the types of electives offered, method of delivering course materials, internship opportunities, and capstone project requirements. Students who attend STEM high schools are provided with more STEM content in core subjects and/or electives. They are provided with work-related experiences and are provided with support to complete a capstone project.

- 100% required a capstone project that reflects learning goals.
- 70% required an internship during 11th or 12th grade.
- 10% offered internships for 9th, 10th, and 11th graders.
- 50% have interdisciplinary or integrated curriculum.
- 50% use traditional curriculum combined with STEM electives.
- 20% have double periods of math and/or science.
- One school had an additional 20 days of instruction.

- One school did NOT offer any AP or IB courses.
- One school had a Saturday technology enrichment program.

Table 35 contains a list of the different types of electives offered at STEM focused high schools in this study.

Table 35

Electives Offered

Architectural computing Astrophysics Bioelectricity Biohazards Biomedical technology Biotechnology Bridge building Broadcast technology Computer integrated manufacturing Computer programming Creative engineering Digital electronics Electrical engineering	Electricity/mechanics Engineering models Engineering of sound Engineering research Environmental biology Environmental science Genetics Geology Information technology Integrated contemporary technologies Intro to engineering Manufacturing Marine biology	Marine science Medical imaging Meteorology Microbiology Networking certification Neurobiology, Organic chemistry, Principles of engineering, Research, Robotics, Scientific literature Technical writing practicum Technology systems

STEM schools used a variety of instructional technologies including computers with Internet access, graphing calculators, calculator-based laboratories, probe ware, and other digital data collection instruments.

- 100% had computer labs available during and after school hours.
- 30% issued personal computers to all faculty and students.

Technology was used to research, produce, and present academic projects, to assist in investigating solutions to inquiry-based lessons, and to engage parents through an online parent portal.

Teacher professional development results showed that training opportunities for teachers at STEM high schools are focused on developing teachers as leaders, collaborators, and creators of student learning experiences. Key features of professional development included:

- A dedicated time set as a priority for teacher training.
- Conducted collaboratively with teacher from different content areas.
- Teachers were leaders in selecting and leading the activities.
- Individual schools focused on curriculum and instruction that pertained to STEM content and pedagogy.
- Topics focused on curriculum and instruction relevant to the school mission.
- One school had an approved teacher certification program embedded in its program.

There were three charter schools in this study. The programs offered and students served at the charter schools were similar to the noncharter schools in this study. The only difference between theses schools was the type of funding received and teacher licensure requirements.

Study Limitations

A number of limitations should be noted in this study. The variables impacting these limitations are the size of the population selected, duration of the study, the methodology selected, participants selected, the number of years since school was established, and the data collected. The number of participants and the case study methodology used prohibits generalizability. The case study methods implemented in this study describes what is occurring at each site but does not measure how successful these programs are. The duration of the study provides only a snapshot of current programs implemented at each STEM high schools. The short implementation period does not show how programs were modified or improved over time. The finite number of questions asked limited the scope of this project. Schools that were newly established did not have any standardized test score available limiting the data included in this study. These schools were limited to 9th and 10th-graders because they were in the process of building the program one year at a time. These schools did not have any experiences implementing the capstone projects to share. This study is limited by the perspectives of the participants interviewed. The results in this study reflected the school administrator's perspective of their own school and were limited to what they were willing to share.

Recommendations for School Leaders

This study contains descriptions of several STEM-focused high schools in the United States that will be helpful to individuals desiring to start a STEM program. Those considering starting a STEM-focused high school should consider the following.

The schools in this study have a focused mission statement that guides leadership and decision-making and serves to align the content, curriculum, and teacher professional development. The mission statement is a covenant that guides the school. One school describes it as "the backbone for the schools design and operation." The initial school designers will need to determine how students will be selected. All of the schools in this study had an application process. Some designed their admissions process targeting certain populations while other used random selection.

Another consideration is the type of academic program selected. This will determine the type of faculty and unique skills that are needed. One principal stated, “Our academic requirements exceed the states in additional coursework requirements. Some courses include engineering electives.” Another principal said, “Make sure the program is rigorous and has clear expectations.” Because these schools have accelerated STEM courses and a broad range of unique electives, additional faculty is needed. All of the STEM schools required an internship and/or capstone project. Faculty or staff members must set up the internship and ensure that the internship learning environment supports academic goals. Additional support is needed to assist students with the capstone project and to evaluate their progress.

The principals described faculty as a key component to the success of their schools − “It starts with quality teachers.” One principal attributed his schools success to faculty who “are truly committed to developing the next generation of leaders.” Some schools in this study hired business professionals to teach courses while others relied on certified teachers. Principals need to schedule time for teachers to collaborate and participate in professional development activities. Schools in this study stressed the importance of having a dedicated time set as a priority for teachers to work together. Teachers should be encouraged to take a leadership role in the development of student learning experiences.

The geographic location needs to be considered during the initial planning stages. One school faced a transportation challenge because students lived a long distance from the school and no public transportation was available. The cost for transporting students was a large part of the operating budget.

STEM high school models in this study required a commitment from principals, community members, and teachers. Schools in this study were directed by visionary principals who were confident and committed to making a difference in the lives of students. One experienced principal said, “No one has the budget to do this, go out and find the means to get it done. Principals who want a creative environment cannot live within their means. Imagine it, and then make it happen.”

Implications for Future Research

This study was unique from past research on STEM schools because it highlights specific features of STEM schools located in different regions of the United States. Future research is needed to identify the benefits and drawbacks of different school models. Building on these results, further study is needed to learn the effectiveness of each of the STEM school models. Now that we know the types of programs that students have participated in, we need to track their progress to determine if students who completed these programs chose to pursue STEM degrees. We would benefit from research documenting modifications made to these STEM schools over time. Do the schools in this study continue with the current programs or do they make changes? What type of changes? And, why?

Results from this study indicate that teachers at STEM schools have regularly scheduled professional development that focus on aligning content and curriculum. Further research is needed to determine the impact of the professional development on teacher behaviors. Does the professional development provided at STEM schools impact changes in teachers' method of teaching? How is the instructional technology available at STEM school being implemented into instructional units?

Results from this study indicate that STEM programs are rigorous with a broad variety of STEM courses, technology enhancements, and longer days. It would be helpful to know what it would cost for each of the additional courses and technology in each of the STEM high school models. Results from this study reflect the principals' perspective about their schools along with document data verifying specific facts about each school. It would be advantageous to find out what teacher and parents say about STEM high schools and how it compares to the principals perception.

It was clear from documents collected and the email and telephone conversations that I had with school personnel, that the faculty and staff at the STEM schools in this study are committed to students and have a sincere desired to provide them with the skills and content knowledge needed to pursue STEM careers. Students at these schools are very fortunate to have the opportunity to learn in an environment where the community and educational staff share this kind of commitment.

APPENDIX A

E-Mail Request for a Telephone Interview

Dear Principal:

The purpose of this email is to request your participation in a study of STEM-focused high schools. This study will result in a "Design Guide" of various STEM programs in the United States. The project title is "A Comparative Case Study of the Characteristics of STEM-Focused High Schools."

Your school was selected because of your commitment to increase all students' content knowledge in STEM subjects. If you choose to participate, your name and the name of your school will be replaced with pseudonyms. After your school information is summarized you will receive a preliminary copy of the data to confirm the accuracy of the information. At the conclusion of this study, you will receive a summary report of findings.

I am requesting 45 minutes of your time to participate in a telephone interview. This will be followed up with a "Summary of Findings" document for your review. A follow up telephone interview will be conducted to verify the accuracy of the information and add any missing information.

If you are willing to share your experiences leading a STEM school, please respond to this email with a time, day, and phone number that you are available during the week of January 6-9 or January 12-16.

This research is being conducted by Catherine Scott, Graduate School of Education at George Mason University. She may be reached at (xxx) xxx-xxxx for questions or to report a research-related problem. Faculty Supervisor is Dr. Margret Hjalmarson she can be reached at (xxx) xxx-xxxx. This research has been reviewed according to George Mason University procedures governing your participation in this research.

Thank-you for your time and consideration,
Catherine Scott

APPENDIX B

Data Sources

School	Source
Archimedes	• Educators Virtual Mentor website. • Archimedes High School website. • National Center for Education Statistics website. • No Child Left Behind Data Reports. • Online document: Professional Development at Archimedes High School. • STEM Education Coalition website. • Gaming website. • Telephone interview and email communication with school principal.
Boyle	• State Department of Education School Performance Report. • Boyle High School website. • National Center for Educational Statistics. • Online article: Why We Did It. • Boyle School District School Accountability Report Card. • Telephone interview and email communication with school principal.
Priestly	• Priestly School District website. • National Center for Educational Statistics website. • State Education Agency website. • Telephone interview and email communication with school principal.
Pythagoras	• State Department of Education website. • Pythagoras High School website. • School Report Card website. • Newspaper article: School that Offers Model for Success. • Newspaper article: Making High School Better. • National Center for Education Statistics website. • Telephone interview and email communication with school principal.
Einstein	• Einstein High School website. • National Center for Education Statistics website. • State Department of Education website. • Online article: New School Does Well on State Graduation Exams. • Newspaper article: School will Foster Learning of Math, Science, Technology.

	• Telephone interview and email communication with school principal.
Galileo	• Galileo High School website. • State Department of Education website. • National Center for Education Statistics website. • Online article: Science Talent Search. • Online article: A School with STEM. • Telephone interview and email communication with school principal.
Plato	• State University online article: Department of Eduation Reform. • Plato High School website. • Online article: Public Charter Schools. • Newspaper article: STEM Leaders Plan. • Telephone interview and email communication with school principal.
Marconi	• Marconi School District website. • Newspaper article: High School Focused on Science, Technology, Engineering, and Math to Open Thanks to Efforts of Business Community. • Marconi High School. • Online report: Proposal to the Partnership for Continued Learning STEM. • Telephone interview and email communication with school principal.
Euclid	• State Department of Education website. • National Center for Education Statistics website. • Euclid High School and County websites. • Telephone interview and email communication with school principal.
Pascal	• Pascal High School and website. • Press Release. School District website. • School Report. Annual Community Report 2006. • National Center for Education Statistics website. • School Data Direct website. • State Department of Education website. • Telephone interview and email communication with school principal.

APPENDIX C

School Principal: Telephone Interview Questions

1. What is your current position?
2. How long have you been at __________ school?

School:

3. What are the goals or purpose for having a STEM school?
4. Can you give some examples of how the school mission has impacted the program or school design?
5. What advantages/disadvantages does the STEM program at you school have for students who attend?
6. What is the schools relationship with the community? Parent involvement? University involvement?
7. What makes your school an innovation on the school reform landscape?
8. What is unique about your program? Do you have any other information about your school that makes your STEM program different from other schools in your district?

Students:

9. Can you describe your student body? Is there an entrance exam? How are students selected?
10. What are the student admission requirements? What percentages of applicants are accepted each year?
11. What students would you like to reach? What efforts are made to include under-represented student populations (ethnicity, socioeconomic status, language deficiencies, and learning disabilities)?
12. Can you tell me a story about individual students who were impacted by your program? What about a student who wasn't as affected.

Academic Requirements:

13. What courses are students required to take in order to graduate? How do these requirements compare to other schools in your district?
14. What courses/electives do you offer that are specific to your STEM program?
15. Do you have any additional graduation requirements? Internships or projects?

Teachers:

16. Teacher professional development: What training do teachers receive? Any specific training to link all disciplines to STEM content?

17. What criteria are used for faculty selection? How are teachers hired? Are there criteria or commitments they have to make?
18. Grading practices: Do you routinely assess for students' growth in STEM disciplines? Can you tell me about that?

Conclusion:

19. What advice would you give to new administrators tasked with creating a STEM high school?
20. Is there anything that I have not asked that you would like to share?

APPENDIX D

E-Mail Requesting document verification

Dear Principal:

Thank you for taking the time to talk to me about your program. Attached is a draft of the information I have gathered through our conversation and from documents accessed on the Web. I have replaced your school name with a pseudonym to protect your identity. Once you have verified the accuracy of this information, I will also change the citations to generic references. Please feel free to make any corrections or additions to this document.

Once I have the documents from the other nine schools in this study, I will provide you with a summary of the different STEM high school models.

Thank you for taking time out of your busy schedule to assist with this project,
Catherine Scott

This research is being conducted by Catherine Scott, Graduate School of Education at George Mason University. She may be reached at (xxx) xxx-xxxx for questions or to report a research-related problem. Faculty Supervisor is Dr. Margret Hjalmarson she can be reached at (xxx) xxx-xxxx. This research has been reviewed according to George Mason University procedures governing your participation in this research.

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CURRICULUM VITAE

Catherine Scott, an American citizen, received a Master of Education in Educational Psychology from the University of Virginia in 1996 and a Bachelor of Science in Mathematics Education from Liberty University in 1985. She is a National Board-certified secondary mathematics and computer science teacher who taught a variety of mathematics and computer science courses in the International Baccalaureate and Advanced Placement programs in Fairfax County, Virginia. She has served as a mentor to new high school mathematics teachers and has provided professional development workshops at state and national conferences.

In 2004, she enrolled in the PhD Education program at George Mason University. Her university experience included service as a faculty member in the College of Education at Virginia Polytechnic Institute and State University, Northern Virginia Center, where she supervised preservice teachers and taught a variety of courses including research and secondary mathematics pedagogy courses in the master's degree program. She currently serves as Director of the NASA eClips™ program, a NASA-funded project, produced by the National Institute of Aerospace in Hampton, Virginia.