SUCCESSFUL K-12 STEM EDUCATION

Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics

Committee on Highly Successful Schools or Programs for K-12 STEM Education

Board on Science Education and Board on Testing and Assessment

Division of Behavioral and Social Sciences and Education

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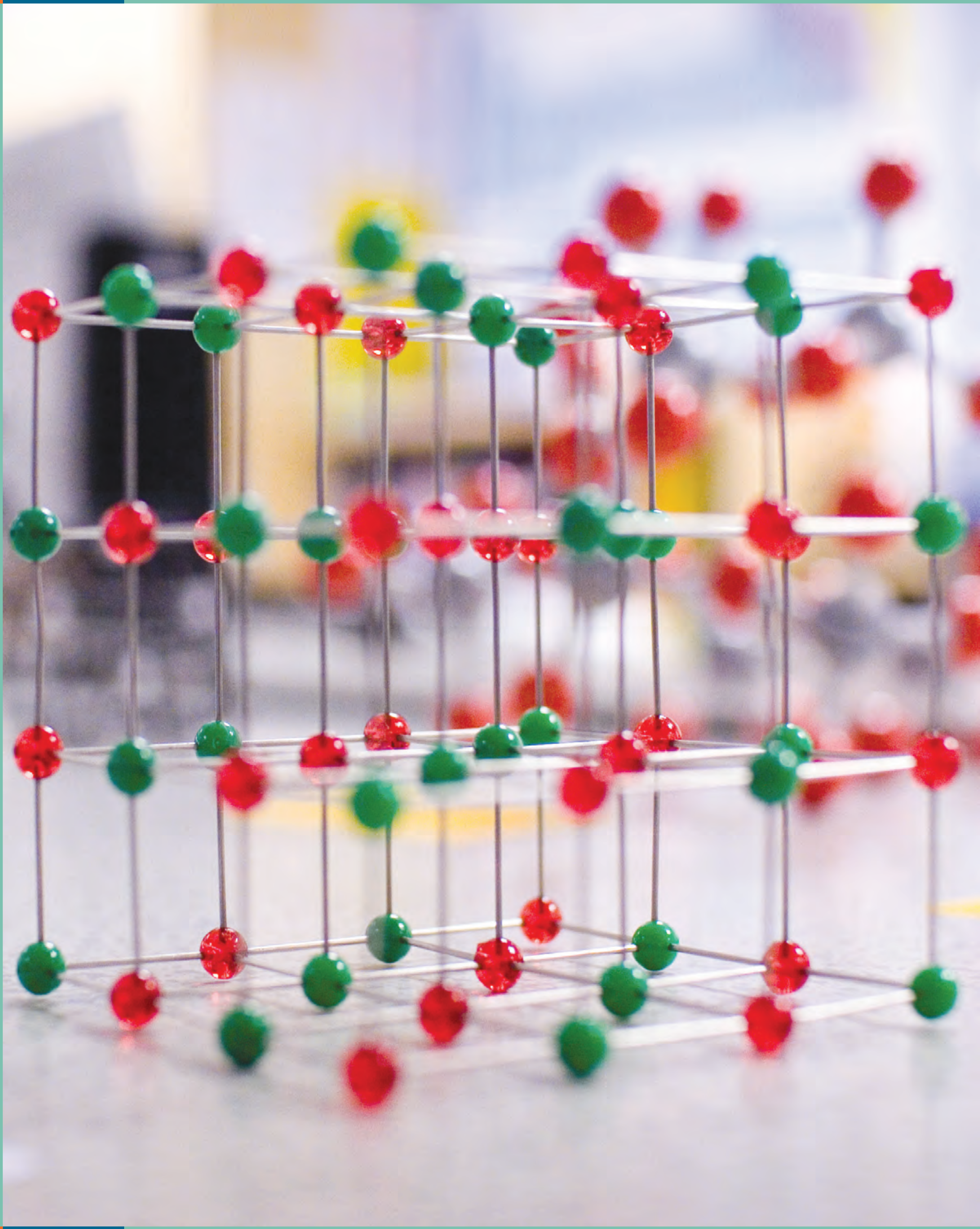


INTRODUCTION

This report responds to a request from Representative Frank Wolf (VA) for the National Science Foundation (NSF) to identify highly successful K-12 schools and programs in science, technology, engineering, and/or mathematics (STEM). In response to a request and with support from NSF, in October 2010 the National Research Council (NRC) convened an expert committee to explore this issue.

The Committee on Highly Successful Schools or Programs for K-12 STEM Education was charged with **"outlining criteria for identifying effective STEM schools and programs and identifying which of those criteria could be addressed with available data and research, and those where further work is needed to develop appropriate data sources."** This effort also included a public workshop on May 10-11, 2011[1] that was planned to address the following charge:

> An ad hoc steering committee will plan and conduct a public workshop to explore criteria for identifying highly successful K-12 schools and programs in the area of STEM education through examination of a select set of examples. The committee will determine some initial criteria for nominating successful schools to be considered at the workshop. The examples included in the workshop must have been studied in enough detail to provide evidence to support claims of success. Discussions at the workshop will focus on refining criteria for success, exploring models of "best practice," and analyzing factors that evidence indicates lead to success. The discussion from the workshop will be synthesized in an individually authored workshop summary.

To carry out its charge, the committee solicited background papers to be prepared for the workshop (see the Appendix for a list of the papers). The committee also examined the limited body of existing and forthcoming research on STEM-focused schools, the broader base of research related to effective STEM education practices, and research on effective schooling generally.[2] The goal of this report is to provide information that leaders at the school district, state, and national level can use to make strategic decisions about improving STEM education.

In examining the research, the committee considered findings to be *suggestive* if they identified conditions that were associated with success, but could not be disentangled from the types of students found in such conditions. We considered findings to give *evidence of success* if they resulted from research studies that were designed to support causal conclusions by distinguishing the effectiveness of schools from the characteristics of the students attending them.

What Aspects of STEM Are Addressed in This Report?

Although there are a variety of perspectives on what STEM education in K-12 schools entails, for the purposes of this report the committee focused its analysis on the science and mathematics parts of STEM. This decision was influenced by the fact that the bulk of the research and data concerning STEM education at the K-12 level relates to mathematics and science education. Research in technology and engineering education is less mature because those subjects are not as commonly taught in K-12 education.[3] Although integrating STEM subjects is not the focus of this report, the committee recognizes the variety of conceptual connections among STEM subjects and the fact that science inquiry and engineering design provide opportunities for making STEM learning more concrete and relevant.

The nature and potential value of integrated K-12 STEM education are the focus of an ongoing study of the National Academy of Engineering and the National Research Council by the Committee on Integrated STEM Education. It is expected to be completed in 2013.

THE NEED TO IMPROVE STEM LEARNING

Science, mathematics, engineering, and technology are cultural achievements that reflect people's humanity, power the economy, and constitute fundamental aspects of our lives as citizens, workers, consumers, and parents. As a previous NRC committee found:[4]

> The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering. . . . 4 percent of the nation's workforce is composed of scientists and engineers; this group disproportionately creates jobs for the other 96 percent.

An increasing number of jobs at all levels—not just for professional scientists—require knowledge of STEM.[5] In addition, individual and societal decisions increasingly require some understanding of STEM, from comprehending medical diagnoses to evaluating competing claims about the environment to managing daily activities with a wide variety of computer-based applications.

Several reports have linked K-12 STEM education to continued scientific leadership and economic growth in the United States.[6] At the same time, there are many reasons to be concerned about the state of STEM learning in the United States in the face of research that suggests that many students are not prepared for the demands of today's economy and the economy of the future. For example, as measured by the National Assessment of Educational Progress, **roughly 75 percent of U.S. 8th graders are not proficient in mathematics when they complete 8th grade.**[7] Moreover, there are significant gaps in achievement between student population groups: the black/white, Hispanic/white, and high-poverty/low-poverty gaps are often close to 1 standard deviation in size.[8] A gap of this size means that the average student in the underserved groups of black, Hispanic, or low-income students performs roughly at the 20th percentile rather than the 50th percentile. U.S. students also lag behind the highest performing nations on international assessments: for example, only 10 percent of U.S. 8th graders met the Trends in International Mathematics and Science Study advanced international benchmark in science, compared with 32 percent in Singapore and 25 percent in China.[9]

Employers in many industries lament that job applicants lack the needed mathematics, computer, and problem-solving skills to succeed,[10] and international students fill an increasing portion of elite STEM positions in the United States. Indeed, in 2007, "international students constituted more than a third of the students in U.S. science and engineering graduate schools," and more than 70 percent of those students currently remain in the United States after earning their degrees.[11] However, an increasing number of foreign students are finding viable career options in their home countries. This is particularly true for China and India, which, in December 2009, provided 47 percent of the approximately 248,000 foreign science and engineering students in the United States,[12] thereby limiting the talent pool available to U.S. employers.

GOALS FOR U.S. STEM EDUCATION

Questions about effectiveness can be addressed only in the context of the purposes or goals one wants to measure. Three broad and widely espoused goals for K-12 STEM education in the United States capture the breadth of the purposes for STEM education and reflect the types of intellectual capital needed for the nation's growth and development in an increasingly science- and technology-driven world. These goals are to increase advanced training and careers in STEM fields, to expand the STEM-capable workforce, and to increase scientific literacy among the general public.[13]

These three goals are not mutually exclusive. Moreover, because they are broad long-term goals for STEM education in the United States, numerous intermediate goals are encompassed in and central to all of them. Among others, the intermediate goals include learning STEM content and practices, developing positive dispositions toward STEM, and preparing students to be lifelong learners.[14]

GOAL 1: Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.

During the past century, the STEM fields propelled the United States to the forefront of an innovation-based global economy. Indeed, more than half of the tremendous growth to per capita income in the 20th century can be accounted for by U.S. advances in science and technology.[15] Several reports have drawn a direct line between the nation's competitiveness and K-12 STEM education to support the next generation of scientists and innovators.[16] Thus, one goal for STEM education focuses on the flow of students into STEM majors and careers.

An important dimension of this goal is to increase the participation of groups that are underrepresented in the sciences, especially blacks, Hispanics, and low-income students who "disproportionately fall out of the high-achieving group" in K-12 education.[17] It is important to provide opportunities for highly talented students from these groups because "changing immigration patterns, the rapid improvement of education and economies in developing countries, and a heavy focus on talent development—and competition for the talented—in both developing and developed countries [have] drastically changed the playing field for American education."[18] Indeed, only 10 percent of all STEM doctorates are awarded to nonwhite, non-Asian students, although these groups now represent one-quarter of the U.S. population.[19] The changing demographics in the United States will require increased

participation by domestic nonwhite and non-Asian students in STEM. Efforts in K-12 to serve these groups will play a major role in addressing this crucial issue.

GOAL 2: Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.

Although there is a clear need to increase the number of students who obtain advanced degrees in the STEM disciplines, it is equally important to the U.S. economy to increase the number of people who are prepared for STEM-related careers, such as being K-12 teachers in the STEM disciplines, medical assistants, nurses, and computer and green energy technicians.[20] These careers generally require vocational certification with specialized STEM knowledge, an associate degree, or a baccalaureate degree with a major in a STEM field.[21] The current demand for STEM-capable workers surpasses the supply of applicants who have trained for those careers. Moreover, 16 of the 20 occupations with the largest projected growth in the next decade are STEM related, but only 4 of them require an advanced degree.[22] Given these unmet needs for a STEM-capable workforce, the nation's economic future depends on preparing more K-12 students to enter these fields.

GOAL 3: Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

Personal and societal decisions in the 21st century increasingly require scientific and technological understanding. Whether about health, the environment, or technology, a certain level of scientific knowledge is vital to informed decision making. Thus, another goal of STEM education is to increase STEM literacy—defined as the knowledge and understanding of scientific and mathematical concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity for all students. [23] Targeting all students, not just those who will pursue postsecondary education or careers in STEM or STEM-related fields, will better prepare citizens to face the challenges of a science- and technology-driven society.

Schools and districts might not consciously adopt and work toward these three broad goals for STEM education. Instead, they may have their own, intermediate goals for success, such as increased enrollment in STEM courses, achievement test scores, high school graduation rates, college or career readiness, and matriculation into postsecondary institutions. Scientific research provides little evidence about how to accomplish the three broad goals. Research is even limited with respect to the intermediate goals, including goals related to accountability, when success is often measured at the school or district level.

THREE TYPES OF CRITERIA TO IDENTIFY SUCCESSFUL STEM SCHOOLS

To approach our charge, the committee explored three types of criteria for identifying successful STEM schools: criteria related to STEM outcomes, criteria related to STEM-focused schools, and criteria related to STEM instruction and school-level practices. We addressed criteria related to STEM outcomes because success typically is measured in terms of outcomes. We examined criteria related to STEM-focused schools because those schools are often viewed as the most effective route to improving STEM education. We explored STEM-related practices because practices are foundational elements of schools, and research is available to connect what happens in schools and classrooms to the desired outcomes. In this section we discuss each set of criteria, spending the most time on the third—STEM instruction and school-level practices—because the evidence base is the strongest for this set of criteria.

Student STEM Outcomes as Criteria for Success

One way to outline criteria for success relates to outcomes: **which outcomes should be used to identify effective STEM schools?** In fact, several outcomes might be used, assuming that research can disentangle the effects of the school from the characteristics of the students attending the school.

Student- and school-level achievement test data are the most widely available measures and the measures used for accountability purposes, therefore, they are the measures most commonly used to gauge success, regardless of the goals of a particular school or program. **Test scores, however, do not tell the whole story of success.** Consider the example of the Thomas Jefferson High School of Science and Technology in Alexandria, Virginia. The mission of this highly selective magnet school is to provide students a challenging learning environment focused on math, science, and technology, to inspire joy at the prospect of discovery, and to foster a culture of innovation based on ethical behavior and the shared interests of humanity (see http://www.tjhsst.edu). Test scores certainly are critical to compare the school's performance with others, and for Thomas Jefferson's students to matriculate into STEM majors at top-tier postsecondary institutions. However, gauging the school's success relative to its full set of goals necessitates using other criteria. Although it is difficult to measure interest and motivation ("joy at the prospect of discovery"), creativity ("a culture of innovation"), or commitment to "ethical behavior and the shared interests of humanity," it is essential to do so given the importance of preparing students to be leaders in STEM innovation—and not just good test takers.

Entry into STEM-related majors and careers and making good choices as citizens and consumers also require applying and using STEM content knowledge in other settings besides tests. For example, measures of success could include students' understanding of how to navigate college application and financial aid

AREAS FOR FUTURE RESEARCH ON CRITERIA RELATED TO OUTCOMES: Additional research and data are needed on organizational and instructional practices to complement the growing body of longitudinal data on student outcomes, as well as additional research that measures outcomes other than test scores.

processes and such skills as the ability to solve problems and work effectively in teams, as well as the kinds of knowledge and skills measured on state assessments and college admission tests. Participation in formal STEM courses in middle and high school and other kinds of STEM education—such as through museums, after-school clubs or programs, internship and research experiences—could be used as indicators of students' engagement.

Some states have data that allow the identification of schools in which students in the aggregate appear to perform particularly well or particularly poorly on achievement tests.[24] Such analyses, however, provide little information about the instructional practices and conditions in individual schools, so identifying criteria in this way does not help schools determine how to achieve desired outcomes or to decide which aspects of an apparently successful school to replicate. Researchers at the National Center for Scaling Up Effective Schools are working to link data on high- and low-performing schools with survey data on instructional practices and organizational conditions, but their research was only just beginning at the time of this report.

STEM-Focused School Types as Criteria for Success

It is also possible to think about effective STEM schools in terms of different school types or programs that focus on STEM. Such schools are often viewed as the best route to achieve desired STEM outcomes. Indeed, it is conceivable that a specific school type or program, on average, produces stronger student outcomes than other models. Such schools and programs are important because they can serve as exemplars for districts across the nation that are attempting to elevate the quality of STEM education. The schools of interest are typically characterized by specific attention to the STEM disciplines, often for a targeted population, such as highly talented students or students from underserved groups. This specific attention to STEM frequently manifests itself in a rigorous curriculum that deepens STEM learning over time, more instructional time devoted to STEM, more resources available to teach STEM, and teachers who are more prepared to teach in the STEM disciplines.

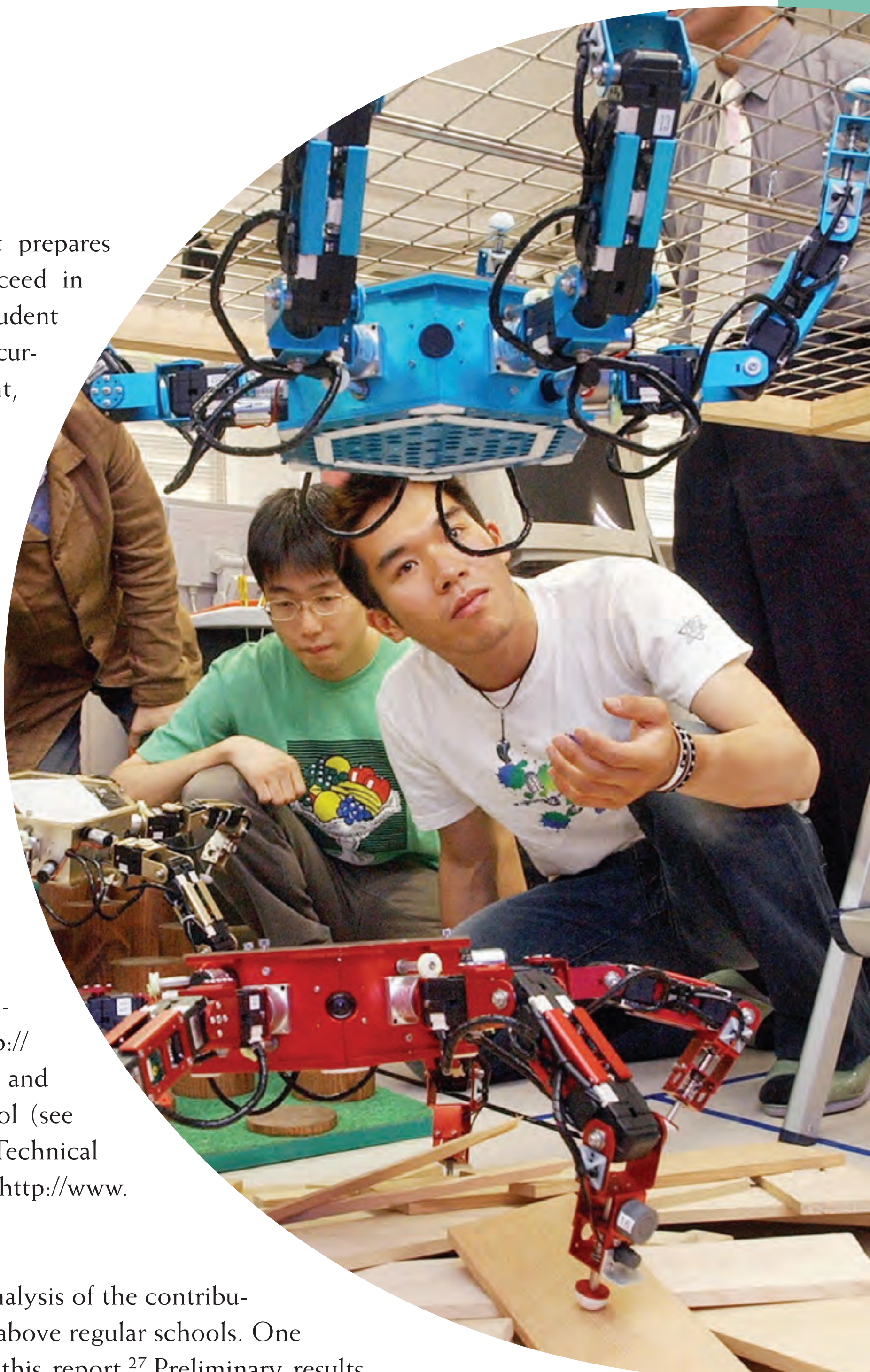
The committee identified three broad categories of STEM-focused schools that have the potential to meet the overarching goals for U.S. STEM education that we have described: selective STEM schools, inclusive STEM schools, and schools with STEM-focused career and technical education (CTE). Although these categories do not represent the full universe of STEM-focused schools, each category includes many different models of schools, and most of these models can be adapted for any level of the education system (elementary, middle, secondary). Each type of school has strengths and weaknesses and poses a unique set of challenges associated with implementation.

It is challenging to identify the schools and programs that are most successful in the STEM disciplines because success is defined in many ways and can occur in many different types of schools and settings, with many different populations of students. It is also difficult to determine the extent to which a school's success results from any actions the school takes or the extent to which it is related to the population of students in the school. For instance, selective STEM specialty schools have their own data about their return on investment, a variety of student outcomes, and their impact on individual students, especially those from disadvantaged backgrounds. Yet there are no systematic data that show whether the highly capable students who attend those schools would have been just as likely to pursue a STEM major or related career or make significant contributions to technology or science if they had attended another type of school. Furthermore, specialized models of STEM schooling are difficult to replicate on a larger scale because the context in which a school is located may facilitate or constrain its success. Specialized STEM schools often benefit from a high level of resources, a highly motivated student body, and freedom from state testing requirements. These conditions would be difficult, if not impossible, to implement more widely.

Some studies—mostly at the high school level—have been conducted or are under way to understand these school types and their impacts. Although those studies are in varying states of completeness and have limitations, we present some findings here, along with a description of the school type to which they apply.

Selective STEM Schools

Selective schools are organized around one or more of the STEM disciplines and have selective admissions criteria. Typically, these are high schools that enroll relatively small numbers of highly talented and motivated students with a demonstrated interest in and aptitude for STEM. The workshop identified four types of selective STEM schools: (1) state residential schools, (2) stand-alone schools, (3) schools-within-a-school, and (4) regional centers with half-day courses.[25] All of these selective STEM schools seek



to provide a high-quality education that prepares students to earn STEM degrees and succeed in professional STEM careers. They support student learning with expert teachers, advanced curricula, sophisticated laboratory equipment, and apprenticeships with scientists.[26] These schools often provide professional development and supplementary programs to teachers and students from public schools in their regions.

On the basis of membership in the National Consortium for Specialized Secondary Schools of Math, Science and Technology, there are approximately 90 selective STEM specialty high schools in the United States. Examples include Thomas Jefferson High School of Science and Technology, a stand-alone school in Virginia (see http://www.tjhsst.edu/); the North Carolina School of Science and Mathematics, a residential school for grades 11-12 (see http://www.ncssm.edu/); the Illinois Mathematics and Science Academy, a residential high school (see https://www3.imsa.edu/); and Brooklyn Technical High School, a stand-alone school (see http://www.bths.edu/).

No completed studies provide a rigorous analysis of the contributions that selective schools make over and above regular schools. One such study was under way at the time of this report.[27] Preliminary results from that study presented at the workshop show that when compared with national samples of high school graduates with ability and interest in STEM subjects, the experiences of students who graduate from selective schools appear to be associated with their choice to pursue and complete a STEM major.[28] **In particular, students who had research experiences in high school, who undertook an apprenticed mentorship or internship, and whose teachers connected the content across different STEM courses were more likely to complete a STEM major than their peers who did not report these experiences.**

SELECTIVE STEM SCHOOL
Example: North Carolina School of Science and Mathematics

The North Carolina School of Science and Mathematics (NCSSM) is a public, residential, coeducational high school, located in Durham, for academically talented 11th and 12th grade students from across the state. It was established by the state's General Assembly in 1978, and in 2007 it become a part of the University of North Carolina system. Only North Carolina students are admitted, and they apply for admission in their sophomore year. Students from each of the state's 13 congressional districts are admitted on the basis of a formula established by state legislation. Criteria for selection include a student's interest in science and mathematics, standardized test scores, academic performance, essays, special talents, accomplishments, and extracurricular activities. There are no fees associated with applying, being accepted, or attending the school.

Academic Characteristics: Students take four or five courses per trimester as juniors and five courses per trimester as seniors. There are required minimal trimester credits: six for science, five for mathematics, two for social science, three to six for foreign language, and one for physical activity and wellness. The average class size is just over 20 students. A significant component of the academic experience at NCSSM includes research and mentorship. More than 65 percent of students participate in research and/or mentorship opportunities during their 2 years at NCSSM. Students must also engage in service learning for a nonprofit agency in North Carolina. NCSSM students participate in more than 22,000 hours of community service each year.

Student Population: Student enrollment is limited to 680 residential students. In 2010-2011, the residential student population had the following racial/ethnic makeup:

- White, 64 percent
- Black, 11 percent
- Hispanic, 1 percent
- Asian/Pacific Islander, 22 percent
- Native American, < 1 percent

Other Features: More than 99 percent of NCSSM graduates attend college the year after graduation; the few students who do not do so usually elect to do volunteer work or defer college for a following year. As part of its outreach mission, NCSSM provides services to students across North Carolina through its distance education courses and enrichment activities. NCSSM serves over 900 high school students from across the state each semester through its advanced mathematics, science, and humanities online and videoconference courses. NCSSM serves an additional 2,000 K-12 students from across the state through videoconference enrichment activities. NCSSM also provides mathematics and science professional development for North Carolina teachers from across the state.

Inclusive STEM Schools

Inclusive schools emphasize or are organized around one or more of the STEM disciplines but have no selective admissions criteria. These schools seek to provide experiences that are similar to those at selective STEM schools while serving a broader population. Many inclusive STEM schools operate on the dual premises that "math and science competencies can be developed, and that students from traditionally underrepresented subpopulations need access to opportunities to develop these competencies to become full participants in areas of economic growth and prosperity."[29] Examples include High Tech High, a set of schools in southern California (see http://www.hightechhigh.org); Manor New Technology High School in Texas (see http://www.manorisd.net/portal/newtech); the Denver School for Science and Technology in Colorado for grades 6-12 (see http://www.dsstmodel.org); and Oakcliff Elementary School in Georgia (see http://www.dekalb.k12.ga.us/oakcliff/).

Insights from inclusive STEM schools come from an ongoing study of high school reform in Texas.[30] **Early findings suggest that students in that state's 51 inclusive STEM schools score slightly higher on the state mathematics and science achievement tests, are less likely to be absent from school, and take more advanced courses than their peers in comparison schools.** The schools in the Texas study are new—having opened in 2006-2007 or later—and they have been able to achieve these gains within their first 3 years of operation. **Factors that appear to have helped the schools include a STEM school blueprint that helps to guide school planning and implementation, a college preparatory curriculum and explicit focus on college readiness for all students, strong academic supports, small school size, and strong support from their district or charter management organization.**[31]

The Texas study has carefully identified a set of comparison schools that were equivalent to the inclusive STEM schools on a wide range of school characteristics, such as student demographics and prior achievement and teacher characteristics.[32] However, this approach does not eliminate the possibility that the apparent benefits of inclusive schools reflect the students who choose to attend them. The students who attend inclusive STEM schools may do so because of their greater interests in STEM fields, despite being otherwise similar to students in comparison schools.

INCLUSIVE STEM HIGH SCHOOL
Example: Manor New Technology High School

Manor New Tech opened near Austin, Texas, in 2007 as one of the official Texas Science, Technology, Engineering, and Mathematics (T-STEM) Academies of the Texas High School Project. The school prepares students in grades 9-12 to excel in an information-based and technologically advanced society. Its instructional program encourages student to develop problem-solving skills, interpersonal skills, and the resilience they need to succeed in a rapidly changing and competitive world. The curriculum brings together modern technology, community partnerships, problem solving, interdisciplinary instruction, and global perspectives in a student-centered, collaborative, project-based community.

Academic Characteristics: Manor New Tech uses the New Tech Network's school model, which has three major components: (1) use of a project-based learning instructional approach to offer engaging, collaborative opportunities for learning; (2) use of technology integrated across the curriculum; and (3) creation of a school culture that is based on trust, respect, and responsibility. Graduation requirements in mathematics include algebra I, II, geometry, and an elective in precalculus, college algebra, and/or calculus. Science requirements include biology and three other courses selected from integrated physics and chemistry, environmental science, chemistry, and physics.

Student Population: For the 2009-2010 school year, Manor New Tech High served a total of 315 students. The student population had the following racial/ethnic makeup:

- White, 32 percent
- Black, 22 percent
- Hispanic, 44 percent
- Asian/Pacific Islander, 2 percent

About 56 percent of students in 2009-2010 were considered to be economically disadvantaged, and 5 percent participated in special education programs.

Other Features: The school's Think Forward Institute is designed to train educators in best practices for project-based learning, leadership, and 21st-century skill applications.

Schools and Programs with STEM-Focused Career and Technical Education

STEM-related CTE serves mainly high school students and can take place in regional centers, CTE-focused high schools, programs in comprehensive high schools, and career academies.[33] An important goal of STEM-focused CTE is to prepare students for STEM-related careers, often with the broader goal of increasing engagement to prevent students from dropping out of school. As a result, students explore STEM-related career options and learn the practical applications of STEM subjects through the wide range of CTE delivery mechanisms. Examples include Loudoun Governor's Career and Technical Academy, a Virginia high school (see http://www.doe.virginia.gov/instruction/career_technical/gov_academies/academies/loudoun); Sussex Technical High School in Delaware (see http://www.sussexvt.k12.de.us/web/); and Los Altos Academy of Engineering, a California high school (see http://www.lasv.org/).

Despite many examples of highly regarded CTE schools and programs, there is little research that would support conclusions about the effectiveness of the programs, particularly in comparison with alternatives. One rigorous study of mathematics content that was integrated in occupational education found positive effects on student achievement in mathematics, with no loss in occupational knowledge.[34] **These findings suggest that CTE, assumed to motivate learning through real-life applications, does not have to be in conflict with academic achievement.** A similar study of integrated science is under way.

More broadly, **the limited research base on the three school types hampered the committee's ability to compare their effectiveness relative to each other and for different student populations or to identify the value these schools add over and above non-STEM focused schools.** However, the available studies suggest some potentially promising—if preliminary and qualified—findings associated for each school type. Those studies also raise questions that merit further exploration about variations within and across school types and about whether these schools are making progress toward the three broad goals for U.S. STEM education. Our collective understanding of these schools would be enhanced by more information about the instructional practices in these schools and the factors that influence them.

STEM-FOCUSED CAREER AND TECHNICAL EDUCATION
Example: Dozier-Libbey Medical High School

Dozier-Libbey Medical High School is a pathway school for the Antioch, California, Unified School District. Opened in August 2008, Dozier-Libby will eventually serve 600 students in grades 9-12. The school's 4-year program prepares students for health-related careers and has a strong emphasis on mathematics and science.

Academic Characteristics: Students are required to take a minimum of four mathematics and four science courses and a minimum of 2 years of foreign language. All students who successfully complete the program meet or exceed the A-G requirements for admission into the University of California system.

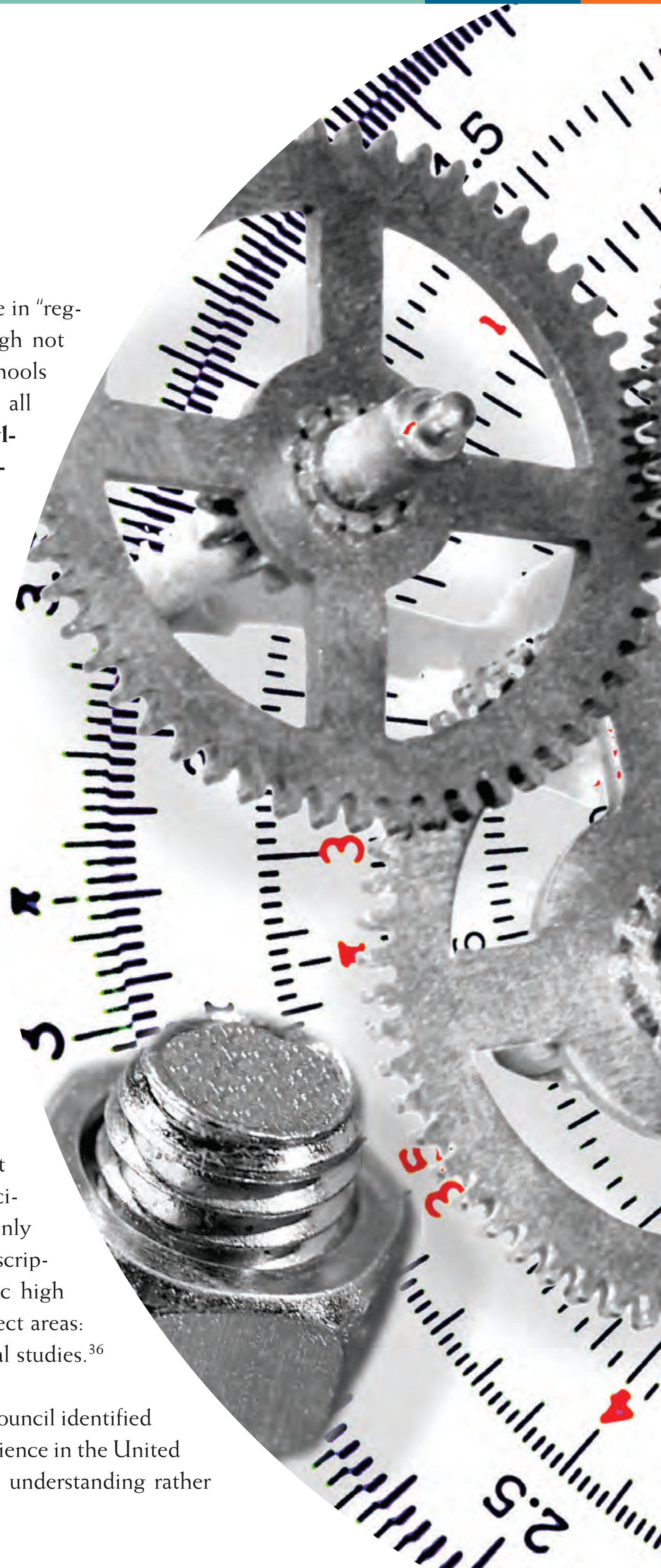
The health science theme is integrated throughout all curricular areas with heavy emphasis on integrated project-based units. In addition to the A-G requirements, students take a medical terminology course their freshmen year, which is articulated with Los Medanos Community College. Students who pass the course with a B or better receive three college credits. Students also take a health science course each year with subject matter that is specific to health-related industries such as medical career exploration, global medicine, ethical and legal practices, and employability skills.

Student Population: For the 2009-2010 school year, Dozier-Libbey served a total of 343 students. The student population had the following racial/ethnic makeup:

- White, 29 percent
- Black, 15 percent
- Hispanic, 35 percent
- Asian/Pacific Islander, 17 percent
- Not reporting, 3 percent

Of these students, 45 percent in 2009-2010 were eligible for free or reduced-price lunch.

Other Features: Frequent hands-on instructional activities are a key part of the program and are developed with industry and postsecondary partners. Examples of these activities are job shadowing, guided study tours, service learning opportunities, presentations by guest speakers, cross-curricular research projects, digital portfolios, and internships. In addition, all students are strongly encouraged to join and participate in Health Occupation Students of America. In 2011, Dozier-Libbey was one of 97 public middle and high schools that were named California Distinguished Schools.



STEM in Comprehensive Schools

Of course, successful STEM education also takes place in "regular" comprehensive schools in grades K-12. Although not explicitly focused on the STEM disciplines, these schools might instead strive for excellence for all students in all disciplines. **Much of the available research knowledge of effective practices comes from comprehensive schools, which educate the vast majority of the nation's students—including many talented and aspiring scientists, mathematicians, and engineers who might not have access to selective or inclusive STEM-focused schools.** The STEM education goals of comprehensive schools vary widely and can include helping to prepare the next generation of scientists and innovators, expanding the number of capable students for the STEM workforce, increasing science literacy for all, and generally preparing students for postsecondary success. To these ends, mathematics and science requirements in comprehensive schools have increased in the past 25 years. In 2008, for example, 31 states required three or more credits in science for high school graduation, and 37 required three or more credits in mathematics.[35]

In terms of STEM-focused programs in regular comprehensive high schools, Advanced Placement (AP) and International Baccalaureate (IB) are the most widely recognized programs of advanced study in science and mathematics in the United States, and the only two that are national in scope (see box for a brief description). As of 2009, roughly 35 percent of U.S. public high schools offered AP or IB courses in the four core subject areas: English language arts, mathematics, science, and social studies.[36]

A 2002 study of AP and IB by the National Research Council identified several ways to improve advanced study of math and science in the United States. These suggestions included emphasizing deep understanding rather

STEM IN A COMPREHENSIVE SCHOOL
Example: Christa McAuliffe Elementary School (P.S. 28)

The Christa McAuliffe School is a public school in Jersey City, New Jersey, with full-day programs for pre-K and K students, as well as for 1st through 8th grade students. A substantial number of students participate in the extended-day tutorial program and many after-school programs, which include preparation for the New Jersey Assessment of Skills and Knowledge, the tutorial program, yearbook, Community League, Scholastic Bowl, science/technology classes, choir, band, show choir, seasonal sports teams, and robotics. School programs are designed to develop sound character, creativity, ethical judgment, concerned attitudes, and the ability to live productively and harmoniously in a global workforce.

Academic Characteristics: The school offers a challenging standards-based academic curriculum with 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, 8th grade algebra, and a fine and performing arts program. Classes are designed to foster curiosity, inquiry, and discovery in curriculum foundations. The school has an integrated curriculum for all students in which learning extends beyond the classroom walls.

Student Population: In the 2008-2009 school year, the school's population of nearly 900 students had the following racial/ethnic makeup:

- White, 12 percent
- Black, 6 percent
- Hispanic, 76 percent
- Asian/Pacific Islanders, 6 percent
- Native American, < 1 percent

Of these students 84 percent in 2008-2009 were eligible for free or reduced-price lunch.

Other Features: The Broad Foundation and Rutgers University have recognized the school for its efforts in closing the achievement gap between white and minority students, and in 2010 INTEL selected P.S. 28 as a "School of Distinction" finalist.

AREAS FOR FUTURE RESEARCH ON CRITERIA RELATED TO SUCCESSFUL SCHOOLS AND PROGRAMS: Large- and smaller-scale research is needed on STEM-focused schools and programs that (1) disentangles school effects from the characteristics of students who attend them, (2) identifies and describes distinctive aspects of their educational practices, and (3) measures the schools' long-term effectiveness relative to the broad goals for U.S. STEM education.

than comprehensive coverage, aligning these programs with the current understanding of how students learn in a discipline, drawing on current research directions in the disciplines, and emphasizing the development of inquiry and reasoning skills. In response to that report and other influences, a comprehensive effort is under way to redesign AP science courses. The goals of the redesign are to produce a more inclusive and more engaging program of study for each AP discipline.[37] For each discipline, the redesign has focused on a developing a well-defined set of learning objectives that support teaching for deeper understanding, aligning the AP exams with these learning objectives, and providing AP instructors with the tools and professional development opportunities that support teaching, learning, and success on the AP exams.[38]

Advanced Placement and International Baccalaureate: Examples of Programs of Advanced Study in Science and Mathematics[39]

The IB program was developed in the late 1960s to provide an international standard of secondary education for children of diplomats and others stationed outside their countries. One goal was to prepare students for university work in their home countries. The International Baccalaureate Organisation authorizes participating high schools. Schools cannot offer only a subset of IB courses; instead, they must offer a full IB diploma program. Although some students take individual IB courses as they would an honors course, most are diploma candidates, taking a program of six or seven courses over 2 years.

Developed in 1955, AP is the predominant national program for advanced courses in U.S. high schools. The College Board provides topic outlines for AP courses, generated largely by surveying colleges and universities. However, teachers are allowed considerable leeway in implementation. Elective, end-of-course examinations are designed to be comparable with "typical" introductory college-level courses in a subject area.

STEM Instruction and School Practices as Criteria for Success

Because informative research on programs and practices can be at a smaller scale than research on types of schools, a larger body of rigorous evidence is available on practices that are associated with better student outcomes, regardless of whether students are in a STEM-focused school or in a regular school. Although many of these practices have been studied separately and in individual classrooms, the committee believes that it may be possible to improve STEM education for all students by combining successful practices and implementing them school wide. Thus, the committee believed that **the most useful way of identifying criteria for success relates to educational practices: what practices should be used to identify effective STEM schools?** Focusing on practices instead of outcomes provides schools with concrete guidance for improving the quality of STEM instruction and, presumably, of STEM learning.

Several recent NRC reports on effective programs and practices in science and mathematics and other select syntheses informed the committee's deliberations. Drawing on this evidence, we focused on two key aspects of practice that are likely to be found in successful schools: instruction that captures students' interest and involves them in STEM practices and school conditions that support effective STEM instruction.[40]

Effective STEM Instruction

Research in STEM learning and teaching over the past two decades allows the committee to characterize effective STEM education.[41] Briefly, **effective instruction capitalizes on students' early interest and experiences, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest.**

This description is consistent with the vision that inspired the *Conceptual Framework for New Science Education Standards.*[42] It addresses all three broad goals for K-12 STEM education in the United States that we discuss in this report.

According to the research, effective instruction actively engages students in science, mathematics, and engineering practices throughout their schooling. Effective teachers use what they know about students' understanding to help students apply these practices. In this way, students successively deepen their understanding both of core ideas in the STEM fields and of concepts that are shared across areas of science, mathematics, and engineering. Students also engage with fundamental questions about the material and natural worlds and gain experience in the ways in which scientists have investigated and found answers to those questions. In grades K-12, students carry out scientific investigations and engineering design projects related to core ideas in the disciplines, so that by the end of their secondary schooling they have become deeply familiar with core ideas in STEM and have had a chance to develop their own identity as STEM learners through the practices of science, mathematics, and engineering.

Presentations and papers at the committee's May workshop revealed that, to varying degrees, students in all school types can engage in the practices of science and engineering. In selective schools, students regularly design and conduct scientific research, sometimes in collaboration with working scientists. Inclusive STEM schools aim to provide this same kind of experience. Students in these schools have opportunities to learn science, mathematics, and engineering by addressing problems that have real-world applications.[43] The same is true in some comprehensive schools.[44] For its part, career and technical education is predicated on the idea of making learning relevant and connecting the content with its applications.[45] CTE schools and programs commonly use engineering as a mechanism for making content relevant, and they rely heavily on technology as a tool for engaging in scientific practices.

However, this type of STEM instruction remains the exception in U.S. schools. It is typically facilitated by extraordinary teachers who overcome a variety of challenges that stand between vision and reality. Further transformation is needed at the national, state, and local levels for this type of K-12 STEM instruction to become the norm. In the rest of this section we identify some of the key elements that might be able to guide educators and policy makers in that direction.

Key element: A coherent set of standards and curriculum. As noted above, roughly 75 percent of U.S. 8th graders are not proficient in mathematics when they complete 8th grade (as measured by the National Assessment of Educational Progress).[46] These students are unprepared for the increasing demands of high school mathematics and for science courses that require mathematics. International comparison data suggest that these results might be explained by differences in U.S. standards, curricula, and textbooks in comparison to those of higher performing countries. **The research shows a clear link between what students are expected to learn and mathematics achievement: At a given grade level, greater achievement is associated with covering fewer topics in greater depth.**[47]

Current work on the Common Core State Standards for mathematics[48] and the *Conceptual Framework for New Science Education Standards*[49] may allow states to move toward curricula that address the most important topics and are focused on developing proficiency in mathematics and science.

Some evidence suggests that these kinds of efforts—namely, adopting rigorous standards and aligning curriculum and assessments to those standards—can lead to gains in student achievement.[50] Indeed, Minnesota provides an example of a state that adopted rigorous standards, pared down the number of topics in its curriculum, and realized gains in student achievement. According to one report:

> Although there is no conclusive causal evidence that Minnesota's gains between 1995 and 2007 were primarily due to changes in its standards, the data do support the hypothesis that there is a relationship between standards and achievement—that content coverage led by coherent, focused, and rigorous standards properly implemented by teachers can improve student outcomes in mathematics. Most importantly, this improvement can happen in an American state.[51]

The adoption of common standards can also provide an opportunity to focus teacher preparation and professional development opportunities on material that will be relevant to their work. This development is promising because research has shown that the extent to which prospective teachers are prepared to use the mathematics curriculum that they will be teaching has a significant effect on their students' test scores when they begin teaching.[52]

Key element: Teachers with high capacity to teach in their discipline. Teaching in ways that inspire all students and deepen their understanding of STEM content and practices is a demanding enterprise. To be effective, teachers need content knowledge and expertise in teaching that content, but the research suggests that science and mathematics teachers are particularly underprepared for these demands. For example, in both middle and high schools, unacceptably high percentages of teachers who teach science and mathematics courses are not certified in the subjects they teach and did not major in a related field in college.[53] Estimates of the number of out-of-field science and mathematics teachers in secondary school are between 10 and 20 percent.[54] A recent survey of university teacher preparation programs found that future elementary teachers were required to take, on average, only two mathematics courses.[55] The lack of preparation is reflected in a lack of comfort by teachers in teaching the required content: using the criterion of whether at least 75 percent of teachers reported feeling comfortable teaching the major topics in the middle school curriculum, one survey found that no topic met that criterion.[56]

Weak initial teacher preparation heightens the importance of continuing professional development, but the available research suggests that professional development in STEM, when available, is often short, fragmented, ineffective, and not designed to address the specific need of individual teachers.[57] Although some careful studies of particular professional development programs in mathematics and science have shown positive effects on student achievement, others have shown no effect or even negative effects.[58] Despite these mixed research findings, there is emerging agreement on the characteristics of effective professional development. **In any discipline, effective professional development should**

- **focus on developing teachers' capabilities and knowledge to teach content and subject matter,**
- **address teachers' classroom work and the problems they encounter in their school settings, and**
- **provide multiple and sustained opportunities for teacher learning over a substantial time interval.**[59]

The evidence suggests that these characteristics are levers for changing teachers' practices.[60] However, the evidence of their effects on student achievement is more tenuous because very little research traces the causal pathway from professional development to student achievement.

Moreover, professional development alone is not a solution to current limitations on teachers' capacities.[61] Instead, it is more productive to consider teacher development as a continuum that ranges from initial preparation to induction into the practice of teaching and then to systematic, needs-based professional development, including on-site professional support that allows for interaction and collaboration with colleagues.

Key element: A supportive system of assessment and accountability. **Current assessments limit teachers' ability to teach in ways that are known to promote learning of scientific and mathematical content and practices.** In mathematics, for example, since implementation of the No Child Left Behind (NCLB) Act, there has been a shift away from complex performance assessments toward multiple-choice items. According to one report, "States reported that the use of multiple-choice items in assessments has limited the content and complexity of what they test."[62] The report further states: "The focus on student results, combined with the focus on multiple choice items, has led to teachers teaching a narrow curriculum that is focused on basic skills."[63]

A previous NRC committee recommended that each state develop a "system of science assessment . . . comprised of a variety of assessment strategies" to meet the requirements of NCLB.[64] More generally, the report notes:[65]

> A successful system of standards-based science assessment is coherent in a variety of ways. It is *horizontally coherent*: curriculum, instruction, and assessment are aligned with the standards; target the same goals for learning; and work together to support students' developing science literacy. It is *vertically coherent*: all levels of the education

system—classroom, school, school district, and state—are based on a shared vision of the goals for science education, of the purposes and uses of assessment, and of what constitutes competent performance. The system is also *developmentally coherent*: it takes into account how students' science understanding develops over time and the scientific content knowledge, abilities, and understanding that are needed for learning to progress at each stage of the process.

A supportive accountability system focuses not just on student outcomes but also on teacher practices. Consider the example of the Illinois Mathematics and Science Academy (IMSA), which counts "inquiry-based, problem-centered" teaching and learning as core competencies. IMSA uses three different methods to determine the extent to which this objective is achieved:

- Every semester, for every teacher, IMSA students complete course surveys, which include questions on this objective.
- Faculty and staff trained in classroom observations conduct frequent visits to gauge the actual use of inquiry-based methods.
- External reviewers evaluate two or three departments each year to identify the extent to which IMSA's teaching and learning is "inquiry-based and problem-centered."

Key element: Adequate instructional time. The NCLB Act has also changed the time for science, technology, engineering, and mathematics instruction in the K-12 curriculum. Particularly in elementary school, the predominant instructional emphasis is on mathematics and English language arts because those subjects are tested annually under the current accountability system. In the 2006-2007 school year, for example, elementary schools (on a nationally representative survey) reported spending an average of 178 minutes per week on science instruction, 323 minutes on mathematics, and 503 minutes on English language arts.[66] A closer look at those data revealed that 28 percent of districts reported decreasing their instructional time in science in elementary schools, with an average decrease in those districts of 75 minutes per week. In contrast, 45 percent of districts reported increasing instructional time for mathematics in elementary schools, with an average increase of 89 minutes per week.[67]

A 2007 study of science education in California paints a starker picture. That survey of nine counties in the San Francisco Bay Area found: "80 percent of K-5th grade multiple-subject teachers who are responsible for teaching science in their classrooms reported spending 60 minutes or less per week on science, with 16 percent of teachers spending no time at all on science."[68] Those researchers estimate that their results actually overstate the amount of science instruction in the Bay Area because "teachers who took the time to respond to the survey are more likely to be engaged in science education than those who did not."[69] **Overall, the decrease in time for science education is a concern because some research suggests that interest in science careers may develop in the elementary school years.**[70]

Key element: Equal access to high-quality STEM learning opportunities. The achievement gaps among students from different socioeconomic, racial, and ethnic groups are well documented.[71] Many factors contribute to these gaps, including poverty, but we focused on some of the structural inequalities that states, schools, and districts have the potential to address. For example, **disparities in teacher expectations and other school and classroom-level factors, such as access to adequate laboratory facilities, resources, and supplies, contribute to gaps in science achievement for underrepresented groups.**[72] Similar structural inequities hinder the mathematics learning of underrepresented minorities and low-income students, such as disparities in access to well-trained or credentialed teachers, less rigorous educational courses, and ability tracking in the early grades.[73] In mathematics, these inequalities can have cumulative effects as students progress through grades K-12 because mathematics is a gatekeeper to academic opportunity.[74]

Policies to ensure that well-prepared teachers are placed in all classrooms can redress the imbalance in access to qualified teachers that currently exists between students from advantaged and disadvantaged backgrounds. In addition, although "detracking"—creating classrooms with students of mixed abilities—is often proposed as a solution to unequal learning opportunities in schools, the research evidence suggests that this approach is not always beneficial. For instance, when detracking fails to provide challenging learning opportunities for all students, low-income and minority students may have the most to lose because they often lack academic support outside school that could compensate for weak instruction in school.[75] However, cases of successful detracking do exist, and they suggest that supplemental instruction for low-achieving students (such as through tutoring or extra class sessions) makes it possible to offer challenging instruction to all students in mixed-ability settings.[76]

School Conditions and Cultures That Support Learning

Strong teachers and focused, rigorous, and coherent curricula are certainly important factors to improve student learning in STEM. However, school and community conditions also affect what is taught, how it is taught, and with which results. **Research suggests that although teacher qualifications matter, the school context—its culture and conditions—matters just as much, if not more.** As an example, research conducted in several school districts over 10 years highlights teacher learning communities as among the most powerful sources of improvement in teacher and student learning and identify multiple factors that strengthen and sustain those learning communities (e.g., school and district leaders, parents, and community).[77]

AREAS FOR FUTURE RESEARCH ON CRITERIA RELATED TO INSTRUCTIONAL AND SCHOOL-LEVEL PRACTICES: Additional research is needed on the effects of STEM teacher professional development on student achievement and on which elements of school culture contribute to STEM learning, particularly in schools serving low-income and minority students who are underrepresented in the STEM majors and careers.

Longitudinal data from public elementary schools in Chicago bolster these and other findings from the considerable body of research on structuring schools to promote high-quality teaching and learning.[78] In a study of 200 low-performing elementary schools in Chicago, no schools with a poor learning climate and weak professional community substantially improved math or reading scores. Roughly half of schools with a well-aligned curriculum and a strong professional community among teachers substantially improved math and reading achievement.[79] These gains are notable because they were made in high-poverty schools located in severely disadvantaged communities.

The elementary schools that improved student learning in mathematics and reading shared five common elements:[80]

1. **School leadership as the driver for change.** Principals must be strategic, focused on instruction, and inclusive of others in the leadership work.
2. **Professional capacity** or the quality of the faculty and staff recruited to the school, their base beliefs and values about change, the quality of ongoing professional development, and the capacity of a staff to work together.
3. **Parent-community ties** that involve active outreach to make school a welcoming place for parents, engage them in supporting their children's academic success, and strengthen connections to other local institutions.
4. **Student-centered learning climate.** Such a climate is safe, welcoming, stimulating and nurturing environment focused on learning for all students.
5. **Instructional guidance** that is focused on the organization of the curriculum, the nature of academic demand or challenges it poses, and the tools teachers have to advance learning (such as instructional materials).

The strength of these supports varied within and across elementary schools in Chicago: some schools were strong along all dimensions, and some were stronger in some dimensions than in others. Although not all of these supports need to be strong for schools to succeed, schools that were weak on all of these dimensions showed no gains in achievement.[81]

SUMMARY OF CRITERIA TO IDENTIFY SUCCESSFUL K-12 STEM SCHOOLS

In this report we identify three types of criteria that can be used to identify successful STEM schools: criteria related to outcomes, criteria related to school types, and criteria related to instruction and school-level practices.

The strongest research comes from criteria related to practices, where the evidence allowed the committee to characterize effective STEM instruction, identify key elements that contribute to effective instruction, and identify school characteristics that support learning. Effective STEM instruction capitalizes on students' early interest and experiences, identifies and builds on what they know, engages them in STEM practices, and provides them with experiences to sustain their interest. Key elements that contribute to effective STEM instruction include a coherent set of standards and curriculum, teachers with high capacity, a supportive system of assessment and accountability, adequate instructional time, and equal access to quality STEM learning opportunities. The research also suggests that effective elementary schools share common elements, namely, strong leadership, professional capacity among teachers, strong ties to parents and the community, a student-centered learning climate, and instructional guidance for teachers. These elements have been shown to support learning gains even in schools in areas of extreme poverty and hardship.

With respect to criteria related to schools, we identified three types of STEM-focused schools (selective, inclusive, and CTE) that have different goals, strategies, and student populations—all with the potential to improve STEM learning. Because of the challenges with conducting causal research on these schools, little research is available that demonstrates the effectiveness of STEM-focused schools in comparison with other schools or that contrasts the relative effectiveness of their different approaches on a variety of student outcomes. As a result, the committee is not able to identify a distinct set of criteria related to STEM-focused schools themselves. However, these schools do offer a range of compelling models for the ways that the various effective STEM practices can be combined into a working whole. Hence, these schools provide an important resource for extending the implementation of effective STEM practices—to individual students and throughout entire districts and states.

Finally, a wide variety of outcomes can be used as criteria to identify successful schools, though it should be noted that outcomes alone do not provide insight into the practices that contribute to success. Powerful new research is being conducted using longitudinal data on student achievement; among other things, such research will provide a systematic and inclusive way to define schools that have positive student outcomes. Such research should be broadened to include outcomes other than student test scores, graduation rates, and data on the effective STEM practices we have identified. In the years ahead, this approach could provide a much more comprehensive analysis of the relative effectiveness of different schools in promoting STEM and the reasons for the differences across schools.

In many respects, effective practices for STEM are closely related to effective practices for education in general. This is not surprising. Still, it is important to pay attention to these practices in STEM because the research suggests that some strategies are unique to STEM learning and some challenges particularly affect success in STEM. STEM education is vital to our nation's continued growth, leadership, and development, but this report has documented some important shortcomings that could hinder our progress. Drawing on these findings, we propose a series of next steps at the local, state, and national levels to strengthen K-12 STEM education.

WHAT SCHOOLS AND DISTRICTS CAN DO TO SUPPORT EFFECTIVE K-12 STEM EDUCATION

We offer five proposals for schools and districts to improve K-12 STEM education. These proposals are not listed in order of importance, but together they address vital aspects of the STEM education system.

First, **districts seeking to improve STEM outcomes beyond comprehensive schools should consider all three models of STEM-focused schools** described in this report to meet the various goals they may hold for STEM education. Districts should be aware that each type comes with its own set of strengths and limitations. The research base does not support recommending one school type over another or treating a particular type of school as an indicator of STEM excellence by itself.

Second, **districts should devote adequate instructional time and resources to science in grades K-5.** A quality science program in the elementary grades is an important foundation that can stimulate students' interest in taking more science courses in middle school and high school and, possibly, in pursuing STEM disciplines and careers.

Third, **districts should ensure that their STEM curricula are focused on the most important topics in each discipline, are rigorous, and are articulated as a sequence of topics and performances.** Ideally, STEM curricula should be aligned across disciplines from grades K-12.

Fourth, to improve teaching and learning in the STEM disciplines, **districts need to enhance the capacity of K-12 teachers.** STEM teachers should have a deep knowledge of their subject matter and "an understanding of how students' learning develops in that field, the kinds of misconceptions students may develop, and strategies for addressing students' evolving needs."[82]

Fifth, **districts should provide instructional leaders with professional development that helps them to create the school conditions that appear to support student achievement** (see section above on school conditions). School leaders should be held accountable for creating school contexts that are conducive to learning in STEM.

WHAT STATE AND NATIONAL POLICY MAKERS CAN DO TO SUPPORT EFFECTIVE K-12 STEM EDUCATION

We offer proposals to policy makers that collectively have the potential to improve K-12 STEM education. To make progress in improving STEM education for all students, **policy makers at the national, state, and local levels should elevate science to the same level of importance as reading and mathematics.** Science should be assessed with the same frequency as mathematics and literacy, using a system of assessment that supports learning and understanding. Such a system is not currently available. Therefore, **states and national organizations should develop effective systems of assessment** that are aligned with the next generation of science standards and that emphasize science practices rather than mere factual recall.

National and state policy makers should invest in a coherent, focused, and sustained set of supports for STEM teachers to help them teach in effective ways. Teachers in STEM should have options to pursue professional learning that addresses their professional needs through a variety of mechanisms, including peer-to-peer collaboration, professional learning communities, and outreach with universities and other organizations.

Furthermore, **federal agencies should support research that disentangles the effects of school practice from student selection, recognizes the importance of contextual variables, and allows for longitudinal assessments of student outcomes,** including the three strategic goals of STEM education and intermediate outcomes. Federal funding for STEM-focused schools should be tied to a robust, strategic research agenda. Only knowledge of this sort will allow a full response to the questions that were put to this committee.

APPENDIX
Background Papers Prepared for May 2011 Workshop

Engineering for Effectiveness in Mathematics Education: Intervention at the Instructional Core
Jere Confrey with Alan Maloney

Effective STEM Strategies for Diverse and Underserved Learners
Okhee Lee

Building on Learner Thinking: A Framework for Improving Learning and Assessment
Jim Minstrell with Ruth Anderson and Min Li

Mathematics Learning and Diverse Students
Na'ilah Suad Nasir with N. Shah, Jose Gutierrez, Kim Seashore, Nicole Louie, and Evra Baldinger

STEM Reform: Which Way to Go?
William H. Schmidt

Delivering STEM Education Through Career and Technical Education Schools and Programs
James R. Stone, III

Successful Education in the STEM Disciplines: An Examination of Selective Specialized Science Mathematics and Technology-Focused High Schools
Rena F. Subotnik and Robert H. Tai

Effective STEM Teacher Preparation, Induction, and Professional Development
Suzanne Wilson

Inclusive STEM Schools: Early Promise in Texas and Unanswered Questions
Viki M. Young with Ann House, Haiwen Wang, Corinne Singleton, and Kristin Klopfenstein

NOTES

[1] The workshop agenda is available at http://www7.nationalacademies.org/bose/STEM_SchoolsWorkshop_Agenda.pdf.

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to STEM teacher retention; enabling factors outside the school, such as parents, business, and community; information about the relative cost of implementation; the role of science fairs; and practices such as mentorships, research experiences, and internships.

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