An Investigation of Science, Technology, Engineering and Mathematics (STEM) Focused High Schools in the U.S.

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Abstract

This study examined the characteristics of 10 science, technology, engineering and mathematics (STEM) focused high schools that were selected from various regions across the United States. In an effort to better prepare students for careers in STEM fields, many schools have been designed and are currently operational, while even more are in the planning phase. Data collected, analyzed and documented in this report included websites, national statistics databases, standardized test scores, interviews, and published articles. A comparative case design was used to identify key components of STEM high school designs.

Results from this study indicate that students who attend STEM-focused high schools outperformed their peers at similar institutions. Although programs varied, a common theme that emerged from these schools was a focus on more rigorous course requirements with electives centered on STEM content and application. Students who attended STEM schools were engaged in real-world problem solving and completed internships and/or a capstone projects to fulfill graduation requirements. Most students attending STEM schools in this study were admitted based on a lottery system while two out of the ten schools admitted all applicants. The student population was comprised of a higher number of minority students compared to other schools in the United States. The findings in this study are significant because they indicate that many students, when given the opportunity and support, are able to successfully complete rigorous STEM academic programs that go beyond the basic graduation requirements.

Introduction

The decline in the number of science, technology, engineering and mathematics (STEM) undergraduate degrees awarded in the United States has stimulated interest in creating and implementing STEM programs. In the revised CRS Report for Congress , 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 (Library of Congress, 2006 & 2008). About $2.8 billion was appropriated for these programs providing financial support for students or scholars, institutional support to improve educational quality, support for teacher and faculty development, and institutional physical infrastructure. Of the 207 programs, 53 of them were targeted toward high schools. In the Executive Report to the President (2010), the President's Council of Advisors on Science and Technology (PCAST) continued to highlight the importance of STEM education for the United States to remain a leader among nations and to solve the immense challenges in such areas as energy, health, environmental protection and national security. One of the specific recommendations from the PCAST was the "creation of at least 200 new highly-STEM-focused high schools and 800 STEM-focused elementary and middle schools over the next decade, including many serving minority and high-poverty communities" (Executive Report to the President, 2010, pp. 8).

Over the past 30 years many states have created opportunities to increase students' exposure and engagement in STEM content learning. Some of the many options available to students include: Dual enrollment, AP and IB programs, Early College entrance programs, summer programs, residential STEM schools, non brick-and-mortar type educational programs, STEM academies or schools, internships and mentorships, contests and competitions, and service learning programs. One of the advantages that STEM academies or high schools have is an extended time with students to go further into the stages of expertise. They design programs that move students from interest in subject area to competencies, to expertise. Specialized STEM high schools come in different forms: state residential schools, schools within schools, self-contained schools and part-time sites. Roughly about 18 percent are residential, 82 percent non-residential (Jones, 2010). Some schools are on college campuses and are organized under the state's higher education system. Others are administered under a local or regional school system. We know that there has been an increase in the number of STEM schools over the past decade, but we do not know which of these is most effective for whom (Subotnik, Kolar, Olszewski-Kubilius & Cross, 2010). Several networks have been formed around the STEM academy development. Some of these include: The National Consortium of Specialized Secondary Schools of Mathematics, Science and Technology (NCSSSMST) (www.ncsssmst.org); The Ohio STEM Learning network (www.osln.org), T-STEM academies (http://www.tea.state.tx.us/index2.aspx?id=4470&menu_id=814) , and the Colorado STEM network (http://coloradostemeducation.com/) . These organizations provide a communication network for sharing ideas and obtaining professional development for specialized teaching methods and leadership.

Early studies on the effectiveness of STEM academies resulted in a student interest-persistence in STEM study conducted by Hilton and Lee (1998). In their report on the STEM pipeline, they analyzed students' interest and persistence in science, but did not offer any model for developing this interest, nor did they connect early interest to earning degrees in STEM-related fields. Another study conducted by Pfeiffer, Overstreet and Park (2010) compared residential and non-residential STEM schools and found similarities between the two. They reported that all 16 schools in their study offered research opportunities for students to complete independent research projects at lab facilities or off-campus sites. These programs offered an extensive array of intermediate and advanced science and mathematics course offerings not offered in public schools nationwide. One interesting finding was that less than half of the residential academies offered Advanced Placement (AP) or International Baccalaureate (IB) courses compared to non-residential schools that all offered AP or IB courses.

As the nation considers policies to address STEM education issues, research is needed to measure the impact and influence of specialized STEM high schools. Subotnik, Tai, Rickoff and Almarode (2010) found that there are no existing studies that provide a comprehensive analysis of the contribution these schools make over and above regular high schools to the STEM pipeline. To date, no large-scale data-based research study has addressed these questions. Brody (2006) further suggested that the success of STEM programs may be measured in the short and long term. In the short term, a program's impact could be measured by way of increased exposure to content, raised interest and confidence, and enhanced views of the utility of STEM disciplines on the part of participants. In the longer term, a program would be evaluated based on enrollment and success in advanced courses, selection of STEM majors, awards and recognition, and entry into STEM careers.

In spite of the growing numbers of specialized STEM high schools, student access is not widely available. According to Subotnik, Edmiston, and Rayhack (2007), access to STEM schools is geographically uneven. Only 27 out of 50 states offer STEM talent programs such as regional centers, magnet schools, governor schools, or exam schools. A select few of these states have five or more programs: Georgia (eight schools), Maryland (five schools), Michigan (10 schools), Virginia (nine schools), New Jersey (eight schools), and New York (seven schools). Many other states with similar population sizes do not offer any such educational opportunities. Given the push to create additional schools, it seems imperative that "best practice" with regard to specialized STEM high schools be identified in a scientifically robust manner.

In an effort to respond to the current status of STEM education in the nation, school systems continue to develop and implement strategies that have the potential to improve STEM education; however, little is known about what strategies have been implemented in existing STEM programs. The problem is further compounded by what the NSF has identified as a shortage of reliable indicators for assessing the quality of STEM education projects and programs. As is 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, pp. 7).

This study begins to examine STEM high schools: the type of courses offered, population served, student performance on achievement tests, the schools' vision statements, highlights of unique academic programs and entrance requirements. The purpose was to begin gathering data from current STEM programs so findings could be shared with school districts that are considering the development and implementation of a STEM program or school. The following questions guided this study: (a) What are the characteristics of STEM-focused high schools? (b) How are students selected to attend the STEM schools? (c) What student populations do the STEM schools serve? (d) What are the academic programs provided? (e) What are the requirements for graduation?

Methods

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, pp. 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. According to Yin (2003), 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" (pp. 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" (pp. 47).

A criterion-based selection was used to choose the site and participants to be studied. The initial site selection began with a national search of STEM secondary schools that were specifically intended as STEM schools. According to Atkinson, Hugo, Lundgren, Shapiro and Thomas (2007), more than 100 high schools are designed with a STEM focus. The second criterion for selecting a school site was those designed specifically to enhance all students understanding of science, mathematics, engineering and technology, as opposed to programs that were primarily for advanced or gifted students. Schools designed as magnet programs or that have strict entrance requirements are often regarded as "elite" schools and were not included in this study. STEM schools

Pseudonym	Location	Grade Level	Year Established	Locale	Charter/ Magnet	Title I	Student Enrollment
Archimedes HS	South East	9-12	2004	Large City	N/Y	N	705
Boyle HS	West	9-12	2000	Large Suburb	Y/N	N	549
Priestly HS	South West	9-12	2002	Large Suburb	N/N	Y	899
Pythagoras HS	West	9-12	2004	Large City	Y/N	N	728
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	1,615
Plato HS	South East	9-10	2008	Small City	Y/N	Y	182
Marconi HS	Mid West	9-10	2008	Large City	N/N	Y	163
Euclid HS	North East	9-12	2008	Rural	N/N	N	1760
Pascal HS	South East	9-12	2007	Small City	N/N	N	1609

Note. Data collected January 2011 from National Center for Education Statistics, 2008.

Table 1. STEM School Overview

that have statements indicating that their goal is to provide opportunities for all students, including underrepresented student populations, were selected for further study. The 10 schools that are included in this study are located in various regions across the United States, three of which qualified for Title I status. The regions in the U.S. that schools were selected from are defined as follows: North East: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Washington DC; South East: Alabama, Arkansas, Florida, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia; West: Alaska California, Colorado, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming; South West: Arizona, New Mexico, Oklahoma, Texas; Mid West: Minnesota, Wisconsin, Michigan, Indiana, Ohio, Illinois, Iowa, Missouri, Kansas, Nebraska, South Dakota, and North Dakota. Table 1 contains a list of the participants using pseudonyms to protect their identity.

Six schools in this study were new schools that were designed specifically for the implementation of the STEM program. These schools began with a new building, faculty and staff members. Four schools were already in existence, but were re-invented in order to change their academic emphasis to STEM content. Most of the schools had traditional school facilities while two of the new schools were located in business or commercial settings.

Data Collection and Analysis

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. Documents were collected from multiple sources including school websites, State Department of Education archived test score databases, grant applications and applications for admissions materials. Merriam (1998) identified the greatest advantages in using documentary material is its stability and objectivity. She wrote that, "unlike interviewing and observation, the presence of the investigator does not alter what is being studied" (p. 126).

For each school, standardized test scores were used to compare the STEM school with other schools in their state. 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 because of differences in individual state requirements. Information on student demographics was collected from the National Center for Educational Statistics website http://nces.ed.gov/ for each school. Information about the school profile, mission statement, entrance requirements and graduation requirements was collected from the school websites and other documents provided by participants. These documents provided information about programs for students, internships, research projects, mentorships, required courses and electives, summer opportunities, and design competitions. The combination of these data sources provided information for an overall description of general characteristics of each school program.

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 tape-recorded. 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.

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." (pp. 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 for triangulation of the data strengthening 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.

Results

Results from this study describe a variety of ways that STEM-focused high schools in the United States have implemented 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." Students attending the STEM high schools in this study are provided rigorous courses in STEM content. The test scores and demographic information provide a context for how each school compares to others in their school districts. 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 high schools receive.

How do STEM school students perform on standardized tests?

Students who attended STEM-focused high schools outperformed their peers in mathematics and reading or English on end-of-course assessments.

Participating schools took different state-wide assessments so student performance was measured by comparing the STEM high school average to the state-wide average. When students had more than one mathematics exam (i.e. algebra and geometry), the exit level or graduation required test score was used. The data in Table 2 represents the percentage of students who passed last year's state standardized tests in English, Reading, and Mathematics. On average, STEM high school students had a 13 percent higher pass rate for English and 12.78 percent higher pass rate for mathematics compared to those who attended other schools. Of the nine schools that participated in state-wide testing, all performed higher than the state average in mathematics and English. Plato High school was a newly opened school and is the only school in this study that did not report end-of-course exam results.

	Reading/ English	State AVG Eng/Read	% Difference Eng/Read	Math	State AVG Math	% Difference Math
Archimedes	72	43	+29	76	44	+32
Boyle	98	81	+17	96	81	+15
Priestly	98	92	+6	82	70	+12
Pythagoras	86	66	+20	40	30	+10
Einstein	95	85	+10	97	79	+18
Galileo	99	80	+19	98	84	+14
Plato	Data not available					
Marconi	91	83	+8	88	80	+8
Euclid	87	84	+3	83	80	+3
Pascal	91	86	+5	85	82	+3
AVG			+13			+12.78

Note. Collected from individual State Department of Ed websites (January, 2011).

Table 2. Comparison between STEM HS End-of-Course Exams Pass Rate and the Statewide End-of-Course Exam Pass Rate

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. Of particular note is the lack of value placed on teacher recommendations in the admissions process. STEM school admissions personnel placed a higher value on student interest questionnaires/essays (8 out of 10 schools) and parent recommendations (5out of 10 schools) than teacher recommendations (1out of 10 schools). All of the schools required an application form to be considered for admission along with a variety of additional documents that are listed in Table 3. Once students submitted the requested documents, the selection process began. Galileo was the only school that was specific about the role that grades play in the admissions process and was the only school that required a placement test. Five other schools required academic transcripts, but did not have a specific grade point average (GPA) requirement.

Students interested in attending these STEM high schools completed applications consisting of demographic infor-mation, emergency contact information and program preferences. In addition, schools that required a questionnaire, essay or interview asked students to respond to prompts, for example: Explain why you wish to be considered for admission to a STEM High School. What school and community activities are most important to you? Approximately how much time per week do you devote to them?

Six out of ten schools admitted students based on a lottery system. Two schools in this study were able to accommodate all students who applied. When applications for admissions exceed the number of spaces available, STEM schools employed a computerized lottery generated by zip codes to determine admissions. In order to insure that the student body represents the socio-economic and cultural diversity of the county within which it operated, Plato High School incorporated a separate lottery held by grade level for each zip code in the county. Spaces were allocated to a zip code area based on enrollment data provided by the county office of education. If additional

School	Application	Academic Record	Attendance	Interview	Proof of residency	Parent recommendation	Student interest essay/ questionnaire	Lottery selection
Archimedes	√	√	√	√	√	√	√	
Boyle	√				√		√	Computerized lottery by zip code
Priestly	√				√	√		Lottery system used for selection
Pythagoras	√						√	Random lottery (1/3 chance of acceptance)
Einstein	√	√	√				√	Random Lottery
Galileo	√	√	√				√	
Plato	√					√		Plan to implement a random lottery. New school opening, all applicants accepted during this reporting period.
Marconi	√	√	√			√	√	
Euclid	√	√	√	√		√	√	
Pascal	√	√	√				√	Random lottery

Table 3. Admissions Requirements

openings remained after the first series of zip code-based lotteries were performed, remaining students were aggregated into a single applicant pool for a second random lottery. If admissions spots were available in a particular zip code then those spots were filled with sibling applicants. One school required that students complete Algebra I prior to applying. Students were given an in-house test and if they did not pass, they were required to retake the course during the summer. An interesting theme that emerged from the selection process was that STEM schools in this study did not necessarily look for the highest-scoring students. Those with good basic skills and a passion for science and math were considered the best candidates. Students who wanted to focus on the STEM disciplines were given the opportunity to learn in a place designed and overseen by world-class science-and-technology research.

	% of students enrolled in STEM HS	% of students enrolled in U.S. public high schools	Difference in population
White	32	59	-27
Black	50	16	+34
Hispanic	12	19	-7
Asian	5	4	+1
Other	1	2	-1

Note. Data collected from www.nces.ed.gov (January 2011) and U.S Census Bureau http://www.census.gov/population/www/socdemo/school.html, (May 2011).

Table 4. Ethnicity of STEM HS students vs. HS students attending U.S. public schools

What student population is being served?

When comparing the demographics of the STEM high schools to all public high schools in the United States, there were significant differences. Results show that STEM high schools serve a higher percentage of minority students than the national average. Table 4 lists the percentage of students in each ethnic group that were enrolled in STEM high schools compared to the overall number of high school students enrolled in all U.S. public high schools during the 2009-2010 academic year (School Data Direct, 2010 and U.S. Census Bureau, 2011).

The STEM high school population average for black students was three times higher than the national average of 17 percent, Caucasian and Hispanic students were under-represented. This over-representation of black students in the STEM high schools may be accounted for by location, as several of the STEM high schools were located in urban areas which have higher black populations. The average percentage of economically disadvantaged students attending STEM schools was 42 percent which was the same as the national average (School Data Direct, 2008).

What academic programs are provided?

An important learning characteristic that emerged from this study was the 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 attended STEM high schools were provided with more STEM content in the core subjects and/or electives. They were provided with work-related experiences and were provided with mentoring support to complete a capstone project. All of the schools in this study required a capstone project that reflected learning goals. Eighty percent required an internship during the 11th or 12th grade year. Half of the schools utilized interdisciplinary or integrated curriculum while the other half used traditional curriculum combined with STEM electives. Twenty percent had double periods of math and/or science and one school had an additional 20 days of instruction. Ninety percent offered a variety of AP and/or IB courses, and one school offered a Saturday technology enrichment program.

Table 5 contains a description of the various academic programs offered at STEM-focused high schools in this study. Unique electives required specially trained faculty who were knowledgeable in these fields. Most schools staffed special elective courses with industry professionals with work-related experience in their field while state required elective courses were taught by state licensed teachers.

What technology is being used?

STEM schools use a variety of instructional technologies, including computers with internet access, graphing calculators, calculator-based laboratories (CBLs), probe ware, and other digital data collection instruments. All schools had computer labs available during and after school hours while 30 percent issued personal computers to all faculty and students. Technology was used to deliver inquiry-based lessons, engage in research, produce and present projects, and to engage parents through an online parent portal. Table 6 contains a brief description of the types of technology utilized at STEM focused high schools.

What professional development activities do faculty members participate in?

Professional development opportunities for teachers at STEM high schools in this study 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 that 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 and/or was relevant to the school mission statement. One school had a state approved teacher certification program embedded in its school.

When conducting interviews with STEM school leaders, administrators were asked to describe the professional development opportunities offered to their teaching staff. In addition, some schools provided documents with detailed descriptions of professional development activities offered in their schools. An interesting finding that emerged was the involvement of mentors to train new teachers and develop master teachers. Teachers at Archimedes HS 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 motivate student engagement, reading strategies, assessments and accountability, rigor in the classroom, differentiating instruction, and encouraging critical thinking. In addition to onsite instructional coaches, educators at Archimedes are provided a virtual mentor network. This resource provides a unique, online video staff development. Teachers can watch master teachers demonstrate techniques that work in real classrooms. Archimedes has developed an instructional partnership with a charter school with the purpose of building a professional learning community that observes and analyzes effective instruction.

Teachers are positioned for success at Boyle High School 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. This school offers learning opportunities for practitioners to participate in teacher residencies and institutes. It provides resources for educators including: guides to project-based learning, curriculum integration,

School	Description of academic program
Archimedes	Students select a 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. Students can take extra course work in Interactive Media, including 3-dimensional modeling, 3-D animation, and programming, using professional software combined with complex math, physics, and design courses.
Boyle	Students produce real work products, solve problems, make oral and written presentations, and create a digital portfolio containing artifacts from standards-bearing project work. Teachers and industry experts support these efforts. Students experience inquiry-based instruction and can take community college courses in addition to the high school program, but not in replacement of high school courses. Students are scheduled for "Student Interest Groups" three times per week focusing on 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, cooking, chess etc.
Priestly	Students take seven classes within the academic school year including five academic courses and two electives. Students can focus on architectural, computer, manufacturing or electrical engineering. They have the option of obtaining certifications including A+ and computer 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, computer integrated manufacturing, engineering research design, video photography and broadcast, and robotics.
Pythagoras	Science and Technology elective courses include: astrophysics, biotechnology, bridge building, CAD design, creative engineering, earth science, engineering models, engineering of sound, environmental biology, crashes and biohazards, genetics, JavaScript programming, medical imaging, neurobiology, and robotics
Einstein	Eleventh and 12th graders are required to take Engineering and participate in hands-on, self-directed learning outside the classroom where they are paired with scientists from a corporate sponsor. 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.
Galileo	Students conduct research under the direction of mentor scientists and explore a wide range of subjects. They must select one of two tracks, science or engineering. Science Track: Chemistry, Organic chemistry, AP chemistry, Marine Biology, Biology, AP Biology, Physics, AP Physics, Electricity, Environmental Science, Genetics, Anatomy/Physiology, Earth Systems, or Science Research. Engineering Track: Engineering practicum, electricity/mechanics, surveying, Architectural drawing, CAD, environmental science, AP Chemistry, and AP Physics.
Plato	Students attend school for 198 days which is 20 days longer than the traditional school year. 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. Students complete the core curriculum as well as five additional electives chosen from mathematics, science, technology and engineering.
Marconi	Curriculum is designed to provide students with an integrated core curriculum that includes field experiences, fellowships and apprenticeships in STEM. 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.
Euclid	Math and science courses are teamed, offering comprehensive coursework focused on the interrelationships of science, technology, engineering and mathematics. The curriculum includes dedicated research classes founded upon the application of mastered material, integrated contemporary technologies, and extensive problem-solving experience using an inquiry approach to discovering science and engineering concepts through experimentation, modeling, testing, and observation. Project-based units provide engineering challenges that require students to apply science and engineering concepts. Mathematics is used in the analysis of data related to results of experiments and testing of engineering projects. Coursework is rigorous and emphasizes interrelatedness of science and mathematics content. The culminating senior project identifies a unique problem to study with a comprehensive mentorship with a local science or engineering professional.
Pascal	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. In addition to courses, students must complete a senior project in math, science or technology. This school offers an array of AP courses including traditional AP courses and content specific AP courses in genetics, microbiology, meteorology, astronomy, geology, environmental science, and marine science.

Table 5. Academic Programs Offered

internship program development, teaching diverse learners, student advisory, college advising, facilities development, technology infrastructure, and policies and management. Faculty members at Boyle HS participate in ongoing professional development. This includes 45 minutes per day without students for collaboration and program development. There are various day-long professional development workshops throughout the year and a two-week long teacher preparation session in August prior to the opening of the school year. The state commission on teacher credentialing has approved Boyle High School to certify teachers through its Teacher Intern Program. Boyle partners with the state university to provide a 120-hour pre-service 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 Boyle. Once hired, interns will participate in the program. Like Boyle High School, teachers can be hired at Priestly High School without a state teaching license. 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. Although teachers do not have to be certified by the state to teach at this school, Priestly High School has a prescribed training program that is very thorough. Teachers use common assessments across the departments and across the school.

Einstein High School serves as a laboratory for developing the best ways to teach science and math. The school is staffed by teachers from the surrounding districts, enabling them to take what they've learned back to their home classrooms. Einstein High School provides time for teachers to collaborate, support for instructional improvement, and encouragement to develop as professionals. 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 they examine student work, peer review lessons, and work on collaborative integrated course projects. Coaching is individually tailored to meet teachers needs. The coach meets with teachers one-on-one for an hour, then observes a class, and provides suggestions for improvements based on their improvement plan. The school

School	Instructional Technology Utilized in STEM high schools
Archimedes	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 instructional delivery.
Boyle	Students use technology to create digital portfolios that include artifacts from standards-bearing project work in the humanities, math, science, and elective courses.
Priestly	Technology is utilized for video, photography and broadcast, robotics, CIMS, math remediation, and principles of engineering. An online portal is available for parents and students to access daily grades, homework assignments and attendance.
Pythagoras	Instructors use technology as a tool to enhance learning and integrate it across discipline 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.
Einstein	Technology is used to enhance high school coursework and communicate with mentors and faculty. Students are immersed in hands-on, self-directed learning that requires the use of technology with assistance from teachers and mentors from the community.
Galileo	Students take a year-long 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 mathematics.
Plato	Technology is used in all subjects as a vehicle for learning. Every classroom has a media retrieval system, projector and a document camera. They have smart boards and writing tablets for teacher instruction and for students to use as a tool for learning.
Marconi	Technology is used to support an instructional program that is highly differentiated (i.e. discover, collaborative learning, content integration, workforce relevant and problem-based learning).
Euclid	Students are provided access to 21st century learning through infused, interactive technology incorporated through the use of personal computers, probe ware, data collection instruments, simulation software, and various internet and multimedia resources.
Pascal	Computers, as well as hand-held technology (graphing calculators and calculator-based laboratories), have become an ever-increasing part of the learning environment.

Table 6. Instructional Technology Utilized

provides substitutes so teachers can work with their coaches. Teachers are encouraged to develop as professionals.

The professional development plan at Marconi High School includes three significant characteristics: quarterly faculty institutes, daily common collaborative time and embedded industry internship experiences. Regular professional development is focused on cross-training experiences through development of trans-disciplinary instructional units, and systemic strategies for knowledge sharing among the STEM disciplines. 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 current best practices and research. Specific time is built into the work day for collaborative faculty work sessions. Marconi 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.

Hiring and training teachers in STEM content areas has been a challenge for many schools systems. The principals at Euclid, Galileo and Pascal identified the teaching staff as key components to program success. They try to select the best teachers for their programs then train them on the methods being used. There is collaborative training for teachers throughout the year and in the summer. Teachers work in teams and are responsible for selecting curriculum, developing and delivering integrated lessons, and assessing students. Core learning goals for the state must be accomplished first, but after that teachers have been granted permission to enhance the program as appropriate. Galileo High School provides support to new faculty members through a three-day new teacher orientation. New teachers are paired up with mentors. Teachers are encouraged to visit each other's classrooms, within their disciplines and outside disciplines. This type of collaboration allows teachers to see how creativity and rigor work in another content area, and to see how some of the same students, who they may find challenging, are excelling in other classes. Selected educators at Pascal High School are members of a curriculum planning committee, which collaborates with university partners. Integrated inquiry experiences are provided through collaboration between teachers and university engineers who 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.

Although all of the STEM schools provided professional development for their teacher, Marconi, Einstein and Boyle provided the most extensive training. These schools had regularly scheduled meetings during the work day throughout the school year. They also included mentor support that was instrumental in developing master teachers.

School	Content in mission statement	Distinguishing characteristic implemented in the program.
	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 providing students with rigorous and relevant academic and workplace skills for success in an increasingly technological society.	• 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 close links to the high tech workplace.
Priestly	To ensure that each student achieves their own personal vision.	• Offers 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 degree by providing students with an outstanding liberal arts education with science and technology focus.	• Admits 40 percent 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 produce independent thinkers who are intellectually curious and committed to making a difference personalizing learning so every child can succeed.	• 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 and 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 completing a senior project involving community members and teacher guidance.

Table 7. Mission Statement Connected to Program Implementation

What influenced the school programs?

Results showed that the content in the school's mission statement influenced the establishment of the schools. The way each school approached the academic preparation of students in STEM fields varied, but it was clear that the mission statement guided the focus of their efforts. Table 7 contains examples of the connections between the mission statement and program implementation. School mission statements are grouped into four themes: pathway to university degrees, rigorous academics, student population, and student environment.

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.

Discussion and Conclusions

The schools in this study have focused mission statements that guide leadership and decision-making and serve to align the content, curriculum, and teacher professional development. The mission statement served as a covenant that guided each school. One school described it as "the backbone for the schools design and operation." The initial school designers determined the admissions process and the type of academic programs offered. Some targeted certain populations while others used random selection. The geographic location needs to be considered during the initial planning stages. Rural schools faced unexpected transportation challenges because students lived a long distance from the school and no public transportation was available. The cost for transporting students became a large part of the operating budget.

Academic programs determined the type of faculty and unique skills that were needed. The principals described faculty as a key component to the success of their schools. One principal attributed his school's success to faculty who "are truly committed to developing the next generation of leaders." Additional faculty is needed because these schools have accelerated STEM courses and a broad range of unique electives. Some schools in this study hired business professionals to teach courses while others relied on certified teachers. Results from this study indicate that STEM programs are rigorous with a broad variety of STEM courses and technology enhancements. It was clear from documents collected and conversations 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 needed to pursue STEM careers.

Of the 10 schools in this study, students who attend Archimedes High School were the highest performing on the state end-of-course mathematics exams compared to other schools in its district, with a pass rate 32 percent higher than the state average. This school was established in 2004 with a goal to increase student achievement. To reach this goal, designers integrated a rigorous college preparatory STEM curricula taught by master teachers. Students participated in intense coursework, focused on biomedical technology, information technology or broadcast technology. The other schools in this study had an end-of-course passing rates between 8-18 percent above the state average in mathematics. Euclid and Pascal were the lowest performing schools in this study with 3 percent more of its students passing the end-of-course mathematics exam than the state average. These schools were the newest schools, established in 2008 and 2007 respectively, and served a larger student population, 1760 and 1609 students respectively, than others in this study. A unique characteristic of these schools is that they were existing schools that were reinvented to focus on STEM content.

To select students, Euclid used almost the same admissions documentation as Archimedes, while Pascal used a random lottery. Euclid focused on building a STEM pipeline that spans from grades 4-12 while Pascal focused on providing students with opportunities to become lifelong learners through challenging curricula. Galileo was the only large school (1615 students) that was well established (1997). Although this school did not use a lottery system for admissions it strived to accommodate as many applicants as possible. This was the only school that provided support for students to participate in national competitions in robotics, mathematics and science. The five schools that required a parent recommendation for admissions performed similarly to the five that did not. Plato and Priestley were the only two schools that did not require a student interest survey or essay. Students who attended schools that required essays for admissions performed similarly on end-of-course exams as others in this study. Students who attended Plato did not have to write an essay for admissions, but did have to agree to attend school 20 days (4-weeks) longer than state regulations required. Archimedes and Euclid, the highest and lowest performing schools in this study, were the only ones that required an interview for admissions.

Principals scheduled 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 teaching staff at Euclid High School is responsible for selecting curriculum and developing and delivering integrated lessons. At Pascal, individual teachers are selected to work with university partners to develop real-world integrated inquiry experiences for students. There was a deliberate plan to develop master teachers by having regularly scheduled professional development provided by instructional coaches and virtual mentors. Boyle, Einstein and Marconi provided the most extensive professional development opportunities for teachers and schedule time during the workday for learning teams to meet on a weekly basis. There are various day-long workshops available during the school year and week-long intensives during the summer. These schools also provide mentors or coaches that meet with new faculty on a weekly basis. Priestly and Boyle are the only schools that hired non-licensed teachers to teach state-required course. These schools provided in-house training beginning 2-3 weeks prior to the start of school with continue support throughout the school year. Students who learned from teachers at Priestly performed as well as those who attend STEM schools with all state licensed teachers.

All of the schools reported the utilization of instructional technology in learning experiences such as investigations and production of work products. The impact of various technology used cannot be assessed because data collected does not measure the extent to which teachers and students implemented the technology. All of the STEM schools required an internship and/or capstone project which required additional support. Faculty or staff members must set up the internship, evaluate student progress, and ensure that the internship learning environment supports academic goals. STEM-focused high school models in this study required a commitment from principals, community members, and teachers. They were led by visionary principals who were confident and committed to making a difference in the lives of students.

Implications for Future Research

This study was unique from past research on STEM schools because it highlighted specific features of STEM schools located in different regions of the United States that were specifically designed for a diverse student body. It is clear that new STEM high schools changed the content and classroom experiences for high school students and have the potential to change the way schools are designed in the future. Building on these results, further study is needed to learn the long term 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 need to know what modifications were 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?

The models for structuring specialized STEM high schools vary a great deal.

For a more comprehensive look at specialized STEM programs further research is needed to answer the following questions: Are specialized STEM high-school graduates more likely to remain in the STEM pipeline than students with similar achievement and interests who attended regular public high schools? Which educational/instructional practices used by specialized STEM high schools are associated with higher STEM pipeline retention rates in college and higher rates of entrance into STEM-related professions? What type of curriculum is used and how is it implemented? Are residential-style high schools more effective than local magnet schools? Are specialized schools-within-schools a more beneficial approach compared to regional centers with classes for a half-day or only a few days a week? The duration of this study provides only a snapshot of current programs implemented at each STEM school setting. Further study is needed to measure the long term impact of STEM high school programs.

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