Best Practices in Elementary STEM Programs

In the following report, Hanover Research provides an overview of best practices in elementary STEM education. The first section of the report offers a definition of STEM as it relates to K-12 education. The second section discusses best practices in elementary STEM initiatives including instructional techniques, curriculum and programs, out-of-class activities, the importance of highly-qualified teachers, and long-term program sustainability. The third section of the report discusses professional development for STEM educators. The final section of the report details exemplary elementary STEM school models.
Executive Summary

Introduction

Although STEM-focused schools such as Stuyvesant High School, founded in 1904, and the Bronx High School of Science, founded in 1938, are not an entirely new phenomenon, there has been a dramatic increase in the number of STEM-focused schools in recent years. Currently, 30 states have comprehensive programs for cultivating STEM education, and states such as Georgia, New York, Michigan, and Virginia have a particularly high concentration of these schools. However, few of these schools are found at the elementary level despite research that shows the importance of sparking interest in science at an early age. A recent report found that there are at least 315 public STEM schools in the United States as of the 2007-2008 academic year. Eighty-six percent of these schools serve students in grades 9-12 while only 3 to 4 percent serve students in grades 1-5. This lack of STEM-focused schools at the elementary level has led the President’s Council of Adviser’s on Science and Technology to recommend the creation of at least 800 STEM-focused elementary and middle schools over the next decade (as opposed to only 200 more STEM-focused high schools).

This report provides an examination of best practices in elementary education in science, technology, engineering, and mathematics (STEM). The report is organized according to the following four sections:

- **Section I: Defining STEM** provides a comprehensive definition of STEM including various interpretations of its meaning, the goals of STEM education, and the subjects and skills targeted by STEM educators.

- **Section II: Best Practices in Elementary STEM Programs** discusses best practices in STEM initiatives including instructional techniques, curriculum and programs, out-of-class activities, the importance of highly-qualified teachers, and long-term program sustainability.

- **Section III: Professional Development** discusses the importance of professional development for elementary teachers involved in STEM programs as well as available programs for elementary professionals.

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Section IV: Case Studies describes various model elementary STEM programs found throughout the United States. These schools demonstrate many of the best practices discussed in Section II of this report. The following five elementary schools are profiled:

- Christa McAuliffe School (Public School #28)
- High Tech High Learning Network
- Oakcliff Traditional Theme School
- Sojourner Elementary School
- Westdale Heights Academic Magnet

Key Findings

- Effective elementary STEM programs share the elements of strong leadership, professional capacity among teachers, strong ties to parents and the community, a student-centered learning climate, and instructional guidance for teachers. Out-of-class activities, a standard-based curriculum, and program sustainability are key characteristics as well.

- One way to motivate students and cultivate student interest in STEM subjects, particularly among underrepresented groups, is to offer various extracurricular activities to students. Such activities may include summer programs, after school enrichment activities, science fairs or Olympiads, and other competitions.

- According to a Compendium of Best Practice K-12 STEM Education (which selects programs based on challenging content and curriculum, an inquiry learning environment, defined outcomes and assessment, sustained commitment and community support), the following elementary STEM programs were found to be highly effective: ASSET Inc., Engineering is Elementary, Math Out of the Box, Project Lead the Way, and Seeds of Science/Roots of Reading.

- Professional development is particularly important for elementary teachers involved in STEM education, as research shows that these teachers typically do not receive enough undergraduate education in mathematics and science. Furthermore, professional development for STEM teachers must be provided over an extended period of time.

- All of the STEM-focused elementary schools profiled in the final section of the report are inclusive programs, provide a rigorous curriculum, and offer extracurricular programs related to STEM activities. Two schools utilize the team teaching or content specialization approach in science and math in order to maximize the effect of highly-qualified teachers on student learning.
Section I: Defining STEM

Introduction

American high school students rank alarmingly low among students of industrialized countries when it comes to achievement in science and mathematics. The poor performance of American students in the vital fields of science, technology, engineering, and mathematics (the STEM fields) is a fact borne out in test scores and other assessments of academic achievement. Nationally, only about a third of American students in grades 4 and 8 performed at or above proficient in these subjects, while more than a third scored below the basic level in mathematics and science on the National Assessment of Educational Progress in 2009.5 In grade 12, only a quarter of students performed at or above proficient in mathematics.6

These alarming trends have led to the formation of a broad reform movement encapsulated by the acronym “STEM.” This acronym was first used by the National Science Foundation (NSF) to refer to programming dealing with science, technology, engineering, and mathematics.7 Since then, STEM education has been portrayed by all levels of policymakers as a key to unlocking renewed economic and hegemonic success for the United States:

- **2007 National Governor’s Association Press Release:** “STEM centers will help state K-12 education systems ensure all students graduate from high school with essential competencies in science, technology, engineering and math. These competencies are integral to improving overall high school graduation and college readiness rates and supporting a state economy’s innovation capacity related to the businesses that operate within their leading economic clusters.”8

- **White House Press Release on “Educate to Innovate” Campaign for Excellence in Science, Technology, Engineering & Math (STEM) Education:** “President Obama has identified three overarching priorities for STEM education: increasing STEM literacy so all students can think critically in science, math, engineering and technology; improving the quality of math and science teaching so American students are no longer outperformed by

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those in other nations; and expanding STEM education and career opportunities for underrepresented groups, including women and minorities.”  

- **Massachusetts Stem Initiative:** The Initiative includes three broad objectives: “(A) Increase the number of students planning on STEM majors and career paths; (B) Increase the number of qualified STEM teachers; and (C) Improved overall education for all students in math and science as a foundation for STEM studies.”

- **National Math and Science Initiative:** The Initiative emphasizes the mathematics and science components of STEM, stating that the NSMI was formed “to address one of the nation’s greatest economic and intellectual threats—the declining number of students who are prepared for and take rigorous college courses in mathematics and science. To flourish in the 21st century, the United States must continue to generate intellectual capital that can drive the research and development activities that fuel the economic engine of our future prosperity.”

However, when the NSF popularized the use of this acronym, it did not provide an explicit definition for what “STEM” specifically entails, leaving more detailed definitions up to stakeholder interpretation. This has led to the existence of differing definitions and operational applications across the nation and within organizations. Though not necessarily incompatible, these multiple interpretations have created confusion among many educators. We highlight several clarifying perspectives on STEM education in the remainder of this section.

**Goals of STEM Education**

An appropriate understanding of STEM begins with an examination of its intended outcomes. Generally speaking, these goals are designed to increase America’s global competitiveness in science and technology innovation as well as to increase America’s global competitiveness in science and technology innovation as well as to improve the STEM understanding of all U.S. citizens.

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13 Ibid., p. 3.
improve the STEM understanding of all U.S. citizens. The President’s Council of Advisors on Science and Technology (PCAST) identifies four major goals of STEM Education, examined in the table below.  

By keeping these objectives in mind, educators can develop a set of practices intended to meet these specific goals.

**Figure 1.1: Goals of STEM Education**

<table>
<thead>
<tr>
<th>Goal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ensure a STEM-capable citizenry</strong></td>
<td>This goal seeks to cultivate a citizenry that has “the knowledge, conceptual understandings, and critical-thinking skills that come from studying STEM subjects.” This is important even for those who never directly enter a STEM-related career.</td>
</tr>
<tr>
<td><strong>Build a STEM-proficient workforce</strong></td>
<td>This goal seeks to adequately prepare a sufficient number of workers for job openings in STEM-related careers which are expected to increase in coming years. Additionally, STEM-related skills are increasingly relevant in fields not directly related to STEM subjects.</td>
</tr>
<tr>
<td><strong>Cultivate future STEM experts</strong></td>
<td>This goal aims to educate the best STEM experts in the world because they contribute “to economic growth, to technological progress, to our understanding of ourselves and the universe, and to the reduction of hunger, disease, and poverty.”</td>
</tr>
<tr>
<td><strong>Close the achievement and participation gap</strong></td>
<td>This goal aims to increase women and minority participation and interest in STEM fields in order to tap into the country’s full potential.</td>
</tr>
</tbody>
</table>

Source: President’s Council of Advisors on Science and Technology

**STEM Subjects and Skills**

Taken literally, the acronym “STEM” stands for science, technology, engineering, and mathematics. In the realm of K-12 education, STEM typically refers to coursework related to these disciplines. However, each of these categories may include instruction in several subject areas. The following table outlines common STEM subjects in K-12 education:

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### Figure 1.2: Relevant STEM Subjects

<table>
<thead>
<tr>
<th>Science</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Biology</td>
<td>• Computer/Information Systems</td>
</tr>
<tr>
<td>• Chemistry</td>
<td>• Game Design</td>
</tr>
<tr>
<td>• Marine Biology</td>
<td>• Developer</td>
</tr>
<tr>
<td>• Physics</td>
<td>• Web/Software Developer</td>
</tr>
<tr>
<td>• Science</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td>Mathematics</td>
</tr>
<tr>
<td>• Chemical Engineering</td>
<td>• Mathematics</td>
</tr>
<tr>
<td>• Civil Engineering</td>
<td>• Statistics</td>
</tr>
<tr>
<td>• Computer Engineering</td>
<td></td>
</tr>
<tr>
<td>• Electrical/Electronic</td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
</tr>
<tr>
<td>• General Engineering</td>
<td></td>
</tr>
<tr>
<td>• Mechanical Engineering</td>
<td></td>
</tr>
</tbody>
</table>

Source: STEMconnector

In addition to these subjects, STEM may also include instruction in environmental science and geology.\(^{16}\) Though certain social and behavioral sciences (such as economics, anthropology, and sociology) may be appropriate STEM subjects at the postsecondary level, they are not typically addressed in K-12 education.\(^{17}\) Furthermore, most definitions of STEM education do not include references to the medical fields.

Traditionally, math and science have been emphasized more than technology and engineering in practical applications of STEM.\(^{18}\) For example, the National Assessment of Education and Progress measures these traditional subjects (e.g. math and science) at the elementary and secondary levels, but not technology or engineering. Proponents of STEM education advocate \textbf{increasing the visibility of technology and engineering in the standard K-12 curriculum.} Contrary to popular belief, technology education involves more than just incorporating computer literacy into the curriculum. Technology relates to the way in which humans have developed tools to modify the natural environment and therefore the definition of technology education should be “expanded to include all kinds of devices, instruments, and tools that can be applied in both domains of science and engineering.”\(^{19}\)

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\(^{17}\) Ibid.


In addition to developing content knowledge in these areas, STEM education also seeks to cultivate soft skills such as scientific inquiry and problem-solving skills. By enhancing these skills, STEM education seeks to build a STEM-literate citizenry. This “STEM literacy refers to an individual’s ability to apply his or her understanding of how the world works within and across four interrelated domains.” The following table defines STEM-literacy according to each of the four subject areas.

**Figure 1.3: Defining STEM Literacy**

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Literacy</strong></td>
<td>• The ability to use scientific knowledge and processes to understand the natural world as well as the ability to participate in decisions that affect it</td>
</tr>
<tr>
<td><strong>Technological Literacy</strong></td>
<td>• Students should know how to use new technologies, understand how new technologies are developed, and have the skills to analyse how new technologies affect us, our nation, and the world</td>
</tr>
<tr>
<td><strong>Engineering Literacy</strong></td>
<td>• The understanding of how technologies are developed via the engineering design process using project-based lessons in a manner that integrates lessons across multiple subjects.</td>
</tr>
<tr>
<td><strong>Mathematical Literacy</strong></td>
<td>• The ability of students to analyze, reason, and communicate ideas effectively as they pose, formulate, solve, and interpret solutions to mathematical problems in a variety of situations</td>
</tr>
</tbody>
</table>

Source: National Governor’s Association Center for Best Practices

**Integrated Approach to STEM Education**

Proponents of STEM education are increasingly advocating the interrelated nature of all the STEM subjects and the necessity of implementing an interdisciplinary approach rather than treating the individual subjects as “silos” or stand-alone subjects. The following figure demonstrates this concept by illustrating some of the connections between the various STEM subjects.

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22 Ibid.

This interdisciplinary approach thematically links one or several courses together, allowing topics to “reinforce each other in support of the overall growth of each topic.” Some groups suggest that the term “STEM education” itself implies a more integrated and hands-on education. For example, the American Institute of Biological Sciences made the following comments to the U.S. House of Representatives:

Teaching the way we did 100 years ago no longer meets the needs of students, scientist, or society. To be scientifically literate members of society or future scientists, students must learn by engaging with real-world problems in an interdisciplinary manner.

These comments suggest that STEM education should include interdisciplinary and hands-on, experience-based pedagogical techniques. Currently, however, there is no established consensus on the methodology of interdisciplinary STEM education. 

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24 Ibid., 5.
Section II: Best Practices in Elementary STEM Schools

This section of the report highlights best practices in elementary STEM programs including instructional techniques, curriculum and programs, out-of-class activities, the importance of highly-qualified teachers, and long-term program sustainability. Due to the nature of the literature on STEM education, elementary and secondary practices are often grouped together in a “K-12 package” of recommendations that does not necessarily distinguish between the two levels. Furthermore, when a distinction exists, the focus tends to be at the secondary level rather than at the elementary level. However, this section acknowledges facets of effective elementary STEM programs to the extent that this information is available in the existing literature. Specific example of elementary STEM school programs can be found in Section IV of this report.

General Characteristics and Common Instructional Techniques

Research clearly indicates that early and repeated exposure to STEM subjects is essential for cultivating both future interest and future aptitude in STEM subjects. The unique characteristics of STEM subjects may require the use of alternative pedagogical techniques for effective communication of STEM concepts. Examples of common pedagogical techniques used in STEM-focused schools are:

- Traditional, teacher-led instruction
- Project-based learning
- Workplace or lab-based learning
- Use of technology-supported learning tools

Additionally, according to various research, elementary STEM schools tend to have the following common characteristics:

- Strong leadership
- Professional capacity among teachers
- Strong ties to parents and the community
- A student-centered learning climate
- And instructional guidance for teachers

Adequate Instructional Time

It is essential for teachers to devote enough instructional time to STEM subjects since an interest in these subjects has been shown to develop from an early age.

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However, elementary school teachers have the tendency to focus efforts on subjects that are assessed on standardized tests, namely mathematics and English language arts. According to a nationally representative survey in the 2006-2007 school year, students in elementary schools received an average of 323 minutes of mathematics instruction per week but only received an average of 178 minutes (or about half as much) science instruction per week. Additionally, 28 percent of districts reported decreasing instructional time devoted to science instruction by an average of 75 minutes per week.30

**Standards-based Curriculum**

Research clearly indicates that a **coherent and rigorous curriculum** is essential for any successful STEM school initiative.31 In some cases, actions have been taken at the state level to serve this goal. For example, 44 states (including Texas) and the District of Columbia have adopted the Common Core State Standards in Mathematics.32 This initiative seeks to replace diverse state curricula with standardized student learning goals in mathematics for grades K through 12.33 One of the goals of the Standards is to emphasize a depth of knowledge rather than focusing on a breadth of subjects.34 Research has demonstrated that students achieve higher academic standards when mathematics curriculum is infused with more depth.35

**Technology**

The **International Technology Education Association** has crafted standards for technology education and literacy in grades K-12. The Standards for Technology Literacy (STL) offer a guide for age appropriate content knowledge and skills. The standards have specific applicability to the elementary level with content designed for grades K-2 and 3-5. The goal of this curriculum is to prepare technologically literate students who understand “what technology is, how it is created, and how it shapes society, and in turn is shaped by society.”36

Although the “T” in STEM refers to more than just the incorporation of technology into everyday curriculum, technology is also a useful tool that can be integrated

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30 “Ibid., p. 22.
31 Ibid., pp. 20-23.
34 Ibid.
throughout multiple disciplines to enhance learning. The following figure offers an overview of the range of technological resources and materials available to educators based on three dimensions: the complexity of learning, authenticity of learning, and instructional approach to learning.\(^{37}\)

**Figure 2.1: Technology Tools**

![Technology Tools Diagram](https://via.placeholder.com/150)

*Source: eTech Ohio Commission*

**Engineering Programs**

Massachusetts was the first state to create curricular guidelines and a framework for assessments in K-12 engineering education. This curriculum was developed with the assistance of the National Center for Technological Literacy at the Museum of Science in Boston.\(^{38}\) The organization is currently working with several states in the nation in order to develop similar standards across the country.

Bayer Corporation’s *Compendium of Best Practice K-12 STEM Education Programs*, as well as several other sources, identifies *Engineering is Elementary*

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**District Administration Practice**

(EiE) as a highly effective elementary STEM program.  Through the use of storybooks, students integrate social studies and English skills along with mathematics and science in order to solve engineering problems in a hands-on learning environment. The program, which works with various professional development and regional advocacy partners, pre-service teacher education partners, corporate and foundation partners, and school district partners, identifies the following unifying characteristics of the curriculum:

- Teamwork is strongly valued
- Students learn that there is no single “correct” solution to an engineering problem
- Failure is part of the process and expected
- Everyone can engineer
- The sharing of ideas and learning from others is valued
- Engineering is both collaborative and sometimes competitive

**Other Effective Elementary STEM Programs**

For these programs to be have been selected as highly effective they must meet the following four rigorous criteria:

- **Challenging Content and Curriculum** which is inquiry-based, experiential, and clearly defined.
- **An Inquiry Learning Environment** where teachers and students work together as active learners.
- **Defined Outcomes and Assessment** where goals are clearly defined and success is measured against them.
- **Sustained Commitment and Community Support** with strong leadership and sufficient resources.

Bayer Corporation’s Compendium of Best Practice K-12 STEM Education Programs, as well as several other sources, also identifies **Project Lead the Way** as a highly effective STEM program. Traditionally focused on the middle and high school level, Project Lead the Way also offers a limited number of elementary lessons ranging in length from five days to two weeks. The lessons are designed on the principle that “students engaged in problem-based learning, project-based learning, and activity-based learning will exhibit increased performance in their academic achievement, higher-order thinking skills, and cooperative learning abilities.”

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http://www.iteea.org/Publications/TandC/Sep09.pdf  
42 Adapted from Ibid., p. 8.  
43 Ibid., p. 64.  
Other notable programs from the Compendium of Best Practice K-12 STEM Education Programs that target elementary students are described briefly below:

- **ASSET Inc. (Achieving Student Success through Excellence in Teaching):** Selected by the governor of Pennsylvania to lead the state’s *Science: It’s Elementary* initiative, Asset specializes in professional development curriculum design. It is guided by the principles of standards-based curriculum materials, ongoing teacher professional development, refurbishment of hands-on curriculum materials, assessment and program evaluation, and community and administrative involvement. Evidenced-based research has demonstrated that the program has proven success in raising students’ math and science standardized test scores.45

- **Math Out of the Box:** A national program particularly designed for high poverty students, the curriculum promotes inquiry-based learning in four vertical strands: Developing Algebraic Thinking, Developing Geometric Logic, Developing Measurement Benchmarks, and Developing Number Concepts.46

- **Seeds of Science/Roots of Reading:** This targets elementary students as well as English language learners in an attempt to combine science learning with literacy learning.47

*Integrated Curriculum*

In addition to a coherent and rigorous curriculum, successful STEM school initiatives design and implement *integrated curriculum content*. As noted earlier in this report, STEM schools are increasingly introducing interdisciplinary techniques that thematically link one or several courses together. This strategy allows topics to “reinforce each other in support of the overall growth of each topic.”48 Currently, there is no widespread consensus on the necessity or methodology of interdisciplinary STEM education.49 Fortunately, integration among STEM subjects is most feasible at the elementary level given that students typically spend the majority of their day with the same teacher, reducing the need for lesson plan coordination among multiple teachers.50

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46 Ibid., pp. 54-55.
Highly-Qualified STEM Teachers

Teachers with a strong capacity to teach in their discipline are essential for the success of any STEM school. These highly-qualified STEM teachers are in high demand, as STEM schools typically have low student to teacher ratios which average around 11 students to every one teacher.

Innovative elementary schools have pioneered new methods of maximizing staffing resources at the elementary level. Because of the shortage of qualified math and science teachers at this level, a group of schools in California (led by Rocketship Education) developed a method where teachers with extensive backgrounds in math and science instruct more than one group of students. This “team teaching which allows for content specialization” is one of the factors resulting in Sojourner Elementary School in Oregon being named a “Star Innovator School by Intel Foundation in 2008. In fact, the President's Council of Advisor's on Science and Technology recommend that elementary schools have at least two resident STEM experts, one each in science and math, to serve as leaders and mentors for other teachers.

Out-of-Class Activities

Effective STEM instruction provides students with opportunities for hands-on experiences and real-world applications of scientific problems. One way to achieve this goal is by offering various extracurricular activities to interested students. Such activities may include summer programs, afterschool enrichment activities, science fairs or Olympiads, and other competitions. These activities are particularly relevant for minority groups who are underrepresented in STEM, such as girls, African-Americans, and Hispanics. Research has shown that “as early as elementary school and middle school, many students from these groups begin to think that they will not or cannot excel at STEM.” Out-of-class activities can also

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play a significant role in developing interest among gifted students. Some specific examples of these types of activities include the following:58

**Figure 2.2: Out-of-Class STEM Activities**

<table>
<thead>
<tr>
<th>Out-of-Class Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School-based</strong></td>
</tr>
<tr>
<td>• Mathematics competitions</td>
</tr>
<tr>
<td>• Robotics competitions</td>
</tr>
<tr>
<td>• Science fairs</td>
</tr>
<tr>
<td><strong>After-school Programs</strong></td>
</tr>
<tr>
<td>• Connect mathematics with household activities</td>
</tr>
<tr>
<td>• Build robots using Legos</td>
</tr>
<tr>
<td>• Tell stories with animation technology</td>
</tr>
<tr>
<td>• Study wildlife</td>
</tr>
<tr>
<td><strong>Weekend Programs or Summer Camps</strong></td>
</tr>
<tr>
<td>• Engineering</td>
</tr>
<tr>
<td>• Astronomy</td>
</tr>
<tr>
<td>• Number theory</td>
</tr>
</tbody>
</table>

Source: President’s Council of Advisors on Science and Technology

Elementary students in Carrollton, Georgia, for example, are exposed to an engineering-focused STEM through science and math classes during an introductory robotics course that spans a few weeks.59 At one of the county schools, Bowdon Elementary, students can also participate in an after-school robotics club, which is mentored by local area high school students who have gained increasing STEM expertise in recent years.60 This gives interested students the opportunity to gain additional hands-on experience in STEM-related activities from an early age.

**Connections to the Community**

Although activities such as internships may be more commonly associated with the secondary level, connections with the community are still important for elementary STEM programs. Community connections with parents as well as local businesses and industries can help to equip a school with the necessary tools, support, and professional network essential for a successful STEM program.61

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58 Ibid.
Program Sustainability

Sustaining a STEM program involves several factors including building and maintaining local capacity for continuous improvement to STEM structures. Districts must also ensure the availability of funds for the program beyond the implementation phase. Additionally, ongoing feedback and evaluation is necessary to track, measure, and implement changes to the system including instructional models and professional development for teachers.\textsuperscript{62} The issue of professional development is discussed in more detail in the next section of this report.

Section III: Professional Development

This section discusses the importance of professional development for elementary teachers involved in STEM education as well as best practices in elementary professional development for STEM educators.

The Need for Professional Development

According to a recent survey, university programs for elementary teachers only require two mathematics courses on average in order to graduate.63 As a result of this lack of training, studies have shown that a majority of elementary teachers do not feel prepared to teach mathematics.64 This “math-phobic” attitude of many elementary teachers also has the potential to affect students’ perceptions as well, particularly in the case of female learners (in terms of academic success and gender stereotypes) according to a study from the University of Chicago.65

Elementary school teachers also lack confidence in teaching science courses. According to the National Survey of Science and Mathematics Education in 2000, an alarmingly small percent of teachers felt “very well qualified” to teach a variety of scientific subjects at the elementary level: 28 percent in life science, 24 percent in earth science, and 14 percent in physical science.66 The same survey, which consulted 655 teachers in grades K through 5, also revealed that 23 percent of those surveyed had never completed undergraduate science coursework.67 Teachers who are unprepared to teach seemingly complex, science-related subjects may unknowingly devote less classroom time in favor of other course material.

This lack of preparation and confidence among elementary school teachers in teaching both science and mathematics demonstrates the need for professional development opportunities in STEM education. This professional development is necessary for teachers to develop both content knowledge and pedagogical knowledge as it relates to STEM disciplines.

Design a Long-Term Plan for Professional Development

Best practices specific to STEM professional development draw heavily from general teacher development techniques. However, certain approaches are considered by education experts to be most applicable to STEM teacher needs. Based on our review of the literature, Hanover has produced the list below to highlight these especially

66 Ibid., p. 12.
67 Ibid., p. 11.
relevant practices. Education leaders should design STEM teacher development programs with these principles in mind:68,69

Figure 3.1: Elements of Effective STEM Professional Development

- **Active** – Engage teachers in practicing concrete tasks related to teaching, assessment, and observation of learning.
- **Collaborative** – Include time for teachers to share ideas and practices.
- **Learner-centered** – Draw upon teachers’ questions, inquiry, and experiences.
- **Student-centered** – Build on teachers’ current work with students.
- **Relevant** – Address problems teachers experience in their classrooms.
- **Content-specific** – Develop teachers’ knowledge and capacity to teach specific subject matter.
- **Pedagogy Focused** – Provide modeling, coaching, and problem-solving around specific areas of practice.
- ** Appropriately Structured** – Plan a sufficient amount of time for teachers to participate in and process their professional development.

Sources: Journal of Technology Studies, National Research Council

Long-term strategic planning can enable education leaders to ensure that STEM teachers receive the support they need, utilizing the principles outlined above. Leaders should not underestimate the importance of providing teachers with adequate time to acquire and subsequently apply the skills they obtain in professional development programs. In order to maximize impact, professional development for STEM teachers must be provided over an **extended period of time**.70

**Examples of Professional Development Programs**

Unfortunately, a limited number of professional development programs that specifically target elementary professionals exist. Many K-12 STEM initiatives do not distinguish between the elementary and secondary level and as such, some researchers have noted that “the inadequate preparation of elementary school teachers is a “blind spot” in our portfolio of STEM programming.”71 The following provides an example of a well-established professional development program for elementary educators.

- **National Center for Technology Literacy**: The Museum of Science in Boston offers professional development opportunities for K-12 teachers in engineering and technology. Professional development opportunities include online courses that feature hands-on projects, as well as a workshop “Engineering is Elementary,” specifically designed for elementary school teachers.

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teachers. This program has been particularly successful in improving content knowledge and interest in STEM subjects, especially among underrepresented groups such as girls, English language learners, and minority students.

Another solution to the problem of an under-qualified STEM teacher corps is to empower district teachers to take advantage of scholarships and fellowship opportunities for in-service graduate education. The Coalition for Science After School lists the following programs that are designed to meet the need for specialist education among practicing STEM-field teachers:

- **National Center for STEM Elementary Education, St. Catherine University:** This STEM Graduate Certificate directly responds to the problem of “an overwhelming majority of elementary teachers today [who] did not receive adequate preparation to teach STEM concepts.” The Center works directly with schools and districts to create customized programs of study, delivered in summer or in-service sessions.

- **Mickelson ExxonMobil Teachers Academy:** This one-week professional development summer program is designed for third- through fifth-grade teachers. Curriculum focuses on pedagogy and content teachers can use to motivate and prepare students to pursue careers in STEM fields.

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Section IV: Case Studies

This section provides examples of STEM-focused elementary schools. The President’s Council of Advisors on Science and Technology, in its report to the President on K-12 STEM Education, notes that, while there “are a few examples of elementary schools with rich STEM connections, such as the NASA Explorer Schools, […] we do not know enough to know which models work best.” The profiles that follow provide a representative sample of the types of exemplary programs that exist. First, these were selected based on their identification in literature as “model” STEM programs. These elementary schools were also chosen based on their identification as an Intel Foundation “School of Distinction” in either science or mathematics. In order be a recipient of this award, such a school must demonstrate innovativeness in the field of mathematics or science through teaching and learning standards that meet or exceed national expectations. According to the Intel Schools of Distinction program website:

Successful math and science programs serve as models for schools across the country. By replicating proven programs, schools everywhere can reinvigorate their own mathematics and science programs to inspire the next generation of scientists and mathematicians.

Thus other STEM elementary programs may strive to emulate the programs outlined in this section. The section provides an overview of the program characteristics, curriculum, and extracurricular activities of the following elementary schools:

- Christa McAuliffe School (Public School #28)
- High Tech High Learning Network
- Oakcliff Traditional Theme School
- Sojourner Elementary School
- Westdale Heights Academic Magnet

Christa McAuliffe School (Public School #28)

Program Characteristics

Christa McAuliffe School is a comprehensive school in Jersey City, New Jersey serving students in pre-K through eighth grade. Having been recognized previously by both the Broad Foundation and Rutgers University for success in narrowing the achievement gap, Christa McAuliffe School also found itself among Intel’s “School of

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79 Ibid.
Distinction” finalists for science in 2010, although it did not win the final prize. Ongoing professional development for teachers is an important part the curriculum as well as significant parental involvement as resources, advocates, and supporters.

**Curriculum**

The curriculum is intended to “foster curiosity, inquiry, and discovery” through an integrated approach that “extends beyond the classroom walls.” The curriculum includes the following specialized programs:

- H.O.P.E. (Honors, Opportunity, Potential, Enrichment) classes
- English as second language classes
- Reading Recovery instruction
- Project Raise services
- Inclusion and transitional special education classes
- Bilingual education
- The Response to Intervention (RTI) program
- An 8th grade algebra course
- Fine and performing arts program

**Extracurricular Programs**

Christa McAuliffe School enjoys widespread participation in its extended-day tutorial program and after school program which include the following:

- The tutorial program
- Community League
- Show choir
- Band
- Seasonal sports teams
- Preparation for the New Jersey Assessment of Skills and Knowledge
- Yearbook
- Scholastic Bowl
- Choir
- Science/technology classes
- Robotics

Additionally, **Project Reservoir** is a multi-year, multi-grade, and interdisciplinary project that involves students in the revitalization of a local reservoir. Students benefit from frequent real-world exposure and projects pertaining to various plant and aquatic life. Through these projects students can apply math principles such as

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81 Ibid.
84 Ibid.
85 Ibid.
statistical sampling, extrapolation, and graphing and learn about science topics such as life cycles, reproduction, and environmental science.\(^{87}\)

**High Tech High Learning Network**

Several sources identify High Tech High as a model program for STEM Education.\(^{88}\) The high school was founded in 2000 by a group of high-tech industry professionals seeking to cultivate local STEM talent.\(^{89}\) Originally established as a single charter high school, High Tech High now oversees eleven schools in San Diego including two elementary schools, four middle schools, and five high schools.\(^{90}\) Explorer Elementary School was the sole recipient of California’s Distinguished School Award in the San Diego Unified District in 2004.\(^{91}\) High Tech Elementary in Chula Vista recently opened in September 2011 along with the middle school at the same location. Both of these elementary schools are profiled here.

**Program Characteristics**

The High Tech High network of schools is an inclusive school system that selects students based on a random lottery system.\(^{92}\) However, weighted points may be given “based on Zip code and to students currently receiving free or reduced lunches to ensure a diverse student population.”\(^{93}\) High Tech High has as its overarching mission “to develop and support innovative public schools where all students develop the academic, workplace, and citizenship skills for postsecondary success.”\(^{94}\) The elementary schools serve students in kindergarten through fifth grade.

The high tech focus of these schools is evident in the various architectural designs. High Tech Elementary in Chula Vista, for example, features moveable classroom walls.\(^{95}\) This flexibility in design can accommodate both small and large groups of students depending on the project type or academic activity. Additionally, the transparent windows and doors throughout the building allow students and teachers to see each other’s work, something which fosters an atmosphere of creativity and

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\(^{87}\) “Project Reservoir.” We Are Teachers, Sept. 27, 2011. http://www.weareteachers.com/ideas/partnerask/teachingidea?app=%2017356&grantId=76


team collaboration. The importance of collaboration was also taken into
consideration in the creation of classroom floor plans that allow for team teaching as
well as shared spaces throughout the building where older students may mentor
younger ones through structured activities. Finally, a deliberate effort has been made
to set aside studio space for classes in Performance Arts, Elementary
Engineering/Design, and Fine Arts.96

Curriculum

At High Tech Elementary, project-based learning is a central tenet of student
learning. Through the process of learning (exploring, discussing, designing,
reflecting, and refining) teachers act as guides while students design various projects
that simulate the real world. The projects are intended to be interdisciplinary so that
most include scientific, mathematical, literary, historical, and artistic elements.

Because this type of project-based learning can be difficult to measure, High Tech
Elementary does not rely heavily on traditional weekly exams and tests. Instead, the
elementary schools advocates for performance-based assessment that requires
students to develop projects, solve problems, write reflections of their findings, and
present findings to a panel typically consisting of teachers, community members, and
other students. In essence, according to the school, success is measured by “the
students’ ability to explain or demonstrate his/her learning from the beginning of the
project to the end.”97

High Tech Elementary does not rely solely on traditional materials and resources such as
textbooks and basal publications to advance student learning. Rather, a variety of resources
are employed in order to maximize students’ learning potential. These nontraditional resources
may include information from adults with experience in a related field, primary source documents, other teachers, internet
resources, and peers.98

The school calendar at High Tech allows for a “minimum day” every Wednesday
which ends the day at 12:30pm. Explorer Elementary also takes advantage of half
days on Wednesday. This additional free time allows for time to study, to work on
projects, to work on projects, to meet with other students or mentors, or to
participate in extracurricular activities.

96 Ibid.
98 Ibid.

- Direct Instruction
- Literature circles
- Collaborative learning groups
- Writers workshops
- Differentiated curriculum
- Flexible scheduling
- Guest speakers
- Individual instruction
- Student demonstration
- Rubric-based self evaluation, group evaluation, and class evaluation
- Strategies for analytical thinking using icons of depth and complexity developed by the California Association for the Gifted (CAG)
- Discussion groups
- Field trips
- Technology
- Scholarly circles, debates, and reflections
- Project-based learning
- Whole class instruction
- Flexible grouping
- Independent study
- On-going assessment
- Journaling and writing across the curriculum (math, science, garden, etc.)

**Extracurricular Programs**

High Tech Elementary operates an After School Child Care and Enrichment program which offers scholarships to eligible free and reduced price lunch students. The program runs until 6:00 pm every day.\footnote{100 “High Tech Elementary.” Op. cit.} After school programs available at Explorer Elementary (for an additional fee) include chess, sports, music, art, dance, and Spanish, among others.

**Oakcliff Traditional Theme School**

**Program Characteristics**

Oakcliff is an inclusive elementary school serving students in pre-kindergarten through grade 5. Oakcliff Traditional Theme School is “a diverse learning community […] dedicated to empowering students to become productive members of society and life-long learners in a safe, challenging and creative environment.”\(^{103}\)

**Curriculum**

Students at Oakcliff are held to high academic standards under the belief that higher expectations lead to higher academic performance.\(^{104}\) As a result of the rigorous curriculum, students outperform local and state academic standards in science, math, and reading.\(^{105}\) The curriculum includes the following features:\(^{106}\)

- Concentrated instruction in core subjects
- Emphasis on classical literature
- Spanish instruction
- Science laboratory
- Accelerated Reader Program
- Accelerated Math Program
- Computer Lab, Compass Learning, Hands-on projects and activities
- School wide Tutorial Program
- English services for non-speakers
- A wide variety of school clubs and organizations
- Commitment to protect teaching time for teachers and learning time for students
- Academic Counseling
- Parenting Center/Parenting Library

Students are constantly involved in project-based learning activities that use interdisciplinary, real-world problems for student-centered learning.\(^{107}\)

**Extracurricular Programs**

The U.S. Department of Education has recognized Oakcliff’s Small Fry to Go (SFtG) program as the number one afterschool science program in the United States.\(^{108}\) This program provides instruction beyond the traditional school day to all interested

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108 Ibid.
elementary students throughout the year.\textsuperscript{109} The project follows the growth of rainbow trout, starting from their infancy as eggs to their release as full-grown fish in a local river.\textsuperscript{110}

Students at Oakcliff are also expected to be \textbf{active in the community}. They are encouraged to engage in service learning projects, school beautification, peer tutoring, scouting, mediation, and academic bowls.\textsuperscript{111}

\section*{Sojourner Elementary School}

\textit{Program Characteristics}

Sojourner Elementary School in Oregon was named a “Star Innovator” School by Intel Foundation in 2008.\textsuperscript{112} The mathematics program at Sojourner Elementary has led students to become increasingly proficient in the subject according to Oregon State Assessment data.\textsuperscript{113} This was achieved, in part, through professional development for staff as well as through the use of \textit{team teaching}.\textsuperscript{114}

\textit{Curriculum}

The North Clackamas School District has developed a comprehensive “Technology Plan for Teaching and Learning” that not only outlines the preferred use of technology within the district but also details grade specific desired learning outcomes. Most noticeably, the document places a particular emphasis on staff development with a focus on grade-related expectations.\textsuperscript{115} As a result of the coordinated policy effort, students at Sojourner Elementary School are exposed to technology on a regular basis with instruction in media literacy and the student to computer ratio there is 3:1.\textsuperscript{116}

\textit{Extracurricular Programs}

Students at Sojourner Elementary School have the opportunity to participate in one of several Pods – or mixed interest groups that can span several grades. The groups

\begin{footnotesize}
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\item \textsuperscript{109} “About Small Fry.” Small Fry to Go. http://www.smallfrytogo.net/
\item \textsuperscript{111} “Oakcliff Traditional Theme School.” Op. cit.
\item \textsuperscript{113} Ibid.
\end{itemize}
\end{footnotesize}
lasting anywhere from eight to ten weeks meet 3 times a week for 45 minutes. Examples of these Pods include the following: 

- Musical composition
- Geocaching
- Running
- Recycling
- Chess
- Gardening
- Ultimate Frisbee
- Jewelry making
- Map making
- Musical theater

Westdale Heights Academic Magnet

Westdale Heights Academic Magnet School won the Intel Foundation’s “School of Distinction” award for science excellence in 2010. 

Program Characteristics

Professional development for teachers involved in science instruction is an important aspect of Westdale’s program in order to ensure that teachers are prepared to meet the challenges associated with implementing a rigorous, inquiry-based science curriculum. The school also has five content specialists on staff so that as many students as possible can benefit from their expertise. The content specialization areas include Spanish, Computer Technology, Science, and Literacy. In addition to these four content area specializations there is also a Lead Teacher who can provide guidance in content mastery and pedagogical techniques to teachers throughout the school.

Curriculum

Westdale Heights Academic Magnet School offers several programs with a STEM focus which are designed to support a “rigorous and fast paced curriculum.” For example, the integration of technology into daily instruction is a key facet of the science and mathematics program. Each classroom is equipped with networked computer technology as well as active boards. The school also has a science lab so that students can gain hands-on knowledge and experience.

Environmental sustainability is a common theme throughout the curriculum as students participate in various projects such as LSU Coastal Roots and Native Fish, Carnivorous Plants Program, and the Monarch Butterfly Program as well as the student-run Geaux Green Recycling Program.

The curriculum also places an emphasis on mathematics by integrating problems into various real-world projects which may include measuring chemicals and garden plots or recording and calculating data.

Extracurricular Programs

The Junior Master Gardening Club is an after school program that expands upon school wide sustainability and gardening curriculum.
Project Evaluation Form

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