



BUILDING A  
**SCIENCE, TECHNOLOGY,  
ENGINEERING, and MATH**  
EDUCATION AGENDA

An Update of State Actions





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NGA Center for Best Practices

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### Some STEM Facts

- At all levels of educational attainment, STEM job holders earn 11 percent higher wages compared with their same-degree counterparts in other jobs.
- The top 10 bachelor-degree majors with the highest median earnings are all in STEM fields.
- The average annual wage for all STEM occupations was \$77,880 in May 2009, significantly above the U.S. average of \$43,460 for non-STEM occupations.
- Over the past 10 years, STEM jobs grew three times faster than non-STEM jobs. STEM jobs are expected to grow by 17 percent during the 2008–2018 period versus 9.8 percent growth for non-STEM jobs.
- In 2010, the unemployment rate for STEM workers was 5.3 percent; for all other occupations, it was 10 percent.



## EXECUTIVE SUMMARY

For several years, governors and education policy leaders have been working to strengthen science, technology, engineering, and mathematics (STEM) education throughout the states. The immediate goals are twofold: increase the proficiency of all students in STEM and grow the number of students who pursue STEM careers and advanced studies. The reasons are straightforward: STEM occupations are among the highest paying, fastest growing, and most influential in driving economic growth and innovation. Individuals employed in STEM fields enjoy low unemployment, prosperity, and career flexibility. In short, STEM education is a powerful foundation for individual and societal economic success.

Unfortunately, the United States has fallen behind in fully realizing the benefits of STEM education. Results from the National Assessment of Educational Progress over roughly the past 10 years show little improvement in high school seniors' knowledge of math and science. Moreover, the Program for International Student Assessment, which provides cross-country comparisons, shows that U.S. students currently rank behind 25 countries in math scores and behind 12 countries in science scores. These factors may have contributed to another problem: the slow growth in postsecondary degrees awarded in STEM fields over approximately the past decade. This lack of strong degree growth is causing the United States to fall behind other countries that are surging ahead to create a STEM talent pool. For example, U.S. STEM degrees represent only about one-third of bachelor's degrees, but they represent more than half of the first degrees awarded in Japan, China, and Singapore.

The reasons the United States lags behind its competitors in producing STEM graduates have been well documented. They include:

- **Lack of rigorous K–12 math and science standards.** Standards in math and science have varied greatly across states and, in many cases, do not test students' abilities to utilize concepts and solve problems.
- **Lack of qualified instructors.** A shortfall in the numbers of qualified math and science teachers in the classroom is a chronic problem in the K–12 system; many classrooms are staffed by teachers with neither a certificate nor a degree in their assigned subject area.
- **Lack of preparation for postsecondary STEM study.** A student's ability to enter and complete a STEM postsecondary degree or credential is often jeopardized because the pupil did not take sufficiently challenging courses in high school or spend enough time practicing STEM skills in hands-on activities.
- **Failure to motivate student interest in math and science.** In most K–12 systems, math and science subjects are disconnected from other subject matters and the real world, and students often fail to see the connections between what they are studying and STEM career options.
- **Failure of the postsecondary system to meet STEM job demands.** Although STEM jobs are expected to grow by 17 percent between 2008 and 2018, many higher education institutions—including community colleges, four-year colleges, and research universities—have not made an effort to increase their output of STEM degrees or certificates.

States and their educational institutions have taken the following actions to address these challenges:

- **Adopted rigorous math and science standards and improved assessments.** Through the Common Core State Standards Initiative, led by governors and chief state school officers, states are implementing more rigorous, internationally benchmarked math standards. A separate state-led effort soon will produce improved science standards.
- **Recruited and retained more qualified classroom teachers.** Several states and districts are using financial incentives, support systems, professional development, and improved institutional conditions to recruit, retain, and reward high-performing math and science teachers.
- **Provided more rigorous preparation for STEM students.** Through new school and instructional designs—STEM-specialty schools and academies, early college programs, linked learning, and online courses—states and schools are providing students with more focused and rigorous STEM curricula with real-world applications.
- **Used informal learning to expand math and science beyond the classroom.** Many public and private institutions, such as museums, science centers, and after-school programs, provide valuable out-of-class experiences that demonstrate how math and science connect to everyday life and careers and allow students and teachers to expand their skills. These programs are proving to have a positive effect on STEM interest and achievement.
- **Enhanced the quality and supply of STEM teachers.** A number of higher education institu-

tions have established goals to improve teacher preparation programs, provide support systems and professional development, and generate more qualified math and science teachers.

- **Established goals for postsecondary institutions to meet STEM job needs.** A number of states have worked with postsecondary institutions to boost the number of certificates and degrees in STEM fields.

The above actions should begin to increase the number of students and professionals engaged in STEM fields and occupations, but it will take time to see results. Data through 2008 show only slight growth in STEM degree enrollment. And the percentage of STEM degrees awarded out of all degrees fell from 12.4 percent in 2000–2001 to 10.7 percent in 2008–2009. Because more individuals are attending college each year, the absolute number of STEM degree holders in the United States is expected to grow but not nearly at the rate of some international competitors.

For these reasons, states must push ahead with their STEM initiatives. Fortunately, most elements of the STEM agenda—improved standards, more qualified teachers, and access to advanced coursework—directly align with the larger education reform efforts underway. Where unique actions are needed to boost STEM education, such as the creation of STEM-focused schools and support systems for teachers and students, states at times are combining their own resources with those of the private sector, philanthropic community, and federal government. By more efficiently allocating resources in the K–12 system and improving the productivity of postsecondary institutions, states can find ways to advance STEM education without additional expense.







“One of my favorite quotes is from Carl Sagan, who said it’s suicidal to create a society that depends on science and technology in which no one knows anything about science and technology—and that’s the road that we are headed down. . . . You need to generate the scientists and engineers, starting in school—elementary school, middle school, you have to fund the research that those scientists go on to do—the fundamental research. You have to generate the engineers that can turn those scientific breakthroughs into products and services.”

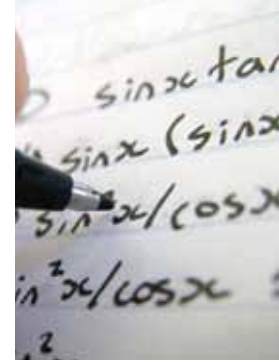
—Sally Ride

### A Note on STEM Definitions

No standard definition exists of what constitutes a STEM job, and different studies often use slightly different groupings. Science, technology, engineering, and math positions appear consistently, but some studies include management and sales in STEM fields, while other research does not. Additional workers not consistently represented are STEM education employees, social scientists, certain health care professionals, and economists. In general, most studies tend to *under-represent* the total number of positions that involve STEM knowledge, such as understanding quantitative analysis.

# 1

## INTRODUCTION



**S**TEM—science, technology, engineering, and mathematics—is critical to and supportive of many education reforms being undertaken today, from adoption of common internationally benchmarked standards to better teacher preparation to enhanced coordination across the entire K–20 education system. In fact, STEM is not a separate reform movement at all; rather, it is an emphasis. It stresses a multidisciplinary approach for better preparing all students in STEM subjects and growing the number of postsecondary graduates who are prepared for STEM occupations.

The motivation behind this new emphasis on STEM is simple. Increasing the number of students versed in STEM and growing the number of graduates pursuing STEM careers or advanced studies are critical to the economic prosperity of every state and the nation. A labor force without a rich supply of STEM-skilled individuals will face stagnant or even declining wealth by failing to compete in the global economy, where discovery, innovation, and rapid adaptation are necessary elements for success. To ensure that the United States does not follow that path, governors, education leaders, and policymakers at all levels have called for a new emphasis on STEM education in our nation’s schools, from K–12 through postsecondary education. How states are working to achieve these goals is the subject of this report.

The National Governors Association (NGA) first addressed STEM in its 2007 report, *Building a Science, Technology, Engineering and Math Agenda*. That report provided an overview of the STEM-related challenges, opportunities, and actions from the state perspective. This report updates those recommendations in light of recent state progress to improve education standards and other efforts to advance STEM education. In addition, this report

incorporates recent data from studies that make the economic case for pursuing a STEM agenda even more compelling than before.

The report’s six brief chapters cover the following issues:

- **Chapter 2** defines the goals of the STEM agenda, focusing on specific measures.
- **Chapter 3** examines why STEM is important in terms of jobs, prosperity, and future economic success.
- **Chapter 4** reviews where the current system is preventing the graduation of more high school and college students with STEM skills.
- **Chapter 5** examines what is being done and can be done to counter these trends.
- **Chapter 6** concludes with a look at the work ahead.

Governors, state education policy staff, and state education leaders can use this guide to further the implementation of STEM agendas. Fortunately, as current state actions demonstrate, emphasizing STEM does not shift the direction of education reforms already underway. The majority of actions called for in this report complement changes initiated in both the K–12 and postsecondary systems over the past several years. A STEM focus merely provides coherence to many of these reforms, uniting them under a common set of goals.

Finally, this report also is designed to inform the public. Public commitment and public will are necessary to mobilize the efforts needed for change and to set higher expectations for the nation’s youth. Without it, we will simply run in place while others pass us by.



**“Because the major pathway to a STEM career is through postsecondary study, boosting the number of individuals in STEM jobs means more individuals graduating from college with STEM degrees or certificates.”**

# 2

## GOALS OF THE STEM AGENDA



The STEM agenda has two basic goals. The first goal is to expand the number of students prepared to enter postsecondary study and pursue careers in the areas of science, technology, engineering, and mathematics. This goal is designed to bolster the innovative capacity of the U.S. workforce, which is falling behind other nations that are creating higher numbers of STEM-trained individuals each year compared to the United States.

The second goal is to boost the proficiency of all students in basic STEM knowledge. This goal is designed to improve the ability of students and workers to assess problems, employ STEM concepts, and apply creative solutions in their daily lives. This second goal requires that all high school graduates be ready with the basic skills to pursue work or study in both STEM and non-STEM fields and meet the demands of most jobs today.

Together, both goals are intended to enhance the global competitiveness of the U.S. economy and help individuals achieve economic security in their careers.

### Increasing the Number of Students and Professionals in STEM

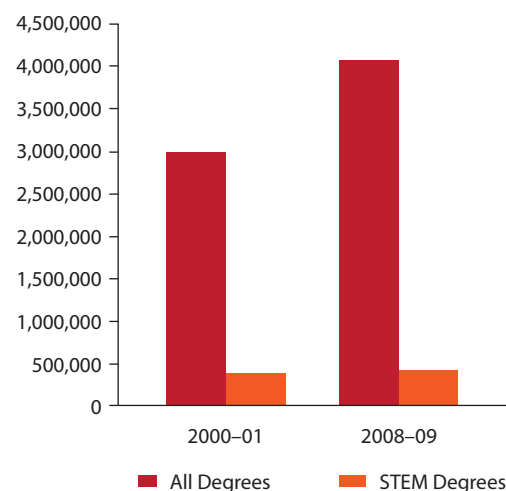
A major goal of the STEM agenda is to increase the number of individuals pursuing STEM careers. Because the major pathway to a STEM career is through postsecondary study, boosting the number of individuals in STEM jobs means more individuals graduating from college with STEM degrees or certificates.

Unfortunately, the growth in postsecondary STEM degrees awarded in the United States over the past decade has been anemic (Figure 2-1).<sup>2</sup> In the 2000–2001 academic year, postsecondary institutions awarded approximately 386,000 STEM de-

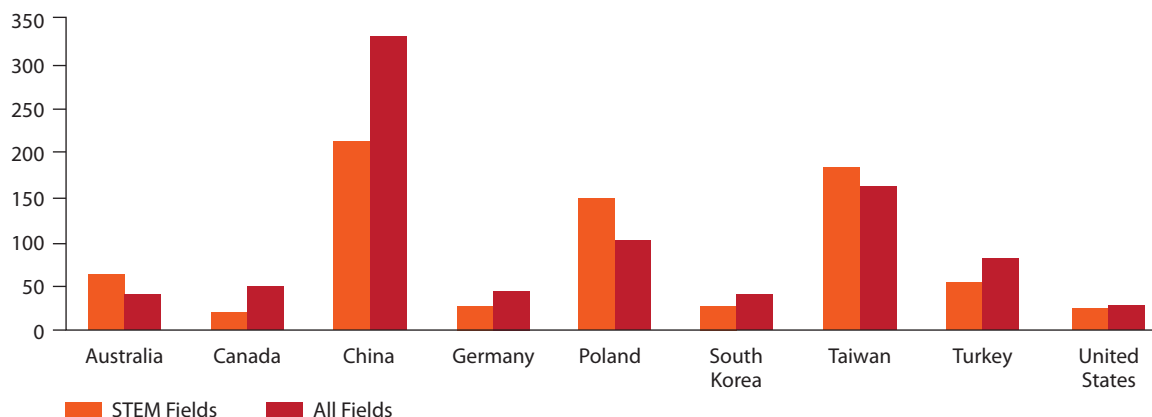
grees out of nearly 3 million degrees in all fields. By 2008–2009, the total number of STEM degrees awarded rose to about 435,000 out of more than 4.1 million. Thus, although the number of degrees awarded in all disciplines grew by 35.5 percent, the number of STEM degrees edged up by just 12.4 percent. Moreover, the percentage of all degrees that represent STEM fields fell from 12.9 percent in 2000–2001 to 10.7 percent in 2008–2009.

When these figures are compared internationally, the numbers look worse (Figure 2-2).<sup>3</sup> Between 1998 and 2006—the years of available data to compare the countries listed—the total number of U.S. undergraduate degrees awarded in all fields grew by 25 percent, while those awarded in STEM grew by 23 percent. In contrast, over the same period, STEM degrees in Poland grew by 144 percent; in Taiwan, by 178 percent; and in China, by more than 200 percent. Moreover, the data show that by 2006, China was already awarding almost twice as many first university degrees in STEM (911,846) compared to the United States (478,858), even though

Figure 2-1: Awards Conferred in Stem and All Subjects



**Figure 2-2: Percent Growth in Degrees Awarded, 1998–2006**



the quality and number of some of the Chinese degrees has been questioned. Nevertheless, given this trend, the degree gap has surely grown.

When comparing U.S. postsecondary STEM-degree attainment with that of rising competitors, other troubling developments come to the fore:<sup>4</sup>

- In China, the number of first university degrees awarded in natural sciences and engineering has risen sharply since 2002, while the number awarded in Germany, Japan, the United Kingdom, and the United States has remained relatively flat.
- In the United States, STEM degrees have for a long time represented about one-third of bachelor’s degrees. Countries where more than half of first degrees are now awarded in STEM fields include Japan (63 percent), China (53 percent), and Singapore (51 percent).
- In the United States, about 5 percent of all bachelor’s degrees are in engineering. In Asia, about 20 percent are in engineering; specifically, in China, about one-third of bachelor’s degrees are in engineering (although the percentage has declined in recent years).

Despite these statistics, the United States continues to be a significant producer of STEM degrees. In fact, when the Organisation for Economic Cooperation and Development (OECD) looks at the top 10 countries with the largest shares of *advanced* science and engineering degrees, the United States is

the largest single contributor of new doctorates, with more than one-quarter of the nearly 89,000 total in 2009 (followed by Germany, the United Kingdom, and France).<sup>5</sup> However, other nations are quickly catching up by awarding STEM advanced degrees at a much higher rate than the United States (Figure 2–3). This is partly why a few corporations have moved some research and development activities overseas.

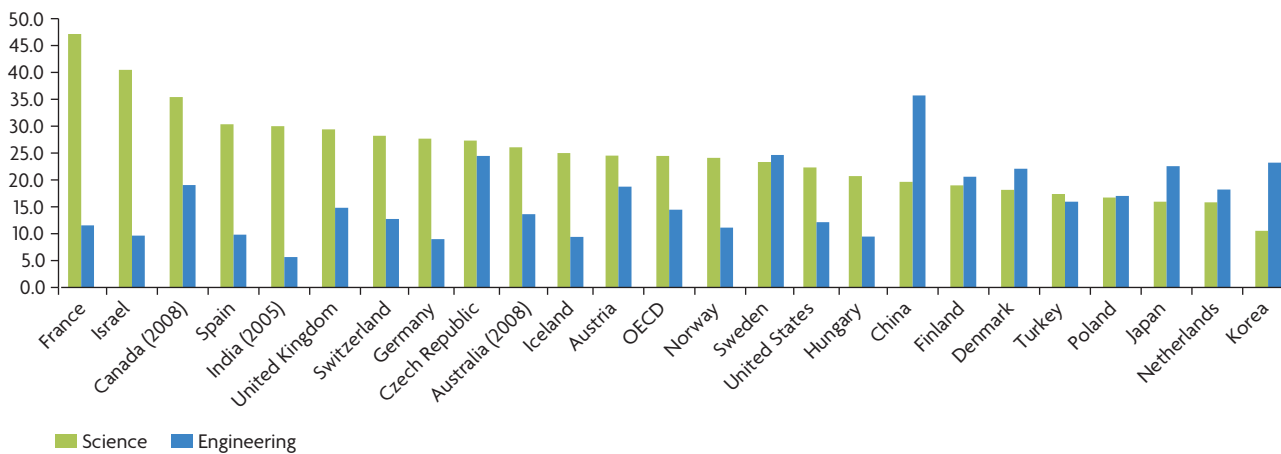
### Increasing STEM Proficiency for All Students

Another goal of the STEM agenda is to improve the proficiency of all students in STEM, even if they choose not to pursue STEM careers or postsecondary studies. The ability to understand and use STEM facts, principles, and techniques are highly transferable skills that enhance an individual’s ability to succeed in school and beyond across a wide array of disciplines. These skills include:

- Using critical thinking to recognize a problem;
- Using math, science, technology, and engineering concepts to evaluate a problem; and
- Correctly identifying the steps needed to solve a problem (even if not all the knowledge to complete all steps is present).

Achieving greater STEM proficiency begins in the K–12 system, where U.S. students have not demonstrated significant gains in math and science knowledge for almost 15 years, according to the National

**Figure 2-3: Science and Engineering Graduates at Doctorate Level (2009)**  
(as percentage of all new degrees awarded at doctorate level)



Assessment of Educational Progress (NAEP). (Note: Currently, the NAEP measures math and science knowledge but does not measure technology and engineering knowledge. Testing of the latter two subjects will begin in 2014 [see sidebar].)<sup>6</sup>

Since 1990, the NAEP has reported performance in terms of three educational levels: basic, proficient, and advanced. At least among 12th-grade students, the results are decidedly mixed.

In math, the percentage of students achieving proficiency or greater more than doubled from 1990 to 2009—from 12 percent to 26 percent. However, over the same period, the proportion of students at or above basic dipped from a peak of 69 percent in 1996 to 64 percent in 2009; only 3 percent of all students scored at advanced in the latest test (Figure 2-4).<sup>7</sup>

Even less promising trends can be found in the 1996–2009 science assessment figures. Although students judged at or below basic fell slightly, those scoring at or above proficient stayed the same (21 percent). Over the same period, the percentage of students at the advanced level fell from 3 percent to 1 percent (Figure 2-5).

Taken together, the numbers suggest that student achievement in math and science has not changed much for almost 15 years—the percentage of 12th-grade students scoring at or above proficiency in math has shown only modest progress, while science skills have remained static over the

### TECHNOLOGY AND ENGINEERING LITERACY

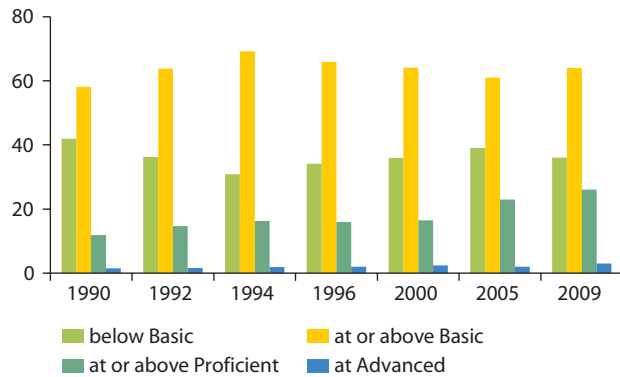
According to the framework guiding the development of the first NAEP Technology and Engineering Literacy Assessment, students will be evaluated in these three major areas:

- **Technology and Society** involves the effects that technology has on society and on the natural world and the resulting ethical questions that arise.
- **Design and Systems** covers the nature of technology, the engineering design process used to develop technologies, and the basic principles of dealing with everyday technologies, including maintenance and troubleshooting.
- **Information and Communication Technology** includes computers and software learning tools; networking systems and protocols; handheld digital devices; and other technologies for accessing, creating, and communicating information and for facilitating creative expression.

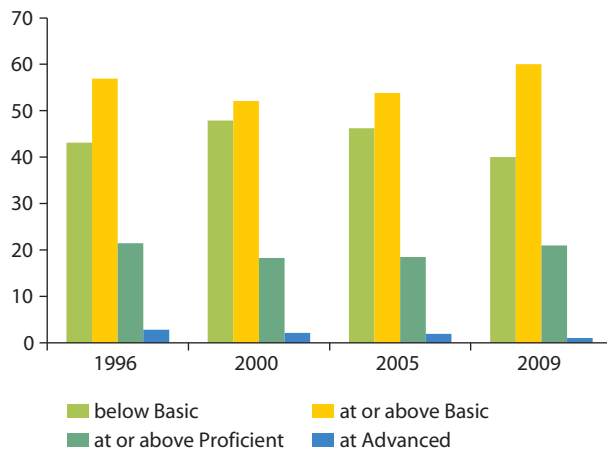
NAEP testing years. More importantly, the nation has made almost no headway in increasing the number of students that reach the advanced level.

Within the data is another troubling aspect—a persistent achievement gap in the math and science scores between white students and African-American and Hispanic youth. Since 1990, the gap in mean scores between African-American stu-

**Figure 2-4: NAEP Math Scores, 12th Grade**



**Figure 2-5: NAEP Science Scores, 12th Grade**



dents and their white counterparts has averaged 27 for math and 34 for science; for Hispanic youth, the average difference has been 22 for math and 26 for science. Because these minority youth represent an increasing share of the nation’s student population, the need to close this gap and the challenge it presents to raising overall math and science scores will only grow.

### **International Comparisons**

Cross-national comparisons shed additional light on the math and science proficiency of U.S. students. The Program for International Student Assessment is an OECD test that measures math and science literacy among students 15 years of age. The results of the most recent tests are shown in Figure 2-6.<sup>8</sup> The tests show that in math, the Unit-

ed States ranked below 25 other countries that participated. The U.S. average math score of 487 also was lower than the OECD average of 496.

For science, the U.S. average score of 502 was not measurably different than the OECD average of 501, but 12 OECD countries had higher scores. At the very least, the numbers suggest that the United States is not dominating its competitors.

Two important measures are the numbers of students at both the bottom and top of the spectrum. In terms of math proficiency, the OECD considers scores *below* level 2 to indicate that students may not be able to consistently employ basic algorithms or make literal interpretation of the results of mathematical operations in real-life settings. Scores *above* level 4 indicate that students can complete higher order tasks, such as solving problems that involve visual or spatial reasoning in unfamiliar contexts. Twenty-three percent of U.S. students scored below level 2 in 2009, which was similar to other OECD countries. However, only 27 percent of U.S. students scored at or above level 4, which is below the OECD average of 32 percent.

The 2007 Trends in International Mathematics and Science Study (TIMSS) found similar results in its international comparisons.<sup>9</sup> At eighth-grade, the average U.S. math score for students taking the test was lower than the average score of students in five countries, higher than 37 countries, and essentially the same as five countries. Similarly, the U.S. average science score for eighth-graders was lower than the average score of students in nine countries, higher than 35 countries, and about equal to three countries.

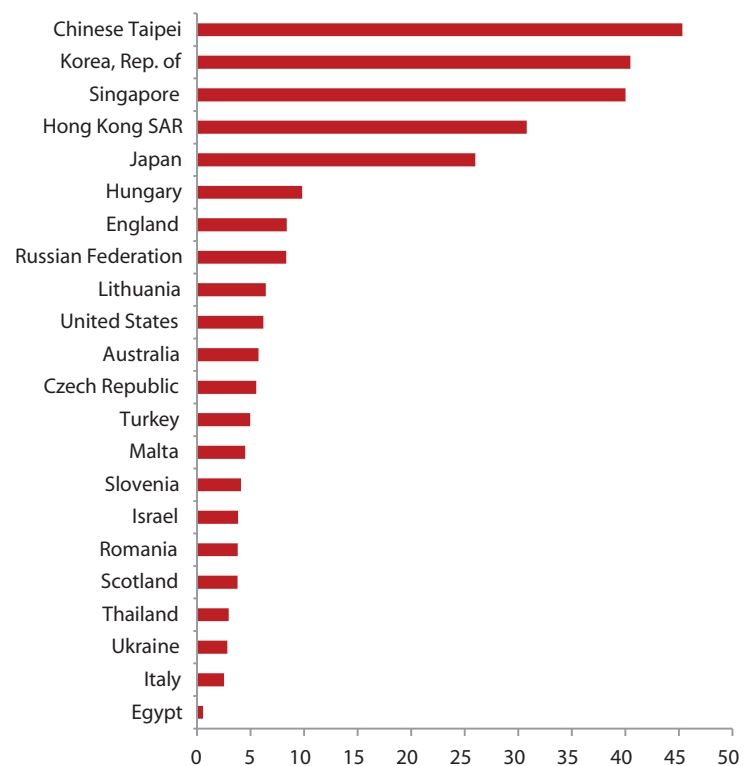
Perhaps the most striking result is the difference among countries in the percentage of students scoring at or above the advanced benchmark. Figure 2-7 depicts the percentage of eighth-grade students that scored at or above advanced in math. Nine countries had higher percentages of students with advanced scores than the United States, and some of the differences in percentages were dramatic (e.g., the Chinese Taipei percentage was more than seven times that of the United States’ percentage).



**Figure 2-6: PISA 2009 Results (Age 15)**  
(ranked by Math Scores)



**Figure 2-7: Percent of 8th Grade Students Scoring at or Above Advanced on 2007 TIMSS Math for Selected Countries**

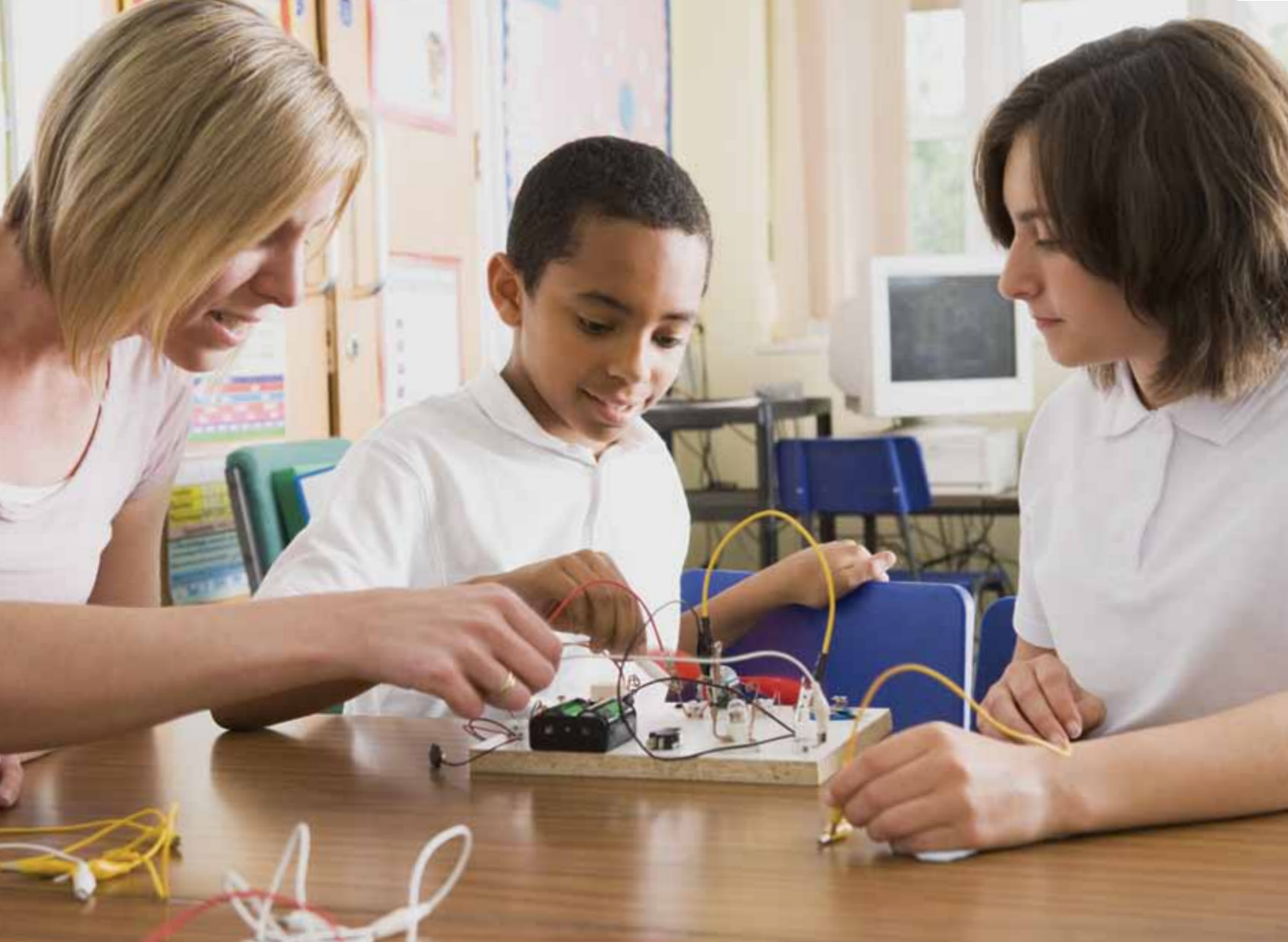


Eighth-grade results for advanced science scores in the 2007 TIMSS were similar: six countries—Singapore, Chinese Taipei, Japan, England, Korea, and Hungary—had higher percentages of students performing at or above the advanced science benchmark than the United States.

### Summing Up

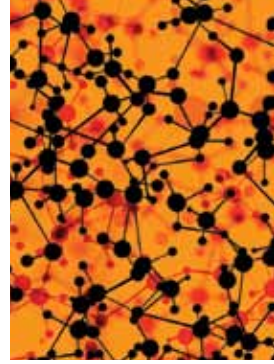
The goals of the STEM agenda are straightforward: increase the number of individuals in the United States in STEM occupations, and increase the

STEM proficiency of all individuals, even if they choose non-STEM careers. Unfortunately, the data show that the United States is not producing enough college graduates to boost the STEM labor force. Our ability to graduate high school students with good math and science skills has only modestly improved at best. In addition, of growing concern is the trend that, compared with key international competitors, the United States is falling behind in producing the *best* students in math and science who are prepared for college or careers.



**“... individuals with STEM degrees who enter STEM careers experience lower unemployment rates compared with workers who enter other fields, which means STEM workers enjoy greater job security.”**

# 3



## WHY THE STEM AGENDA IS IMPORTANT

Increasing the number of high school, college, and postgraduate students majoring in STEM subjects is critical for economic prosperity. Most STEM graduates go into STEM jobs, occupations that are among the highest paying and fastest growing. Moreover, individuals with STEM degrees who enter STEM careers experience lower unemployment rates compared with workers who enter other fields, which means STEM workers enjoy greater job security. Students who study STEM also are able to enter a variety of fields and earn a salary premium even when they pursue non-STEM occupations. Finally, STEM education boosts the competitive edge and innovative capacity of states and regions, which sustain economic growth.

### STEM Salaries Are Above the National Average

A sure way to raise the per capita earnings of a state or region is to increase the number of STEM graduates who reside there. STEM occupations are high paying, with wages significantly above the U.S. average.<sup>10</sup>

According to a recent analysis by the Bureau of Labor Statistics (BLS), the average annual wage for all STEM occupations was \$77,880 in May 2009, and only four of 97 STEM occupations had mean wages below the U.S. average of \$43,460. Moreover, the top 10 bachelor-degree majors with the highest payoff are all in STEM fields, according to the Georgetown University Center on Education and the Workforce (Figure 3-1).<sup>11</sup>

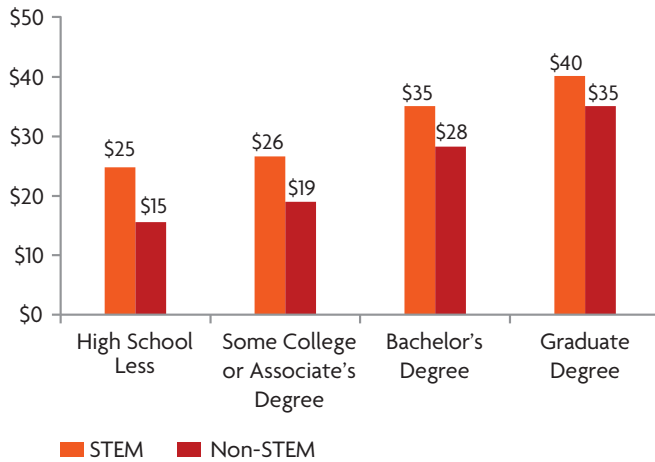
A STEM wage premium seems to hold even when comparing STEM and non-STEM workers at different levels of educational attainment. At each level, STEM job holders enjoy 11 percent higher wages than their same-degree counterparts in other occupations (Figure 3-2).<sup>12</sup> For example, STEM workers with some college or an associate's degree earn \$7.61 more per hour than their non-STEM counterparts. STEM workers with graduate degrees earn \$4.50 more per hour than those in non-STEM jobs.

Similarly, an individual with a STEM education seems to experience a wage advantage even when working in a non-STEM field. According to a recent

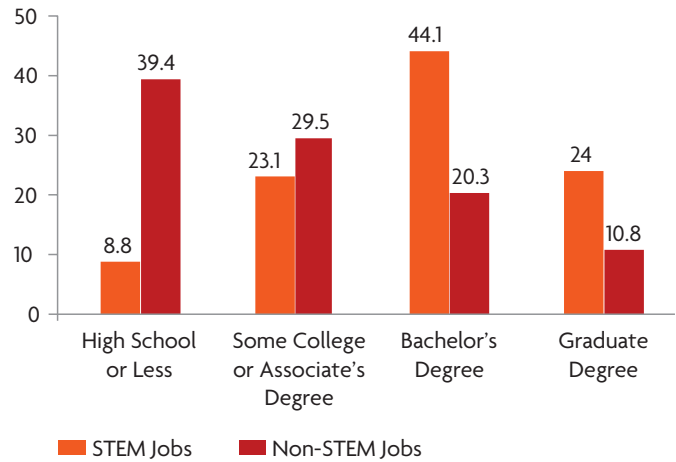
**Figure 3-1: Top 10 Majors with the Highest Median Earnings** (*full time students*)

Major	Median	Earnings at 25th Percentile	Earnings at 75th Percentile
Petroleum Engineering	\$120,000	\$82,000	\$189,000
Pharmaceutical Sciences and Administration	\$105,000	\$83,000	\$120,000
Mathematics and Computer Science	\$98,000	\$75,000	\$134,000
Aerospace Engineering	\$87,000	\$60,000	\$115,000
Chemical Engineering	\$86,000	\$60,000	\$120,000
Electrical Engineering	\$85,000	\$60,000	\$110,000
Naval Architecture and Marine Engineering	\$82,000	\$44,000	\$120,000
Mechanical Engineering	\$80,000	\$59,000	\$105,000
Metallurgical Engineering	\$80,000	\$50,000	\$106,000
Mining and Mineral Engineering	\$80,000	\$52,000	\$125,000

**Figure 3-2: Average Hourly Earnings, Private Full-Time Workers (BLS Report)**



**Figure 3-3: Percent Distribution of Degree Attainment (STEM vs. Non-STEM)**



study that examined Census data over time, the adjusted earnings premium of college-educated workers with a STEM degree was 11 percent higher relative to other college graduates, whether or not they ended up in a STEM job. That premium, however, rose to 20 percent when a STEM degree-holder ended up in a STEM job.<sup>13</sup> Although a STEM degree is the typical path to a STEM job, it is not the only path. Although more than two-thirds of the 4.7 million STEM workers with a college degree have an undergraduate STEM degree, the rest do not. Nevertheless, some level of postsecondary study is critical for landing a STEM job: 91.2 percent of all STEM job holders have some college training or an associate's degree, and more than 68 percent have a bachelor's or graduate degree (Figure 3-3). Thus, the ability to successfully complete postsecondary work is key for pursuing a STEM career.

### STEM Knowledge Bolsters Employment Security

Although they make up only 6 percent of U.S. employment, STEM jobs are growing much faster than other job categories. This means the supply of STEM workers is unlikely to outstrip demand. Over the past 10 years, STEM jobs grew three times faster than non-STEM jobs. From 2008 to 2018, STEM jobs are expected to grow by 17 percent compared to just 9.8 percent for non-STEM jobs.

Equally important, workers in STEM jobs tend to experience lower unemployment rates than workers in other fields. For example, the unemployment rate for STEM workers rose from 1.8 percent in 2007 to 5.5 percent in 2009 before falling to 5.3 percent in 2010. In contrast, the unemployment rate for non-STEM workers jumped from 4.8 percent in 2007 to 9.5 percent in 2009 and 10 percent in 2009.<sup>14</sup>

Some of this premium can be attributed to the fact that the STEM workforce tends to possess higher educational attainment on average (Figure 3-3) than the non-STEM workforce, and this higher educational attainment usually leads to lower unemployment. This fact alone helps lead to lower unemployment levels for STEM workers; for example, the unemployment rate for college-educated workers in both STEM and non-STEM fields hovered around 4.7 percent in 2010. As most business leaders would attest, individuals who can fill STEM jobs remain in high demand and face excellent employment prospects throughout their careers.

Finally, it is important to note that STEM skills are highly transferable and provide individuals with many career options. A 2011 report<sup>15</sup> on STEM from the Georgetown University Center on Education and the Workforce describes STEM knowledge, skills, and abilities and how those assets add value to a wide variety of vocations:

*[STEM] knowledge tends to be highly specialized, [and] it is both transferable and useful in contexts outside the traditional STEM disciplines and occupations. Ultimately, this dynamic gives rise to careers that mix essentially different academic preparation and occupations. A mix of technical preparation and preparation in other disciplines is increasingly advantageous across a wide array of occupations. In addition, the transferability of knowledge allows STEM professionals to shift into other careers, especially into managerial roles midcareer in which their technical competencies are an advantage.*

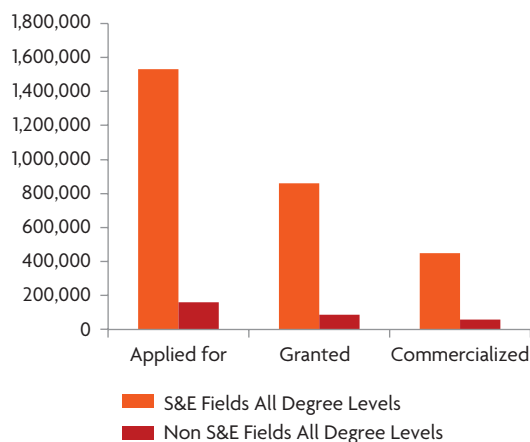
### STEM and Innovation

Linkages between innovation and economic growth are fairly well established. Economists broadly agree that more than half of economic growth since World War II has come from technological innovation.<sup>16</sup> According to the Milken Institute’s *Best-Performing Cities 2010*, “A rich innovation pipeline plays a pivotal role in a region’s industrial development, commercialization, competitiveness, and ability to sustain long-term growth.”<sup>17</sup>

The STEM workforce is a powerful component of this innovation pipeline. STEM occupations employ individuals who create ideas and applications that become commercialized and yield additional jobs. STEM fields overwhelmingly dominate other fields in generating new patents, including those that enter the marketplace. For example, during 1998–2003, scientists and engineers (S&E) applied for nearly 10 times more patents and commercialized almost eight times more patents than applicants from all other fields (Figure 3–4).<sup>18</sup>

STEM workers also contribute to the creation of innovation hubs—areas that usually include technology centers and research parks—that are important sources of economic activity. STEM workers are often found in high concentrations in these ar-

**Figure 3-4: Patenting Indicators for Scientists and Engineers and Other Degrees, 1998–2003**



reas. In addition, research universities and other postsecondary institutions typically are nearby, providing new supplies of STEM graduates and opportunities for collaboration. Innovation hubs can spawn clusters of associated businesses and suppliers in both STEM and non-STEM fields while also rapidly growing jobs.<sup>19</sup>

### The Payoff

Growing a STEM workforce is a sound economic development strategy. The STEM workforce is a key component of an innovation economy and a key ingredient for creating new business clusters and jobs. STEM jobs also are fast growing and pay significantly above the national average. In addition, a STEM education provides individuals with a wage advantage and higher employment security throughout their careers, even if they pursue non-STEM occupations. As a recent U.S. Department of Commerce report concluded, “Although still relatively small in number, the STEM workforce has an outsized impact on a nation’s competitiveness, economic growth, and overall standard of living.”<sup>20</sup>



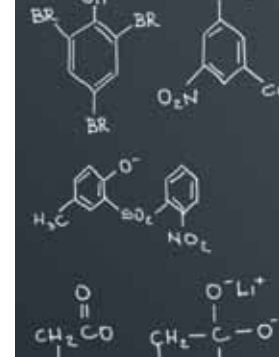
### Seeing Connections

“When students discussed their career ambitions, many did not connect their aspirations with required high school math and science coursework, suggesting a need to help students see the relevance of upper-level math and science coursework in secondary school and beyond.”

—From *The Opportunity Equation* (2007), Carnegie Corporation of New York

# 4

## WEAK LINKS IN THE SYSTEM



A number of studies and blue-ribbon commissions over the past decade have identified problems in the current system that hinder states and the nation from meeting STEM education goals. Many gaps exist, but this report briefly highlights five that states are addressing:

- Inconsistent state standards in math and science;
- Shortfall of qualified math and science classroom teachers;
- Lack of preparation for postsecondary stem study;
- Failure to motivate student interest in math and sciences; and
- Failure of the postsecondary system to meet STEM job needs.

### Inconsistent State Standards in Math and Science

For many years, policymakers have called on states to adopt more academically rigorous common math and science standards, which vary greatly. In many cases, they are too numerous and too broad to correctly define what students need to know. More-

over, many current standards lack the clarity and rigor of standards in other countries, which contributes to the lack of U.S. student gains in international testing.

As discussed in Chapter 5, a national, state-led effort is underway to correct these concerns; therefore, this report does not discuss in great detail the current problems surrounding standards. Nevertheless, because the new standards will take several years to implement, interim steps are needed to make certain that students are properly prepared for postsecondary STEM study. Meanwhile, states must forge ahead with the adoption of the more rigorous math and science standards and assessments to ensure that progress is not delayed.

### Shortfall of Qualified Math and Science Classroom Teachers

A shortfall in the numbers of qualified math and science classroom teachers has been a chronic challenge in the K–12 system.<sup>21</sup> For example, only 63.1 percent of high school math teachers in 2007–2008

**Figure 4-1: Percent of High School Math and Science Teachers Certified or Not Certified in their Assignment**

Selected Main Assignment	Major in main assignment			No major in main assignment		
	Total	Certified	Not Certified	Total	Certified	Not Certified
Mathematics	72.5	63.1	9.4	27.5	16.4	11.1
Science	84.0	73.6	10.4	16.0	12.0	4.0
Biology/life science	76.1	60.2	16.0	23.9	17.2	6.7
Physical science	48.5	39.5	9.0	51.5	29.9	21.6
Chemistry	48.5	36.8	11.4	51.8	34.6	17.3
Earth sciences	33.2	27.2	6.0	66.8	23.3	43.5
Physics	57.7	42.7	15.0	42.3	28.1	14.1



both majored in math and were certified to teach math (Figure 4–1).<sup>22</sup> For science high school teachers, the statistics are better: 73.2 percent both majored in science and were certified. (In comparison, the percentage of teachers that *neither* majored in the subject *nor* were certified was 11 percent and 4 percent, respectively.)

The lack of teacher qualification becomes more acute in some of the physical sciences. In chemistry, only 36.8 percent of teachers held a major and certification in the subject. In earth sciences, only 27.4 percent of teachers majored and held a certificate in the subject. Of more concern, 21.6 percent of teachers in the physical sciences and 43.5 percent

of the teachers in the earth sciences held neither a degree nor a certificate in the subject.

To increase the number of qualified STEM teachers in the classroom, states will need to focus on policies that recruit, retain, and grow the supply of qualified math and science teachers. In addition, they will need to promote policies that help retain teachers who are most effective in raising math and science achievement.

#### **Lack of Preparation for Postsecondary STEM Study**

New, improved math and science standards will go a long way in preparing students for college and ca-



reers, but more is needed to prepare students for postsecondary STEM study and STEM careers. For these students, stronger academic preparation raises their chances for success but is frequently not available.

Research has shown that strong academic preparation in high school improves STEM degree completion rates. For example, students who took trigonometry, pre-calculus, or calculus in high school; earned a high school grade-point average of B or higher; obtained college entrance exam scores in the highest quarter; and expected to attain a graduate degree in the future experienced higher rates of STEM degree completion (including STEM bachelor's degrees) and lower rates of leaving college without earning any credential than did their peers without these characteristics.<sup>23</sup>

In addition, research suggests—at least with regard to science—that certain instructional practices appear to be more effective than others in raising achievement.<sup>24</sup> These include:

- Doing hands-on activities in science;
- Writing long answers to science tests and assignments;
- Talking about measurements and results from hands-on activities; and
- Working with others on a science activity.

Unfortunately, many students who wish to study STEM leave high school without taking sufficiently challenging courses, participating in hands-on and group projects, or practicing concepts learned in math and science by applying them to real-world problems.

### **Failure to Motivate Student Interest in Math and Sciences**

In most K–12 systems, science and math are taught as discrete subjects unconnected to other coursework. Students are not often exposed to the connections between the work they are doing currently in math and science and postsecondary fields of study and STEM occupations. Most of what students learn about the real-world connections to

math and science is relegated to the once-a-year field trip to a museum or planetarium. Yet these students rely on technology every day in smart phones, computers, and televisions without understanding the underlying connections to math and science.

Helping students see the connections between math and science and future career opportunities is a critical aim of the STEM pipeline. Students typically form notions of their career path in secondary school. Without the right information, fully capable students may bypass STEM study because they could not foresee the applications of STEM knowledge.

Motivating interest in math and science requires improved teaching strategies in the classroom and opportunities outside the classroom to demonstrate linkages between math and science, real-world applications, and future careers. Teachers and other school staff will need help in making students see these linkages.

### **Failure of Postsecondary System to Meet STEM Job Needs**

As mentioned in Chapter 3, between 2008 and 2018, STEM jobs are projected to grow by 17 percent, almost twice as fast as non-STEM jobs. Although it represents only 5 percent of the total workforce, STEM employment will expand by more than 1.5 million workers in 2018. More than 90 percent of these jobs will require postsecondary study, with 68 percent requiring a bachelor's degree or more.

However, in many cases, the higher education system—community colleges, four-year colleges, and research universities—fails to see the connection between academic outputs and the needs of the marketplace. Policymakers, including governors and state legislators, contend that more attention must be paid to the job demands of the regional economy. Programs and degree outputs must be better matched to the job market to sustain economic growth. This is particularly important with regard to STEM education, where supplies of STEM teachers are tight and global competition is strong.



“To realize the goals of a STEM agenda, states will need to adopt improved K–12 math and science standards and the assessments that test student knowledge and problem solving. Fortunately, states have made marked progress in this area over the past five years.”



## IMPLEMENTING A STATE STEM AGENDA

**D**espite the financial downturn and tight fiscal situation, states are continuing their efforts to advance a STEM agenda. In addition to state and local government resources, many of these efforts are leveraging support from the philanthropic community, businesses, and, in some cases, the federal government.

Although many simultaneous actions are needed to grow participation and outcomes in STEM education, this report focuses on six key steps that states are or should be taking across the entire K–postsecondary education continuum:

- Adopt rigorous math and science standards and improved assessments;
- Place and retain more qualified teachers in the classroom;
- Provide more rigorous preparation for STEM students;
- Use informal learning to expand math and science beyond the classroom;
- Enhance the quality and supply of STEM teachers; and
- Establish goals for postsecondary institutions to meet STEM job needs

### Adopt Rigorous Math and Science Standards and Improved Assessments

To realize the goals of a STEM agenda, states will need to adopt improved K–12 math and science standards and the assessments that test student knowledge and problem solving. Fortunately, states have made marked progress in this area over the past five years.

### *Common Core Math Standards*

In 2009, a coalition led by governors and chief state school officers released new, rigorous, and internationally benchmarked math and English language arts standards to widespread praise. Called the Common Core State Standards Initiative, the effort was coordinated by the National Governors Association Center for Best Practices and the Council of Chief State School Officers.<sup>25</sup> The standards were developed in collaboration with teachers, school administrators, and nationally recognized experts. As of late 2011, 46 states and territories had adopted the Common Core Standards and were in the midst of a two- to four-year process of bringing them into the classroom.

The standards define the knowledge and skills students should have along their K–12 education progression so that they will graduate high school able to succeed in entry-level, credit-bearing academic college courses and in workforce training programs. The standards:

- Are aligned with college and work expectations;
- Are clear, understandable, and consistent;
- Include rigorous content and application of knowledge through high-order skills;
- Build on strengths and lessons of current state standards;
- Are informed by other top-performing countries so that all students are prepared to succeed in the global economy and society; and
- Are evidence-based.

With regard to the math standards, the Common Core includes a number of improvements that will raise student STEM proficiency:



- The K–5 standards provide students with a *solid foundation in whole numbers, addition, subtraction, multiplication, division, fractions, and decimals*. They are designed to help young students build the foundation to successfully apply more demanding math concepts and procedures and to move into applications.
- The standards stress not only procedural skill but also conceptual understanding. They aim to ensure that students are learning and absorbing the critical information they need to succeed at higher levels.
- The high school standards call on students to *practice applying mathematical ways of thinking to real-world issues and challenges*; in short, they prepare students to think and reason mathematically.

- The high school standards set a *rigorous definition of college and career readiness* by helping students develop a depth of understanding and ability to apply mathematics to novel situations, as college students and employees regularly do.

#### **Assessments**

States also need to adopt and implement new and improved assessments that are aligned to the Common Core. Many current assessments do not fully reflect state standards, do not test problem-solving abilities, and rely too much on questions that test the acquisition of specific information and not more sophisticated skills and concepts. The new assessments will test deeper levels of knowledge and application of concepts. In addition, they will:

- Provide a common and consistent measure of student performance across states, which will allow states to compare performance on a common metric; and
- Offer an opportunity for states to pool financial and intellectual resources to develop better assessments while reducing the cost to each state.

The new assessments, scheduled to be released in 2014–2015, are being designed by two state coalitions: the Partnership for Assessment of Readiness in College and Careers and the SMARTER Balanced Assessment Consortium.

#### **Science Standards**

Developing and adopting new, rigorous, and internationally benchmarked science standards is the next crucial step in improving STEM education. A joint effort led by NGA and the Council of Chief State School Officers, with support from the National Science Teachers Association and the American Association for the Advancement of Science, has led to the development of a consensus report from the National Research Council that is a blueprint for the development of new K–12 science standards. The report, *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, proposes a stronger role for technology and engineering in science education. It also places a greater emphasis on teaching students not only the content and practice

of science but also how to apply science to real-world problems.<sup>26</sup> The framework's introduction states:

*We anticipate that the insights gained and interests provoked from studying and engaging in the practices of science and engineering during their K–12 schooling should help students see how science and engineering are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change. In addition, although not all students will choose to pursue careers in science, engineering, or technology, we hope that a science education based on the framework will motivate and inspire a greater number of people—and a better representation of the broad diversity of the American population—to follow these paths than is the case today.*

The next step is for the states to translate the framework into a set of educational standards that can guide the work of curriculum development, assessment, and teaching. This work is being carried out by Achieve in collaboration with teams from 20 states. The goal is to complete the development of what are being called the Next Generation Science Standards by the end of 2012.<sup>27</sup>

### Recruit and Retain More Qualified and Effective Teachers

To improve K–12 STEM instruction, states will need to recruit more qualified math and science teachers to the classroom. In addition, states will need to focus on policies that retain their most effective instructors. Although more qualified math and teachers are needed, a major problem affecting the supply-and-demand balance today is the high number of skilled teachers who depart for non-retirement reasons.

To reduce departures and fill these hard-to-place jobs, states can utilize financial incentives, provide support systems, and improve institutional conditions. In particular, once placed, polices must focus on retaining the teachers who prove most effective in raising achievement.

### Use Financial Incentives to Recruit and Retain

Salary certainly plays a role in teacher recruitment. A number of states have used signing bonuses in addition to a teacher's salary to attract teachers to hard-to-serve areas or to hard-to-place positions, such as math and science. The Mission Possible initiative in Guilford County, **North Carolina**, is one such program that provides recruitment bonuses. A math teacher can earn a recruitment bonus of \$5,000 per year for working in a hard to staff school and a performance bonus of up to \$12,000 each year (see sidebar, *Mission Possible*).<sup>28</sup>

These financial incentives can play an even greater role in retaining teachers and targeting those who are most effective in raising achievement. A 2010 review of math and science teacher turnover found that 46.3 percent of science teachers and 59.9 percent of math teachers reportedly left their school because of salary reasons.<sup>29</sup> A further analysis found that low salaries were the primary determinant for science teacher departures, although salary did not play as significant a role for math teacher departures.

In 2005, Denver, **Colorado**, implemented ProComp, a compensation system that links teacher pay to the school district's instructional mission.<sup>30</sup> Under the ProComp program, teachers can receive salary increases and/or bonuses by meeting measures such as:

- Working at a hard-to-serve school or in a hard-to-staff position (e.g., math);

#### MISSION POSSIBLE

The *Mission Possible* program in Guilford County, North Carolina, awards both recruitment and retention as well as performance bonuses to qualifying teachers. A math teacher can earn a recruitment bonus of \$5,000 per year for working in a hard to staff school and a performance bonus of up to \$12,000 each year. One month after the program was approved in 2006, the district had 174 applicants to teach math, compared with just seven the year before. Moreover, 87 percent of the teachers from the 2006–2007 school year returned the next year.

- Obtaining advanced degrees and certifications or completing specialized professional development;
- Exceeding student achievement expectations on the state assessment; and
- Working in a school with a significant growth rate in achievement.

A 2010 evaluation of the program found:

- Mathematics and reading achievement has increased substantially from 2002–2003 to 2002–2009;
- Schools with greater rates of ProComp participation experienced higher rates of retention (11 percent since the program started);
- Schools designated “hard to serve” with greater rates of ProComp participation experienced a sharp increase in retention rates in 2006–2007, the first full year ProComp was implemented; and
- In 2009, annual combined salary incentives per teacher averaged \$7,000.

Other incentive pay models similar to the above examples are in use throughout the country, and many have shown positive results in terms of placement, retention, and—most notably—teacher performance.

### ***Improve Institutional Conditions to Promote Retention***

Institutional conditions also can be a major factor in retaining math and science teachers. Institutional conditions include student behavioral problems, the effectiveness of the school leadership and administrative support, the availability of classroom resources, the degree of faculty input into school-wide decisions, the degree of classroom autonomy held by teachers, and the usefulness of professional development in subject-content areas. Many of these conditions are statistically related to math and science teacher turnover.<sup>31</sup>

For math teachers, studies show that strong determinants for leaving include the amount of au-

tonomy a teacher is given in the classroom, degree of student discipline problems in the school, and the extent to which there is useful professional development. Surprisingly, math teachers also preferred larger schools and were more likely to depart small schools.

As mentioned before for science teachers, the strongest factor in leaving is the potential salary offered by school districts. Other factors affecting science teacher turnover are the degree of student discipline problems in the school and the usefulness of professional development.<sup>32</sup>

The findings suggest that, beyond salary, states, schools, and districts can take several actions to help retain more math and science teachers that may not involve increased investments. These include maintaining discipline, providing strong leadership, giving teachers input regarding schoolwide decisions, providing some classroom autonomy, and—most importantly—providing relevant and useful professional development opportunities.

Some states have created special support systems for math and science teachers. For example, the Dayton Regional STEM Center coordinates an established network of regional institutions and professionals that provides STEM teachers with training and curriculum support.<sup>33</sup> Similarly, the Arizona Center for STEM Teachers provides K–12 teachers with professional development courses to improve STEM instruction and online forums for teachers to share experiences. Centers like these often are created with the help of federal and private grants.<sup>34</sup>

### **Provide Rigorous Preparation for STEM Students**

Students pursuing STEM postsecondary study need strong preparation in high school to succeed in their studies and obtain a STEM degree. Data show that 54.9 percent of students entering STEM postsecondary fields obtain a degree within six years, but only 41 percent complete their degree in that field within six years.

Strong academic preparation in high school leads to higher STEM completion rates. Thus, students



who take more rigorous courses like trigonometry, pre-calculus, or calculus have higher rates of STEM degree completion. In addition, new studies are beginning to show that students who had research experience in high school, who were mentored as an apprentice or intern, and whose teachers connected content across different STEM courses were more likely to complete a STEM major than their peers who did not have these experiences.<sup>35</sup>

States have taken a number of actions to promote programs that can give students access to strong preparation, rigorous courses, and opportunities to apply STEM in hands-on projects. These new approaches to teaching STEM include:

- STEM-themed specialty schools;
- Opportunities for earning early college credit;
- Studies linked to future certificate and degree paths in key industrial sectors; and
- Access to online courses in STEM.

Many of these programs work together. For example, a STEM school may offer both online STEM courses and access to early college credit.

### **STEM Schools**

STEM specialty schools provide students with a rigorous, college-ready, STEM-focused curriculum while also preparing pupils for higher level study and professional futures in STEM.

Although the STEM school model varies across the country, most focus on high school. The schools place a heavy emphasis on science, technology, engineering, and math and the teaching environment goes beyond the classroom. Students usually spend significant time working on group projects, and they often receive help from practicing engineers, inventors, and scientists. Many schools also place students in study-related jobs after school.

High Tech High (HtH) in **California** is an example of a specialty STEM school. HtH began in 2000 as a charter high school launched by a coalition of San Diego business leaders and educators. It is now an integrated network of schools spanning grades K-12. It houses a comprehensive teacher certification program and a new, innovative Graduate School of Education.

Students pursue personal interests through projects and compile their work in personal digital portfolios. Facilities are tailored to individual and small-group learning, including networked wireless laptops, project rooms for hands-on activities, and exhibition spaces for individual work. Students go outside the classroom to learn. Juniors complete a semester-long academic internship in a local business or agency, and seniors develop substantial projects that address problems of interest and concern in the community. In earlier grades—ninth and 10th grade as well as middle school—students may “shadow” an adult through a workday, perform community service in a group project, or engage in “power lunches” with outside adults on issues of interest.

Since 2008, HtH has partnered with the National Student Clearinghouse to examine the college completion rates for each of its students. In 2011, National Student Clearinghouse data indicated that 77 percent of HtH alumni are still enrolled or have graduated from a postsecondary institution, with

25 percent of these college graduates earning STEM degrees. In comparison, fewer than 30 percent of California adults in their twenties have a college degree, according to data from the U.S. Census Bureau, and only 17 percent of the state’s college students earn degrees in the STEM fields.<sup>36</sup>

There are many examples of STEM schools throughout the country and a variety of ways to design the schools and curricula (e.g., see the *Linked Learning sidebar*).<sup>37</sup> They can be created as charters, as magnet schools, or as academies within or separate from existing schools. The vast majority are in the public school system. An excellent overview of the different types of STEM specialty schools can be found in the report, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*.<sup>38</sup>

### **Early College**

Early college high schools blend high school and college in a rigorous and supportive program that compresses the time it takes to complete a high

### **LINKED LEARNING**

*ConnectEd: The California Center for College and Career* uses a “linked learning” model for STEM. Linked learning students follow industry-themed pathways in a wide range of fields, such as engineering, arts and media, biomedicine, and health. These pathways prepare high school students for careers through a range of postsecondary options, including attending a two- or four-year college or university, an apprenticeship, the military, and formal employment training. As described on the ConnectEd website, the four core components of linked learning are:

- An academic component that includes English, mathematics, science, history, and foreign language courses that prepare students to transition, without remediation, to the state’s community colleges and universities as well as to apprenticeships and formal employment training programs.

- A technical component of three or more courses that help students gain the knowledge and skills that can give them a head start on a successful career.
- A series of work-based learning opportunities that begin with mentoring and job shadowing and evolve into intensive internships, school-based enterprises, or virtual apprenticeships.
- Support services such as counseling and supplemental instruction in reading, writing, and mathematics that help students master the advanced academic and technical content necessary for success in college and career.

A number of school districts in California are implementing linked learning pathways in their high schools. To implement a certified pathway, the schools must show adherence to several criteria, including providing professional development and growth opportunities for pathway teachers.



school diploma by providing the opportunity to earn college credits, often tuition-free.

A newly opened example is the Wake NC State STEM Early College High School, a joint project of the Wake County (**North Carolina**) Public School System, North Carolina State University, and the North Carolina New Schools Project. STEM is the theme of the school's program. The early college high school lets Wake County students earn a high school diploma and up to two years of college credit at the same time. Students must be interested in science, technology, engineering, and/or math. Students who will be the first in their family to earn a college degree are encouraged to apply. The program is free to students, even when they are taking college classes.

Another example is the Metro Early College High School in **Ohio**, initially funded by a \$560,000 operating grant from Battelle and supported by a \$1.2 million infrastructure gift from the Ohio State University.<sup>39</sup> The school is operated by the Educational Council, a partnership of Franklin County's 16 school districts.

The learning experience is divided into two different phases: preparation and exploration (called Core Prep) and internships and access to college (called College Access). During the Core Prep phase, ninth- and 10th-grade students focus on learning that promotes performance. To exit the preparatory phase, students must demonstrate performance in mathematics, science, social studies, and language arts. This performance demonstration includes successfully passing the Ohio Graduation Tests and completing tasks that showcase a student's ability to work independently and in groups to investigate solutions to real-world problems.

After demonstrating mastery of the Core Prep phase, 11th- and 12th-grade students participate in a curriculum that is focused on "learning outside of the school walls." For example, students may choose a math- or science-focused curriculum where they work with field engineers and take corresponding engineering courses at the Ohio State University or Columbus State Community College.



Student experiences go beyond traditional internships by including demonstrations of problem solving and critical thinking in partnership with the learning lab. The result is a holistic program: Core Prep focuses on capacity building, and College Access focuses on practical experiences, skill development, social maturity, critical thinking, and responsibility.

STEM schools and early college programs often are not overly selective and have been shown to significantly boost high school and college achievement for both minority and disadvantaged students who participate.

### ***Online STEM Learning***

Online learning gives students access to STEM courses they may not have in their current school. These courses can supplement the current learning environment by allowing students to practice skills they studied in the classroom. Online learning often is combined with on-site study in STEM high schools and early college environments, although some states have entirely virtualized high schools and STEM curricula.



The **North Carolina** Virtual Public School is a recent example.<sup>40</sup> The new school will offer North Carolina students access to online Advanced Placement and honors courses as well as online services such as test preparation, career planning services, credit recovery, and Occupational Courses of Study to North Carolina students. Students also can take STEM-related courses at the virtual school. The online school allows all the state's students to access high-level courses taught by qualified teachers in subjects that may not be offered at local schools.

Apex Learning, a program that has existed for more than a decade, provides digital curricula for secondary education to school districts across the country.<sup>41</sup> The comprehensive and standards-based online courses cover a wide variety of subject areas, including core and advanced math and science subjects. Through Apex, for example, students in small or disadvantaged school districts can access a large suite of Advanced Placement courses to help them prepare for the rigors of postsecondary STEM study.

### **Use Informal Learning to Expand Math and Science Beyond the Classroom**

It is important to help students understand the connections of math and science to life and career opportunities. Part of this can be addressed by expanding classroom teaching strategies with hands-on math and science activities. This is the approach taken at STEM schools and early college programs, which focus on real-world problem solving in the classroom and through collaborative projects. These programs also let students participate in projects outside the classroom where they can observe how STEM professionals address issues in fields such as biology, architecture, and physics.

Also important are organized educational opportunities outside the classroom, which include after-school programs, activities at museums and science centers, and virtual learning experiences. Evidence shows that these designed yet informal settings can and do promote science learning.<sup>42</sup>

For example, the 21st Century Community Learning Centers program is a federally funded initiative

that provides academic enrichment opportunities during non-school hours for children, particularly students who attend high-poverty and low-performing schools. Some states have leveraged these funds to further STEM learning goals. For example, the California Department of Education, in partnership with corporations and private foundations, is undertaking a major project to connect after-school program providers with STEM learning opportunities at nine regional support centers. The goal of the project is to reach 1 million youth with high-quality STEM programs annually through after-school programs.<sup>43</sup>

Museums and science centers also offer programs, resources, and classes that help students and teachers expand their knowledge and skills. For example, in **Illinois**, Chicago's Museum of Science and Industry offers courses for teachers to increase their knowledge of science, improve teaching skills, and demonstrate how to use museum programs and exhibits to enhance science curricula.<sup>44</sup> Similarly, the Exploratorium in San Francisco serves both children and adults, offering hundreds of self-guided exhibits, a website with more than 25,000 pages of content, film screenings, and day camps for kids and family science investigations. These exhibits and expertise are shared with museums worldwide.<sup>45</sup>

Other high-quality virtual learning experiences are available. A notable example is the JASON Project, founded by Dr. Robert Ballard, the scientist and oceanographer who discovered the RMS Titanic and who continues to conduct numerous deep-sea scientific and archaeological expeditions.<sup>46</sup> The JASON Project connects students with scientists and researchers—virtually and physically—to provide enriching science-learning experiences. It offers science classroom curriculum, professional development for teachers, digital labs and games, after-school and out-of-school activities, and chances to observe live-action exploration of marine archeological sites.

The value of the JASON Project and similar programs is best described by Dr. Ballard who, in an interview<sup>47</sup> with the Smithsonian Institution, dis-

cussed how children responded after seeing the video of the Titanic discovery:

*They saw it and were mesmerized by this scientific adventure. . . . The kids from Nintendo, from television saw this and said 'That's what I want to do.' They reached out by writing me letters. All of these letters came in and it was a rather impressive number of letters. They all said 'I want to do what you do. How can I do what you do?' And the answer was 'Go to college and take physics for ten years'. And obviously they weren't making that connection between rigorous scientific and technical education and the fun I was having. They wanted to play but didn't know what the price was. And it turns out that they're willing to pay it.*

Governors and state educators can amplify the effectiveness of in-school programs by fully utilizing the vast network of informal learning opportunities that already exist within their state. Doing so does not necessarily require additional financial investments. Much can be gained by encouraging coordination between the formal and informal STEM providers and by building on the complementary strengths of these different institutions.

### **Enhance the Quality and Supply of STEM Teachers**

More and better-prepared math and science teachers are needed to support the STEM learning pipeline. States can work with their postsecondary systems to establish goals to produce more teachers, enhance preparation programs, and create alternative pathways to allow math and science professional to enter the teaching profession. In particular, upgrading the training of teachers before they enter service is particularly important: this helps them acquire the hands-on skills to ensure that students learn and apply math and science knowledge.

The University of North Carolina (UNC) is both enhancing teacher training and increasing STEM teacher production. In 2004, the university set a 10-year target to increase the number of teachers it produces.<sup>48</sup> For math and science teachers, the goal was to increase the number of math teachers by 236



percent and science teachers by 200 percent between 2002 and 2010. To meet these targets, the university uses both traditional and innovative approaches, such as incentives to students, lateral entry programs, mid-career opportunities, e-learning, and collaborative programs with the state's community colleges.

The university also is conducting research to assess the impact of teacher preparation routes and programs on K–12 student performance (test scores). The analysis incorporates almost 500,000 high school end-of-course test scores in mathematics, science, and language arts as well as middle school reading and mathematics test scores. It also takes into account a variety of other factors that affect student performance. This research will allow UNC to more accurately assess the quality of the public school teachers educated through its teacher preparation programs and identify areas for improvement. The ultimate aims are to not only produce more teachers but also better-prepared teachers.<sup>49</sup>

Texas's UTeach program is another successful math and science teacher preparation program.<sup>50</sup> Created in 1997 by the College of Natural Sciences and the College of Education at the University of Texas at Austin (UT Austin), it sought to address the shortage and quality of secondary mathematics, science, and computer science teachers. The program is designed for undergraduates, graduates who wish to obtain certification, and experienced teachers who want advanced degrees. Since its inception, UTeach has more than doubled the number of mathematics majors and increased by six the number of science majors certified to teach.

UTeach is being replicated across the country. Nationally, as of spring 2011, 21 universities joined UT Austin to implement UTeach programs, which collectively enrolled 4,767 students. By 2018, UTeach expects to graduate more than 8,000 teachers.

#### Establish Goals for Postsecondary Institutions to Meet STEM Job Needs

In these times of tight budgets and a slow economic recovery, states are beginning to ask that their postsecondary systems be more responsive to the workforce needs of the region. Given the high rate of STEM job growth and the difficulty businesses experience in filling STEM positions, many states are urging their colleges and universities to increase the number of degree and certificate holders who can enter STEM fields.

This issue was examined in NGA's 2011 report, *Complete to Compete: Revamping Higher Education Accountability Systems*.<sup>51</sup> The report recommended that governors include efficiency and effectiveness metrics in their postsecondary accountability systems so they can begin to answer questions such as how well the system is meeting the need for an educated workforce. The report pointed out that performance funding could be used with such metrics to spur and reward action.

Several states are working with their postsecondary systems to establish measures and set goals for degree and certificate production in STEM fields. Several, including **Indiana, Ohio, and Arkansas**

have been or are in the process of linking a portion of the higher education budget to whether individual institutions meet performance goals, such as degree completion. The funding formula in **Ohio** goes a step further:<sup>52</sup> the Ohio State Share of Instruction program rewards course completion, success in attracting and graduating at-risk students, degree attainment, and meeting participation and completion targets in STEM courses. It also gives more money to campuses that keep costs below the national average.

Career pathways are other approaches many states use to fill high-demand STEM jobs.<sup>53</sup> These typically involve a partnership among community colleges, primary and secondary schools, workforce and economic development agencies, employers, labor groups, and social service providers. Career pathways connect education and training programs to help adults quickly gain a postsecondary credential in a high-demand job field, including STEM. The programs are “mapped”—starting from the postsecondary system through degree or certificate completion—enabling students to easily understand what courses they need to obtain a specific credential degree and what degrees are necessary to advance within specific industries (see sidebar on *Oregon Career Pathways*).<sup>54</sup> Their multiple access points provide a particular benefit to working adults by allowing them to enter postsecondary education programs at the level most appropriate to their experience. Students also receive support services (e.g., academic and career counseling) to help them overcome common barriers to education attainment and employment. Many programs also link students to employment opportunities, where they gain valuable on-the-job experience while working toward a degree or credential.

## OREGON CAREER PATHWAYS

The Oregon Career Pathways initiative—launched in 2004—mirrors programs in other states to connect education and training to careers. Here is how the program is described on the Pathways website:

*“Career Pathways is a series of connected education and training programs and student support services that enable individuals to secure a job or advance in a demand industry or occupation. Career Pathways focus on easing and facilitating student transition from high school to community college; from pre-college courses to credit postsecondary programs; and from community college to university or employment.”*

*Career Pathways Initiative Goals:*

- *To increase the number of Oregonians with certificates, credentials, and degrees in demand occupations.*
- *To articulate and ease student transitions across the education continuum from high school to community college; from pre-college (ABE/GED/ESL) to credit postsecondary; and from community college to university or a job.”*

The student support services available through Pathways include career counseling and planning; internships; placement test preparation; summer institutes in reading, writing, and math to reduce remediation needs; and credits for prior experience and learning. STEM pathways include civil engineering technology, geographic information systems, and health information technology, to name a few.



“Governors have supported the creation of new STEM schools, enhanced the supply and quality of STEM teachers, improved teacher professional development and support, partnered with institutions that expand STEM learning, and asked for more from their postsecondary institutions to grow the STEM labor force.”

# 6

## MOVING FORWARD



States have done much over the past several years to advance the STEM agenda. Governors understand the value to the economy of growing the number of STEM workers and graduates. On many occasions, they have worked with businesses, the philanthropic community, and the federal government to pool the resources needed for change. They have supported the creation of new STEM schools, enhanced the supply and quality of STEM teachers, improved teacher professional development and support, partnered with institutions that expand STEM learning, and asked for more from their postsecondary institutions to grow the STEM labor force. Most importantly, governors led the effort that will significantly improve math standards throughout the states and the assessments aligned with those standards. Improved science standards soon will follow.

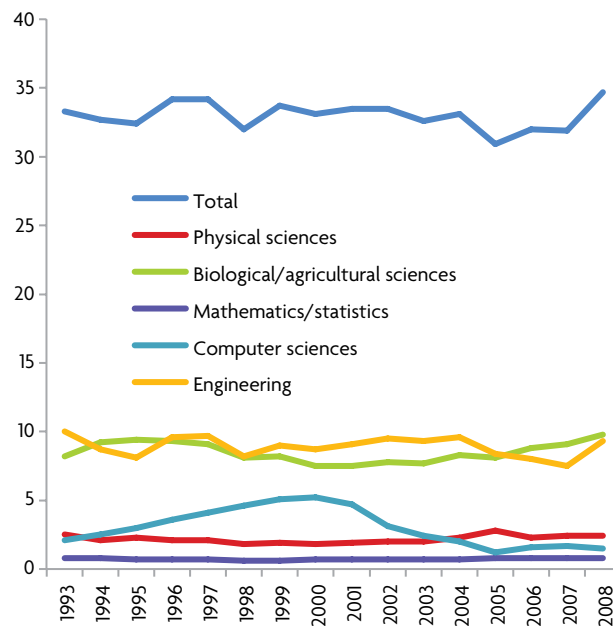
Progress is not immediate, however. For example, data from 1993–2008 show that freshman enrollment in STEM fields has gained only slightly, with an uncertain number moving to degree completion (Figure 6-1).<sup>55</sup> This suggests states cannot afford to relax their efforts.

The current fiscal situation also has made it difficult for states to make new investments or launch new programs. With regard to STEM, however, perhaps the greatest negative outcome of the economic contraction is the drop in state support for STEM-related research and development (R&D). STEM R&D helps drive the discovery of new ideas and products, and it fuels economic growth. Many governors recognize this and, in a number of states, have begun to increase R&D funding as their economies recover. However, it will take time for the levels of state R&D support to be where they were before the 2008 recession.

Still, with regard to STEM classroom investment, much can be done by more efficiently allocating resources already devoted to core educational services. The United States spends more than any other country to educate its students. The current fiscal situation presents an opportunity to bring greater efficiency to the K–12 classroom and to realign some goals (Figure 6-2).<sup>56</sup>

In a recent paper, *Restructuring Resources for High-Performing Schools*, Karen Hawley Miles and others argue that several strategies can be used to allocate more funds to quality instruction and less to activities that do not improve outcomes in K–12 education.<sup>57</sup> The authors suggest these and other strategies to improve the situation:

**Figure 6-1: Trends in Freshman STEM Enrollment, 1993–2008 (thousands)**



- Policies that dictate class size and staffing ratios should be eliminated and replaced with policies that reward and retain high-performing teachers. Although small class size can be beneficial, it is not as powerful as having a high-quality teacher in the classroom.
- States should eliminate mandated pay for longevity and education and instead tie compensation to factors such as effectiveness, student performance, and job responsibilities. Financial incentives that are designed to recruit, retain, and reward high-performing STEM teachers fall under this strategy.
- States and districts should leverage outside partners and technology. Strategies that create charter STEM schools with outside funds and build institutions to support STEM teachers reflect this approach.

A number of states also are pursuing separate initiatives to rein in postsecondary costs and pro-

vide more cost-effective options to students. These include articulation agreements among institutions, early college credit opportunities, and shifting resources to institutions that meet certain degree and efficiency targets (see Chapter 5). More will be needed to raise postsecondary productivity, however.

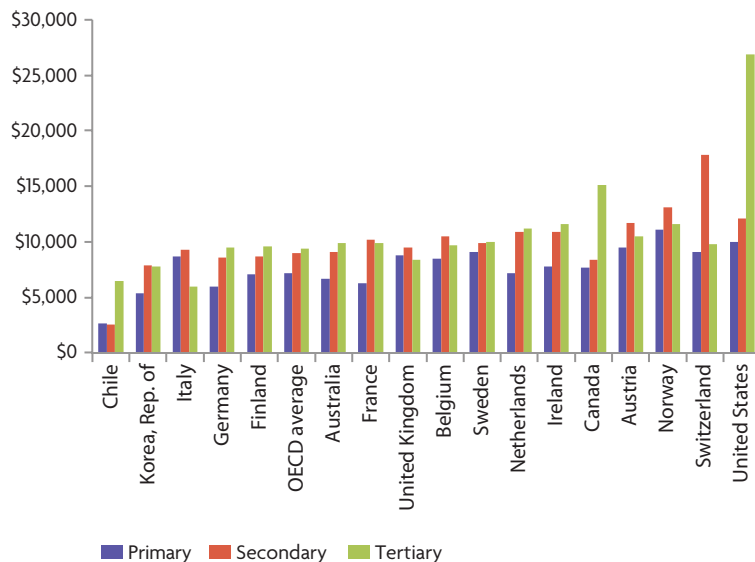
### Taking Stock

This is an opportune time for governors to take stock of their STEM initiatives. As state economies begin to recover from the recent recession, it is important to harmonize the STEM education agenda with the state’s economic agenda. Governors should ask the following questions:

- Are we producing the correct number of degrees and certificates to meet the job demands of specific industries in the region?
- Is our educational system providing a seamless trajectory from K–12 through all postsecondary institutions to allow students to efficiently and cost-effectively build the skills they need for STEM careers?
- Are we taking advantage of all the opportunities and resources available from the various public, private, and philanthropic institutions providing support to the STEM agenda?

Answering these questions requires working closely with the private sector, P–20 councils, the philanthropic community, and all components of the state’s educational system. By coordinating resources, leveraging public and private dollars, achieving greater system efficiencies, and creating partnerships, states can drive a strong STEM agenda, often without new investments. With a strategic plan to create a more STEM-capable workforce, the path to economic growth grows clearer.

**Figure 6-2: Per Capita Education Spending, 2008**  
(selected countries)







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