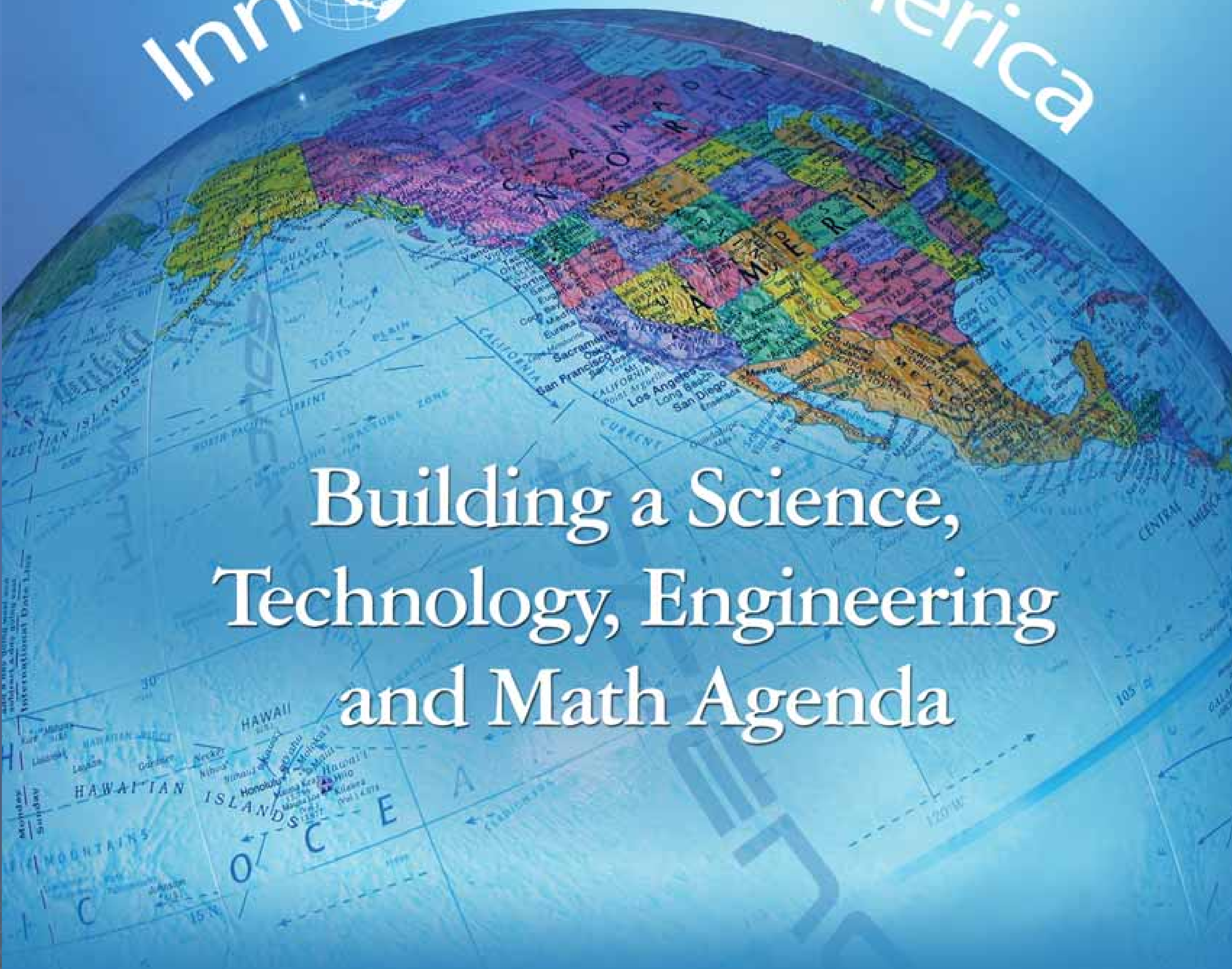
Innovation America



Building a Science, Technology, Engineering and Math Agenda

National Governors Association

Founded in 1908, the National Governors Association (NGA) is the collective voice of the nation's governors and one of Washington, D.C.'s most respected public policy organizations. Its members are the governors of the 50 states, three territories and two commonwealths. NGA provides governors and their senior staff members with services that range from representing states on Capitol Hill and before the Administration on key federal issues to developing and implementing innovative solutions to public policy challenges through the NGA Center for Best Practices. For more information, visit *www.nga.org*.

Foreword

The National Governors Association's *Innovation America* initiative focuses on strengthening our competitive position in the global economy by improving our capacity to innovate. The goal is to give governors the tools they need to encourage entrepreneurship, improve math and science education, better align post-secondary education systems with local economic growth, and develop regional innovation strategies.

To guide the *Innovation America* initiative, we have assembled a bipartisan task force of governors and members of the academic and business communities. Working with the NGA Center for Best Practices, the task force is developing innovation-based education and economic strategies. Through a variety of forums and publications we will collect and share best practice information to ensure every state — and the nation — is equipped to excel in the global economy.

Governor Janet Napolitano, Arizona
Co-Chair, Innovation America Task Force

Governor Tim Pawlenty, Minnesota
Co-Chair, Innovation America Task Force

Innovation America Task Force

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Executive Summary

In the new global economy, states need a workforce with the knowledge and skills to compete. A new workforce of problem solvers, innovators, and inventors who are self-reliant and able to think logically is one of the critical foundations that drive innovative capacity in a state. A key to developing these skills is strengthening science, technology, engineering, and math (STEM) competencies in every K–12 student.

Results from the 2003 Third International Mathematics and Science Study[1], which measures how well students acquired the mathematics and science knowledge they have encountered in school, show that U.S. eighth and 12th graders do not do well by international standards. Further, our own National Assessment of Education Progress confirms persistent math and science achievement gaps between students relative to their race/ethnicity, gender, and socioeconomic status.

Three key issues have been identified as obstacles to having a world-class STEM education system:

On a variety of STEM indicators it is clear that too many of our high school graduates are not prepared for postsecondary education and work. A recent study by ACT, Inc. has demonstrated that regardless of a student's postsecondary pathway, high school graduates need to be educated to a comparable level of readiness in reading and math proficiencies. Nearly three out of 10 first-year college students are placed immediately into remedial courses. In the workforce, employers report common applicant deficiencies in math, computer, and problem solving skills. A wide variety of studies and indicators have demonstrated that our education system continues to fail to prepare many students for the knowledge based economy.

The second obstacle is the misalignment of STEM coursework. Currently, there is a lack of alignment between K–12 postsecondary skills and work expectations; between elementary, middle, and high school requirements within the K–12 system; and between state standards and assessments and those of our international competitors. This misalignment has resulted in a system in which students participate in incoherent and irrelevant course work that does not prepare them for higher education or the workforce.

Finally, the STEM teaching workforce is under-qualified in large part because of teacher shortages caused by attrition, migration, and retirement. This shortage has led to what has been called a "revolving door" of STEM educators. Many of those who are teaching STEM classes are unprepared and/or teaching out of their subject area; thus, students in STEM classes experience a lower number of highly qualified teachers during the course of their studies. Simply increasing the number of STEM teachers through financial incentives and other recruitment strategies will not solve the problem. States must also support high quality preparation and professional development for teachers that lead to improvements in large numbers of classrooms.

Governors are playing a lead role in restoring the value of the American high school diploma. Specific to STEM, states are increasing high school graduation requirements in math and science, strengthening math and science course rigor through expansion of Advanced Placement programs and alignment of ACT assessments and coursework, and building aligned K–16 data systems that can track student progress from K–12 into the postsecondary system.

A state with an effective STEM policy agenda uses its power to set academic content standards; require state assessments, high school graduation requirements, and content-rich teacher preparation and certification standards; and develop new models to support an effective K–12 STEM classroom.

Governors should lead efforts in their states to:

1. **Align state K–12 STEM standards and assessments with postsecondary and workforce expectations for what high school graduates know and can do.**
   - States should focus on aligning standards and assessments with international benchmarks through state level participation in international assessments.
   - States should align K–12 STEM expectations with all postsecondary pathways.
   - States should align STEM expectations between elementary, middle, and high school levels to create a coherent K–12 system.
2. **Examine and increase the state's internal capacity to improve teaching and learning.**
   - States should use a process of international benchmarking to evaluate current capacity.
   - States should support the continued development of K–16 data systems to track the STEM preparation of students.
   - States should develop a communication strategy to engage the public in the urgency of improving STEM.

- States should develop or charge their P-16 councils to lead the alignment of STEM expectations throughout the education system and the workplace.
- States should support promising new models of recruiting, preparing, certifying, compensating, and evaluating teachers in STEM content areas.
- States should support extra learning opportunities to support STEM teaching and learning in the schools.

3. Identify best practices in STEM education and bring them to scale.

- States should create and expand the availability of specialized STEM schools.
- States should develop standards and assessments in technology and engineering as well as math and science.
- States should support the development of high quality STEM curricula for voluntary use by districts.
- States should develop standards for rigorous and relevant CTE programs that prepare students for STEM related occupations.

1. Introduction

The global economy has "flattened" the world in terms of skills and technology. A new workforce of problem-solvers, innovators, and inventors who are self-reliant and able to think logically is one of the critical foundations that drive innovative capacity in a state.[2] The K–12 (kindergarten through grade 12) education system, with the support of postsecondary education, the business sector, foundations, and government, must ensure that 1) all students graduate from high school with STEM competencies to become this workforce; and 2) a greater number of students graduate from high school as potential professionals in STEM fields.

Nobel Laureate Physicist and founder of the **Illinois** Math and Science Academy, Leon Lederman defines "STEM literacy" in a knowledge-based economy as the ability to adapt to and accept changes driven by new technology work with others (often across borders), to anticipate the multilevel impacts of their actions, communicate complex ideas effectively to a variety of audiences, and perhaps most importantly, find "measured yet creative solutions to problems which are today unimaginable."[3]

Building a Science, Technology, Engineering and Math Agenda recommends that governors adopt policy tools in three areas to build a comprehensive STEM policy agenda:

- aligning rigorous and relevant K–12 STEM education requirements to the expectations (inputs) of postsecondary education and the workplace
- developing statewide capacity for improved K–12 STEM teaching and learning to implement that aligned STEM education and work system
- supporting new models that focus on rigor AND relevance to ensure that every student is STEM literate upon graduation from high school and a greater number of students move onto postsecondary education and training in STEM disciplines

2. Why K–12 STEM Matters

America's economic growth in the 21st century will be driven by our nation's ability to generate ideas and translate them into innovative products and services. A strong consensus is emerging among scientific, business, and education leaders that America's ability to innovate and compete in the global marketplace is directly tied to the ability of our public schools to adequately prepare all of our children in STEM.[4]

The saturation of technology in most fields means that *all* students — not just those who plan to pursue a STEM profession — will require a solid foundation in STEM to be productive members of the workforce. When employers were asked to identify job applicants' common deficiencies, most industries reported a lack of mathematics, computer, and problem-solving skills.[5] The United States is also rapidly losing its competitive edge within the STEM fields as our students fail to keep up with their international peers.

State education systems must change their approach to STEM education to respond to this new world. Over time, American education reforms in these areas have swung back and forth between two goals.[6] At times, we have focused more on increasing basic math and science competencies in the general public through more rigorous requirements at the high school level with the hope of increasing general education attainment levels. In other periods, we have focused on creating scientists and engineers as an elite workforce. These shifting approaches were sufficient for much of the 20th century in a less than "flat" world where a high school education or less was sufficient for most good-paying jobs. For decades, the United States has been a beacon for STEM talent from around the globe.

Now, though, other nations are moving forward as the United States stands still. The *Global Competitiveness Report 2006–2007* of the World Economic Forum in its rating of national competitiveness, dropped the United States from first to sixth position, trailing Switzerland, Finland, Sweden, Denmark, and Singapore.[7]

The change in the U.S. position was based on the World Economic Forum's assessment of the United States' performance in all the diverse steps of the innovative process. Thus, for example, the United States was ranked either first or second in the world in market efficiency and technological innovation, but it was rated 27th in the quality of its public institutions (behind Chile and barely ahead of Portugal) and 40th in the areas of education and health (just behind Bosnia and Bulgaria and just ahead of Ecuador, Malaysia, and Estonia). The World Economic Forum's report said that Switzerland, Finland, and Sweden have been boosted by top-notch education systems and because they focus on technology and innovation.

A student graduating from high school in the United States today has many different life options from which to choose: entering the workforce, entering the military, entering a two-year community or technical college, and entering a four-year college. A student today also may choose among any of several pathways to the workforce. Some pathways include the aforementioned options, as shown by increasing numbers of students who are reentering college at a later point in their life. Understanding that there are many different pathways to the workforce demonstrates that a student's high school diploma must include STEM competencies so as not to close them off from any of these options either right after high school or later in life.

3. Where Do We Stand?

Andreas Schleicher of the Organization for Economic Development (OECD) summarized the importance of educational attainment and achievement to a country's well being:

> Individuals and countries that invest heavily in education benefit economically and socially from that choice. Skills are now a major factor driving economic growth and broader social outcomes, both in the world's most advanced economies and in those experiencing rapid development. The long-term effect of one additional year of education on economic output in the OECD area ranges between 3 percent and 6 percent… Together, skills and technology have flattened the world, such that all work that can be digitized, automated, and outsourced can now be done by the most effective and competitive individuals or enterprises, wherever on the globe they are located.[8]

America's public schools face challenges and opportunities in this new world given the increased demands on our education system to support a knowledge-based economy.

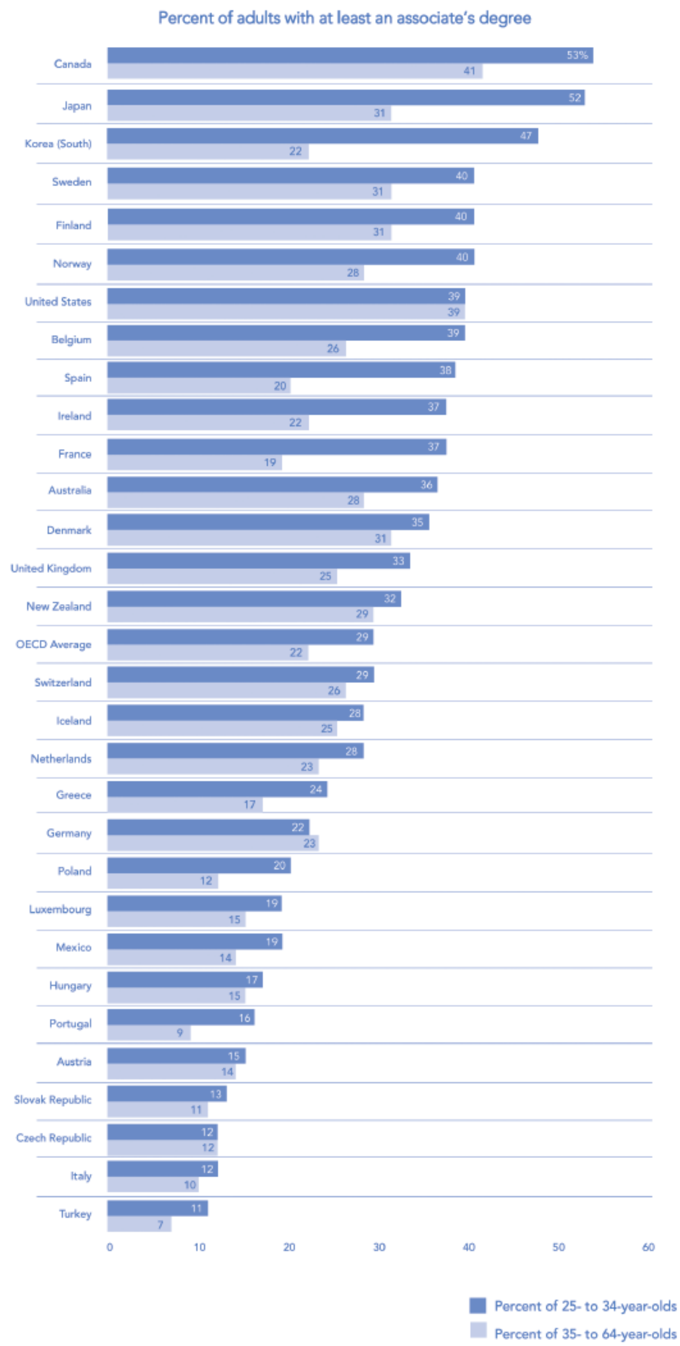
Lagging Educational Attainment of Younger U.S. Population Internationally

After World War II, the United States gained a "first-mover advantage" in educational attainment by massively increasing educational enrollments at the elementary, secondary, and postsecondary levels. Consequently, for most of the 20th century, the United States had the most educated workforce and populace in the world.

That advantage is now eroding as other nations catch up. Although the United States still ranks among the top-performing nations in the world in the percentage of older adults (ages 35 to 64) with a postsecondary associate's degree or higher, it has slipped down the list on that indicator as well as the percentage of adults with a high school diploma or equivalent. The United States now ranks seventh in the educational attainment (associate's degree or higher) of younger adults (ages 25 to 34). In other countries, the younger generation is attaining a higher level of education than the prior generation, but that is not the case in the United States.[9]

ATTAINMENT EDGE SHRINKS

Internationally, the United States still ranks among the top performers in the percentage of older adults (ages 35 to 64) with an associate's degree or higher. But it drops to seventh in the educational attainment of younger adults (ages 25 to 34). While the educational attainment of younger generations is outstripping that of their elders in most other countries, that's not true in the United States.



SOURCE: National Center for Public Policy and Higher Education, 2006

Lagging K–12 STEM Achievement of U.S. Students Internationally

The Trends International Mathematics and Science Study (TIMSS) measures how well students have acquired the mathematics and science knowledge that they have encountered in school. In TIMSS 2003[10], U.S. eighth and 12th graders did not do well by international standards, ranking below average in both grades. When one includes the fourth grade TIMSS 2003 results, where U.S. students were above average, one finds a pattern of a steady decline in the our international ranking from fourth to 12th grade.

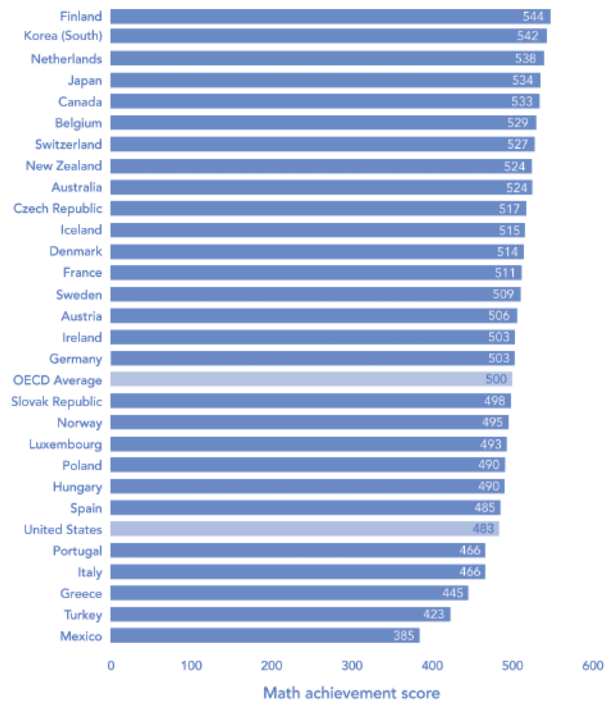
The OECD's Program for International Student Assessment (PISA) is an internationally standardized assessment of mathematics and reading literacy administered to 15-year-olds in schools in participating countries.[11] PISA takes a broader approach than TIMSS by assessing the ability of students to apply their knowledge and skills to real-world problems.

PISA was last taken by 15-year-olds in the United States in 2003. In mathematics literacy and problem-solving, U.S. students had an average score higher than just five countries out of the 30 OECD nations whose students participated in PISA. More than one-quarter of American 15-year-olds failed to demonstrate that they have acquired the most basic mathematical skills (to use direct mathematical inference, use a single representation to help explore and understand a problem; use basic algorithms, formulas, and procedures; make literal interpretations; and apply direct reasoning). Only 2 percent of American 15-year-olds performed at the highest level of mathematics, demonstrating high-level thinking, reasoning, problem-solving, and communication skills. On average, across OECD countries, the share of top performers was twice as large; in Belgium, Japan, and South Korea, the share of top performers was four times as large.

A significant percentage of U.S. students are not doing well on our own assessments. Only a third of American eighth graders can read on grade level on the National Assessment of Educational Progress (NAEP) exam, which is highly predictive of their future math and science performance.[12]

MATHEMATICALLY LAGGING

On international tests of performance, 15-year-olds in the United States, on average, trail behind their peers in many other developed nations. Out of the 30 countries taking part in the 2003 Program for International Student Assessment, or PISA, the average mathematics achievement of U.S. students was higher than that of students in only five countries.



SOURCE: Organization for Economic Cooperation and Development, 2006

Persistent STEM Achievement Gaps by Race, Gender, and Socioeconomic Status

On the 2003 PISA math assessment, the quartile of American 15-year-olds with the lowest socioeconomic status was almost four times more likely to be among the bottom quarter of performers than the quarter of most privileged students.[13] On the 2005 NAEP assessments of student achievement based on U.S. school curricula in mathematics and science, achievement gaps between groups of students based on race/ethnicity, gender, and socioeconomic status continued in both subjects and at most grade levels. Black and Hispanic students were significantly more likely than white students to score below basic on math and science at all levels.[14]

Projected demographic shifts have the potential to magnify the U.S. problem if STEM achievement gaps are not rectified. As the U.S. domestic college population stabilizes at about 30 million students from 2010 to 2025, population groups currently underrepresented in STEM fields will attend college in growing numbers. If the achievement gap persists, increasing numbers of students will be unprepared to succeed in college and in STEM degree attainment.[15]

4. Where Do We Want To Go?

We in the United States now live in a world where individual states, as well as the nation, increasingly must generate their own human capital with the STEM literacies that will allow them to succeed in the knowledge-based work place and community. STEM literacy refers to an individual's ability to apply his or her understanding of how the world works within and across four interrelated domains.

- *Scientific literacy* is the ability to use scientific knowledge (in physics, chemistry, biological sciences, and earth/space sciences) and processes to understand the natural world but to participate in decisions that affect it (in three main areas — science in life and health, science in Earth and environment, and science in technology).[16]
- *Technological literacy* in the modern world means the ability to use, manage, understand, and assess technology. Students should know how to use new technologies, understand how new technologies are developed, and have skills to analyze how new technologies affect us, our nation, and the world. Technology is the innovation, change, or modification of the natural environment to satisfy perceived human needs and wants.[17]
- *Engineering literacy* is the understanding of how technologies are developed via the engineering design process; lessons are project-based and integrate multiple subjects, making difficult concepts relevant and tangible to students and tapping into students' natural interest in problem-solving. Engineering design is the systematic and creative application of scientific and mathematic principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.[18]
- *Mathematical literacy* means the ability of students to analyze, reason, and communicate ideas effectively as they pose, formulate, solve, and interpret solutions to mathematical problems in a variety of situations.[19]

STEM literacy is a interdisciplinary area of study that *bridges* the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos. Consequently, a STEM classroom shifts students away from learning discrete bits and pieces of phenomenon and rote procedures and toward having investigating and questioning the interrelated facets of the world.[20]

One hallmark of a STEM classroom is an emphasis on design and problem-solving in "intellectually messy" learning situations that weave together the disciplines through topics such as nanotechnology, biomedical engineering, and astrobiology. Thus, for example, a STEM classroom might pose a problem and then require students to do original research inspired by a classwide inquiry project, where they must use technology to gather and analyze data, design, test, and improve upon a proposed solution, and then communicate their findings to their peers in another country. A STEM student might spend after-school time, mentored by a local engineer, building a robot that can walk up stairs.

A state with an effective STEM policy agenda uses its power to set academic content standards, required state assessments, high school graduation requirements, and content-rich teacher preparation and certification standards, and to develop new models to support an effective K–12 STEM classroom. Governors have the bully pulpit, convening authority, and the funding levers to help create an aligned and rigorous STEM education system. It is important for governors to use these tools to lead their states to adopt a STEM education agenda that supports their state's economic future.

5. Underlying Obstacles

Lack of K–12 STEM Preparation for Postsecondary Pathways

On a variety of STEM indicators, it is clear that too many American high school graduates are inadequately prepared for postsecondary education and work. A recent study of factors in postsecondary degree completion by the U.S. Department of Education found that taking college-level math as early as possible improved a student's chances of graduating from college with a degree.[21] Yet nearly three out of 10 first-year college students in the United States are placed immediately into a remedial course.[22] Fourteen states still allow students to graduate from high school with two or fewer math units and 20 states allow students to graduate with two or fewer science units. The community college system alone spends an estimated $1.4 billion annually on remediation in math for inadequately prepared freshmen.[23]

ACT, Inc., which administers the American College Test (ACT), has found a connection between a rigorous high school curriculum and students' success on college-entrance exams. One study found that taking upper-level math courses improves the achievement of all students on the math portion of the test, regardless of the student's gender, family income, or racial/ethnic background.[24] Although a greater percentage of ACT test-takers met the college-readiness benchmark on the math and science assessments in 2006 than in 2005, a majority of the test-takers still lacked college-ready skills and are likely to struggle in first-year college math and science courses.

Recent ACT data also suggest that far too few students in the United States are taking sufficiently challenging courses.[25] The ACT-recommended core curriculum in high school consists of four years of English and three years each of math (algebra and higher), science, and social studies. Students who reported taking this core curriculum earned an average composite ACT score of 22.0; students who took less than this core curriculum, on the other hand, earned an average ACT score more than two points lower — just 19.7. Of all 2006 ACT-tested high school graduates, 54 percent reported taking the ACT-recommended core curriculum; 34 percent reported taking less than the recommended core; and 12 percent did not provide information about the courses they took.[26]

ACT, Inc., has found that high school graduates need to be educated to a comparable level of readiness in reading and math proficiencies whether they plan to enter postsecondary education or workforce training programs. A recent study by Richard Murnane concluded that higher-order, complex communication and expert-thinking skills are now more important and more in demand than routine cognitive/manual and nonroutine manual skills.[27]

Outdated Notions of Core Curriculum and Less Than Rigorous Standards

The existing core curriculum, which is divided into silos and focuses on traditional math and science, is often criticized as being irrelevant and boring to today's students.[28] Studies report that the interest levels of American students, especially girls, in science begin to drop around middle school. As factors in turning off high numbers of students to STEM disciplines and professions, researchers point to the artificial separation in the curriculum of natural phenomenon into subjects, the focus on natural sciences and lack of attention to the human-made world of engineering and technology, and the disconnect of coursework from the lives of students. Students and teachers hold the misconception that technology and engineering do not include assistive and inclusive characteristics that appeal to women and minorities.[29]

In response to poor U.S. scores on international assessments, the National Science Board has recommended that stakeholders work together to develop nationwide core competencies in math and science.[30] Established competencies could help to standardize instruction across the nation and align states and localities to the international best practices of standardizing competencies and not courses.

In contrast to their school lives, STEM plays an increasingly important role in the lives of American students outside of school through the use of everyday technologies such as cell phones and computers and an the explosion of STEM-related television programs and Web sites.

Since the 1930s, U.S. educators, policymakers, and researchers have worked to better align the study of STEM with the interests of students; however, the gap between interest and the STEM experience continues to widen.[31] This gap has serious consequences not only for maintaining a STEM-literate population but also in keeping students interested in STEM professions.

Under the No Child Left Behind Act of 2002, a state's academic standards have greater weight than ever before, but independent reviews of state standards in math and science show a continuing lack of urgency for improvement. A 2005 report for the Fordham Institute by a panel of scientists gave grades of "D" or "F" to nearly half the states for their statewide academic standards for K–12 science.[32] The Fordham report came as states face the No Child

Left Behind mandate to have science standards in place by 2006 and to test in this critical subject beginning in 2007. A similar 2005 Fordham study on math standards gave states an average grade of "high D" — and just six states earn "honors" grades of A or B, three of each.

Studies of results from TIMSS 2003 suggest that the top-achieving countries have coherent, focused, and demanding mathematics curricula, whereas the U.S. curriculum is often characterized as "a mile wide and an inch deep".[33] In the top-performing countries, the number of topics that children are expected to learn at a given grade level is relatively small, permitting a thorough and deep coverage of each topic. In the United States, math topics often appear somewhat haphazardly throughout the grades — for example, relatively advanced mathematics are sometimes introduced in the earliest grades before students have had an opportunity to master basic concepts and computational skills.[34]

Underqualified STEM Teaching Force

A shortage of STEM teachers in the United States has been directly linked to the low quality of STEM education in this country.[35] The United States faces a critical shortage of highly qualified math and science teachers — projected to reach 283,000 by 2015.[36] The shortage of technology educators is even more severe, and quality requirements for such educators are minimal. The shortages of STEM teachers is particularly pronounced in low-income, urban school districts in the United States.

The STEM teaching workforce in the United States is changing. The attrition, migration, and retirement of STEM teachers is leading to what has been called a "revolving door" of educators.[37] Simply increasing the number of STEM teachers through financial incentives and other recruitment strategies will not solve the problem. States must address the systemic reasons for the attrition of STEM teachers through high-quality preparation, support, and professional development for teachers in a way that improves the situation in large numbers of classrooms.

Although there are no concrete numbers on teacher retention in STEM fields, there is consensus that it is lower than for other subjects.[38] Teachers with STEM content knowledge and/or experience are often drawn to high salaries and careers in the private sector. Differences in the retention of teachers by high-poverty urban schools vs. suburban schools further exacerbate the problem.

According to the 2003 National Center for Educational Statistics (NCES), 40 percent of U.S. middle-school physical science teachers teach subjects out of their field, 30 percent of middle-school biology teachers teach out of their field, and 20 percent of middle-school math teachers teach out of their field.[39] The percentages of U.S. high school teachers who teach out of their field range between 8 percent and 15 percent. TIMSS 1999 found that eighth grade American math and science teachers were less likely to specialize (i.e., have either an undergraduate major or master's degree) in their STEM subject areas than their counterparts in other countries.[40] A recent study found that only one-quarter of sixth through eighth grade out-of-field math teachers felt, by their own assessment, well prepared to teach a basic set of arithmetic topics.[41]

A recent study by the Illinois Education Research Council examined the lack of effect between the establishment of increased math standards and student achievement.[42] The report concluded that an increase in student enrollment in more advanced math courses was undermined by under qualified teachers. High standards must be coupled with capacity-building policies to increase student achievement.

6. Strategies for Improvement

Redesigning a state's STEM education system may require increased centralization of authority to the state while allowing appropriate local control by school districts. This approach has been used by nine of the states in the NGA High School Honor States program, which have revised and raised statewide academic standards, and the eight states that now require all students to complete a rigorous college preparatory curriculum for graduation, including in STEM areas. Centralized high school reform efforts in such states focus on aligning standards, curricula, and college expectations; creating longitudinal data systems; raising high school graduation requirements; and expanding students' access to postsecondary opportunities.

Recently, governors have taken impressive steps to improve the K–12 education systems in their states, with initiatives ranging from early childhood education to high school reform. Governors are playing a leading role in increasing high school graduation requirements in math and science, strengthening course rigor by expanding AP courses and exams and aligning ACT Assessments and coursework, building aligned K–16 (kindergarten through grade 16) data systems, and defining and beginning to implement comparable measures of high school graduation rates.

It is important for governors to use their bully pulpit, convening authority, and funding levers to lead their states to adopt a STEM education agenda that supports their state's economic future. Governors should lead efforts in their states to align STEM education outputs and expectations within different levels of their state's education system, develop statewide capacity in quality STEM teaching, data systems, and curricular supports; and look for best practice models around the country and around the world.

Three specific recommendations to governors for building a STEM education agenda are presented below.

RECOMMENDATION #1: Align state K–12 STEM standards and assessments with postsecondary and workforce expectations

The United States is falling behind other countries in graduating all students from high school with STEM competencies that ensure that the students are prepared for postsecondary education and the workforce. A key reason is misalignment in STEM areas in many states; between K–12 outputs and postsecondary and work expectations; between elementary, middle, and high school levels within the K–12 system; and between states' standards and assessments and those of our international competitors. To address these misalignment challenges, it is recommended that states consider the three policy strategies discussed below.

STRATEGY #1: **Align state STEM standards and assessments to international benchmarks through state-level participation in the Program for International Student Assessment (PISA) and/or The Trends in International Math and Science Study (TIMSS)**

TIMSS and PISA are two international assessments of that focus on assessing students' math and science achievement. A growing number of countries, as well as states and individual school districts, have chosen to participate in such assessments. They have used the assessments to improve elements of their education systems through evaluation, sharing of best practices, and capacity building. Correlations have been made between a nation's success on the international assessments and its ability to compete in the global innovation economy.[43]

All U.S. states and districts were invited to participate in the TIMSS 1995 International Benchmarks of Mathematics and Science Achievements: Profiles of World Class Performance at Fourth and Eighth Grades. Five states and one consortium of schools participated. The participating consortium — the First in the World Consortium (FiW) — is a collection of school districts located north of Chicago plus the **Illinois** Math and Science Academy, a residential school and professional development center.[44] These schools formed FiW to pursue the goal of being first in the world in math and science. After their scores on the TIMSS showed that they were indeed near the top of the rankings, the FiW used the data from the study to analyze their students' weaknesses and strengths, then used the results to develop specific policies and programs to address the identified weaknesses.[45]

PISA evaluates 15-year-old students in a number of OECD countries to assess the math and science literacy "yields" of a country's education system — or what skills and competencies students have acquired and can apply to real-world contexts at that age. States should consider benchmarking the elements of their STEM education systems to those of PISA and top-performing nations to better align the "yield" of their system with the needs of a innovative economy for a STEM literate citizenry.[46]

Finland, the top achiever in PISA 2000, creates national targets, provides support, and monitors schools but leaves it up to schools to determine how they will meet the targets. In addition, Finland has placed teacher professionalism at the center of its reform efforts, with a focus on highly competitive entry into teaching, high standards for all teachers, and an emphasis on innovation in teachers' professional practice. To date, the reactions to PISA results by participating OECD countries have varied considerably.[47] Germany, a relatively poor performer, has commissioned a multilateral study group to study its results; Denmark initiated a review of its education policies in relation to the educational policies of Finland. Mexico has established a new external educational evaluation institute that reviews its Department of Public Education, and Canada uses PISA to monitor both individual schools and its national system as a whole.

STRATEGY #2: Align K–12 STEM expectations with readiness for all postsecondary pathways to the knowledge-based economy

To implement this strategy, states should do several things. First, they should develop statewide rigorous standards for STEM disciplines that signal for K–12 and postsecondary education systems what it means for students to be ready for success in postsecondary pathways into the knowledge economy. Twenty nine states have joined Achieve's America Diploma Project (ADP) which is dedicated to making sure every high school graduate is prepared for college or work. In 2003, 13 of those states participated in Achieve's Alignment Institutes that provided tools, training, and technical assistance to help states align high school standards with the demands of college and work. This year, Achieve plans another round of alignment institutes with 4–6 additional ADP states focused around the same core set of activities.

Maine's Secondary Education Task Force recommended that the state legislature establish a core curriculum, increase high school graduation requirements, and revise the assessment system. The core curriculum is aligned to the University of Maine's statement on college readiness, which requires each graduate to have successfully completed four years of math (including Algebra II) and three years of laboratory science.

Second, states need to support the STEM-readiness standards for postsecondary success by including those readiness standards in state-required tests for graduation and public school accountability. A number of states are moving toward state-developed end-of-course tests in 11th grade Algebra II through which those standards can be more easily measured. For example, nine states (Arkansas, Indiana, Kentucky, Maryland, Massachusetts, New Jersey, Ohio, Pennsylvania, and Rhode Island) are collaborating with Achieve to develop a common end-of-course Algebra II test that can be used to track progress on shared goals and compare achievement across states. Over time, the goal is for institutions of higher education to use the end-of-course Algebra II test as a placement instrument, streamlining the connection between K–12 and postsecondary education and reducing the number of assessments students take overall. These nine states will be collaborating on aligned instructional systems to support this effort as well. **Maine** recently made national headlines when Governor John Baldacci enacted a moratorium on all localized assessment systems and adopted the College Board's Scholastic Achievement Test (SAT) as both Maine's 11th grade No Child Left Behind assessment tool and college-readiness measure. To prepare for the SAT, all 10th graders were administered the Preliminary Scholastic Achievement Test (PSAT) at state expense, and additional preparation courses were offered virtually.

Third, states need to require a college preparatory curriculum, with a strong STEM component, as the default for all of their students. At this time only 12 states (Arkansas, Delaware, Indiana, Kentucky, Michigan, Minnesota, Mississippi, New York, Ohio, Oklahoma, South Dakota, and Texas) have aligned their high school graduation requirements with college and workplace expectations, according to a 2006 study by Achieve, Inc. **Arkansas** requires all of its students to complete a rigorous, college preparatory curriculum called Smart Core. This curriculum includes four years of math (including algebra I, geometry, and algebra II) and three years of science. Arkansas uses the bulk of the NGA High School Honor States grant to build upon this foundation to align its standards to college and workplace expectations and to develop end-of-course assessments to ensure course rigor. The state is particularly eager to reduce the 10 percent of students that opt out of the Smart Core curriculum. **Delaware** created a recommended curriculum from which districts can opt out only by demonstrating the curriculum they offer is equally rigorous. **Texas** enacted a requirement that students have four years of science (including biology, chemistry, physics, and one elective, including engineering) for high school graduation.

Fourth, governors should consider supporting efforts already underway to align the basic elements of all college-ready exams (e.g., AP, ACT, SAT). Governors should carefully evaluate the advantages and disadvantages of choosing different required assessments for their particular state to ensure that the knowledge and skills being assessed are in alignment with expectations of the state's postsecondary system and private sector. **Michigan** has recently created the Michigan Merit Exam, which combines the ACT college-readiness exams, WorkKeys, and a series of subject tests developed by the state in collaboration with the state universities.

STRATEGY #3: Align STEM expectations between elementary, middle, and high school levels to help create a coherent K–12 STEM system

Experts agree that we must start in elementary school to capture and maintain student interest in STEM fields throughout middle and high school.[48] The Engineering Is Elementary: Engineering and Technology Lessons for Children curriculum, developed by the National Center for Technological Literacy (NCTL) at the Museum of Science in Boston, **Massachusetts**, has shown significant improvement in understanding of technology and engineering and has tremendous appeal among girls, English language learners, and minority students.[49]

First, states should expand access for K–12 students to high-quality preparation programs like the International Baccalaureate Diploma Program and the College Board's AP Programs that view alignment as a key factor in preparing students for success at the higher levels of their programs. The College Board produces a series of guides for pre-AP coursework that focus on vertical alignment and will release their newly revised AP science courses and tests over the next five years. A state could benchmark its pre-AP coursework to the content and skill expectations laid out in the guides. Several states are working with ACT, Inc., on aligning their curricula to prepare students for those college-readiness assessments in math, science, and other areas.

Second, states should examine how their state and local standards work in concert to achieve excellence. **New York** State's high school standards and graduation requirements are governed by the New York State Regents exams. The state sets the content and skill standards, and achievement is measured by subject-area exams. Some state-created regional entities have combined their management and resources to create region-wide pre-Regents STEM curricula so that all students within the collaboration receive the same aligned instruction.

Third, states should establish public-private partnerships to support K–12 alignment of STEM expectations. **Delaware** has been a leader in aligning the state's K–12 science standards, curricula, and assessments. In the early 1990s, then-Governor Mike Castle helped create the Delaware Science Coalition. This coalition, made up of the state, school districts, and the Delaware Foundation for Math and Science (a group of local businesses who fund the work), maintains a focus on long-term science education reform, intense professional development, and innovative curriculum development with rigorous pilot studies. In 1997, **Maryland** created an interagency task force that examined the human capital needs of high growth regional industries. The task force then backward mapped those needs to focus the STEM education system on the important areas of demand.

RECOMMENDATION #2: Examine and increase the state's capacity to implement a rigorous aligned STEM education system statewide to improve teaching and learning

While improving the rigor, relevance, and alignment of STEM education, states should also examine and increase the capacity of their education systems to graduate all students from high school with STEM competencies. Key challenges in capacity include a lack of statewide data systems to show strengths and weaknesses; a lack of public and political consensus on the urgency of improving the system; the capability of the teaching force to effectively deliver a high-quality STEM education; a disconnect between in school and out-of-school STEM education; and a lack of high-quality, state-level support entities to support the local work in specific STEM areas. To address these capacity challenges, governors should consider the seven policy strategies discussed below.

STRATEGY #1: Evaluate the current capacity in the state for effective STEM teaching and learning at the K–12 level that is preparing all students for postsecondary pathways

To implement this strategy, governors should first support their state's participation in international STEM assessments to evaluate the state's capacity and to spur change.

Illinois was among five states to participate in the TIMSS 1995 International Benchmarks of Mathematics and Science Achievements: Profiles of World Class Performance at Fourth and Eighth Grades, as well as in the TIMSS 1999 study. On the basis of the results of the TIMSS 1999 study, Illinois commissioned a report on its math and science education system that compared Illinois to the other participating states and nations.[50] That data-driven report detailed specific strengths and weaknesses of the state system and was then used to create specific state policies.[51]

Second, governors should develop comprehensive communication plans to evaluate the state's capacity for improved STEM, increase the visibility of STEM education within the community, and look for new approaches to STEM education. State P–16 (preschool to grade 16) Councils, with K–12, postsecondary, and business involvement, can be a key vehicle for this effort.

In July of 2005, a P-20 Council was established in **Arizona** under the leadership of Governor Janet Napolitano. In February 2006, TIMSS 1999 results for **Illinois** demonstrated that, in general, math teachers in the state were expected to cover more topics in less breadth than their international counterparts. The report recommended that a new curriculum add depth during the early grades by devoting more time to whole numbers, measurement, and estimating.

In response, the Illinois Business Roundtable funded the P–20 Commission at Northern Illinois University to produce a report on the status of STEM Education in Illinois. The *Illinois STEM Education Report* was issued in June of 2006 and became a major part of the Keeping Illinois Competitive initiative's linking STEM education and the state's ability to compete in the global innovative economy. The initiative lays out five major elements of increasing economic competitiveness and provides specific economic development, K–12 STEM education, and postsecondary objectives.

Governor Napolitano and the Council were presented with the report "*From Education to Work: Is Arizona Prepared?*" The report examines the expectations for high school graduates that have been defined through analysis of workforce and postsecondary demands nationally and specific to Arizona. The council, under Governor Napolitano's guidance, has worked closely with high growth and emerging industry sectors to define the educational and training requirements for key occupations within those sectors and create recommendations to align the K-12 and postsecondary education system to the needs of industry. The report then laid out specific recommendations for action to address the gaps identified in the report.

Delaware's P–16 Council, as part of the state's communication strategy around increased high school graduation requirements in math and science, held focus groups with parents and business leaders to determine their level of awareness about and support for the increased expectations for high school graduates. Focus group participants questioned whether the state and its districts and schools have the necessary capacity — in the form of highly qualified teachers, facilities, district and state support, public support, and funding — to meet the demands. In response to the concerns raised by these focus groups, Delaware has developed recommended math and English language arts curricula; it has also charged subcommittees with the task of making recommendations for providing supports to teachers and students that would help students meet higher expectations.

The **Maine** Readiness Campaign continues to move forward aggressively with its three-pronged approach of media advocacy, community engagement, and policy support. Its central message is that Maine's students need to be better prepared for college and careers. The goal is to build public support for redesigning high schools. Significant state funds are being used for the following activities:

- using television, radio, the Internet, and community events to extol the importance of graduating ready for college
- helping 50 communities take concrete actions that will ensure that their high schools are graduating students ready for college, career, and citizenship
- informing and coordinating opinion leaders to act as advocates for high school reform

Minnesota is taking a top-down and bottom-up approach using communications to support their STEM education reform. The state solicited guidance from teachers and community leaders through 12 regional forums to develop the state's STEM initiative. Minnesota has also developed resources for students and teachers such as STEM tool kits distributed to every high school and a student-oriented website.[52] The state also hopes to learn from recent grant awards allowing 20 high schools to develop model programs in digital content, technology and engineering, and math/science remediation. Thus far, the governor has convened two STEM summits and 10 regional forums to advance the state's technological and economic agenda with key business leaders.

STRATEGY #2: **Support the continued development of statewide K–16 data systems to track the STEM preparation of K–12 students for postsecondary pathways and to give educators data tools to improve instruction**

The Data Quality Campaign has identified 10 essential elements and fundamentals of a longitudinal data system. Although not specific to STEM education, collection of K–12 data can include individual student data in science, math, engineering, and technology for all students and allow the tracking of students between the P–12 (preschool to grade 12) and higher education systems. Currently, **Florida** is the only state that has a longitudinal data system with all 10 of the essential elements identified by the Data Quality Campaign.[53]

Recognizing the importance of data, **Arkansas** developed an electronic transcript to facilitate the exchange of information about students between the K–12 education system, the postsecondary education system, and employers. Pilot schools in the state began using the electronic transcript this fall, and more than 200 educators have been trained on the system. Using an electronic transcript system has the potential to yield answers to important policy questions. For example, linking the K–12 and postsecondary data systems helps state officials analyze correlations between taking high school courses and success in postsecondary education.

Since taking office in January 2006, **Virginia**'s Governor Tim Kaine has embraced high school redesign. He has pushed the state's P–16 Council to define college readiness and lead the creation of a P–16 longitudinal data system. Virginia's P–16 longitudinal data system is now in its third year of implementation and will be able to provide data on the first complete high school cohort next year. The state department of education has awarded a contract for two studies now underway: 1) a study to identify high-performing high schools and the qualities that make them successful; and 2) a study to examine academic weaknesses of recent high school graduates, focusing on graduates who are required to take remedial courses upon college entrance — an analysis in which the state's longitudinal data system will be critical.

Delaware plans to track student performance throughout the education system. The P–16 Council's post-secondary success subcommittee is building a data cube to integrate K–12 and higher education student-progress data. A new state policy allows for unique student identifiers to facilitate information exchange across the systems.

STRATEGY #3: Support promising new models of recruiting and preparing STEM teachers.

Addressing the shortage of STEM teachers in the United States is critical. As noted earlier, the United States faces a critical shortage of highly qualified math and science teachers — projected to hit 283,000 by 2015.

In 2002, the National Commission on Mathematics and Science Teaching recommended that greater visibility be given to outstanding examples of innovation, initiative, and leadership in recruiting and preparing teachers. A 2006 report of the National Academy of Sciences, *Rising Above the Gathering Storm Report: Energizing and Employing America for a Brighter Economic Future* recommended that the country increase America's talent pool by vastly improving science and mathematics teaching, and for annually recruiting 10,000 science and mathematics teachers.

One approach to addressing the shortage of STEM teachers is to rely more heavily on nontraditional and alternate teacher certification programs, which made their initial appearance in the 1980s. The number of nontraditional and alternative programs has been increasing over the years. According to the National Center for Alternate Certification, 48 states plus the District of Columbia now report having at least one alternate certification pathway at the state level.[54] It is estimated that one-third of teachers nationwide received their initial certification through an avenue other than a four-year degree. In addition to recruiting additional STEM teachers, states need to be able to retain them. Without addressing the "revolving door" of STEM educators and maintaining quality control of all certification pathways, states will have difficulty addressing this vital capacity issue.

Florida has several initiatives underway to recruit, prepare, and retain STEM teachers. The state has developed an intensive campaign to recruit and retain an increased number of middle-school science teachers. Its program, funded by the U.S. Department of Education, focuses on recruitment, alternate certification, and retention of career-changing STEM professionals. Between 2003 and 2005, Florida's program recruited 176 new teachers, 33 of whom resigned before their second year — an attrition rate that is slightly below the national average of 20 percent for new STEM teachers. Community colleges around the state are training college graduates for careers in education in new Education Preparation Institutes. The training courses, some as short as eight weeks, are meant to plug one of the nation's most urgent teacher shortages. Florida's program has drawn praise for its convenience, rigor, and ability to attract nontraditional teaching candidates. The program, combined with others, has the potential to double the state's new teacher stock in 2007–2008, infusing the state with a record number of career changers.

The **New Jersey** Alternate Route Program, a collaborative effort between the state, local districts, and local colleges, attracts not just career changers but also recent college graduates at the top of their classes. Teaching candidates participate in a year-long training program while in their first year of teaching; they also receive intense mentoring provided by the school district. The Alternate Route Program now provides the state with 42 percent of its new hires. It has been especially successful in placing graduates in urban districts that have been traditionally difficult to staff. The initial Alternate Route Program is paired with an intensive mentoring program aimed at teacher retention.

The Teach For America (TFA) program for new college graduates has been successful in attracting top STEM graduates. In 2006, nearly 20 percent of TFA's 19,000 applicants majored in a STEM field.[55] TFA also has a specially designed program to provide support and training for STEM teachers. This success demonstrates that top STEM graduates are interested in teaching. The American

Board for Certification of Teacher Excellence's (ABCTE) Passports to Teaching graduates may apply for teaching licenses in six states. ACBTE has set a goal to recruit 5,000 new math and science teachers by 2009.

Governors can encourage traditional, postsecondary-based teacher preparation programs to think differently about the way they prepare math and science teachers. A recent report highlighted several examples of postsecondary institutions and/or systems that are successfully pushing reform, often with gubernatorial support.[56]

UTeach, a partnership within the University of **Texas** at Austin's College of Natural Sciences and College of Education and the Austin Independent School District, is engaging arts and sciences faculty as leaders of reform. UTeach is working to increase the number and diversity of math, science, and computer science students entering the teaching profession in the state and assuming positions of educational leadership in their fields. UTeach has options for undergraduates to receive a bachelor's degree with a major in these fields and a teaching license in four years, college graduates who want to return for certification, and for experienced teachers who want an advanced degree. Since UTeach began 1997, it has increased more than fivefold the number of STEM teachers being certified, and most graduates are still teaching.

The Boston (**Massachusetts**) Teacher Residency Program is a 13-month teacher preparation and certification program aimed at recent college graduates, mid-life career changers, and community leaders with experience working with children. The program, a collaboration between the Boston Public Schools, the Boston Partnership for Excellence in Public Schools, U-Mass Boston, and a coalition of local foundations, has found just over half of its middle-school and high-school teaching residents are of color and about half are math and science candidates.

In **California**, Governor Arnold Schwarzenegger has marshaled significant state and private resources (including several million dollars in corporate contributions) to support the joint efforts of the state's two university systems — California State University and the University of California — to significantly increase their production of math and science teachers over the next five years. The Cal-State system, which trains 60 percent of the state's elementary and secondary teachers, pledges to double the number of credentialed math and science teachers it annually produces from 750 to 1,500 by 2010. The U-Cal system will adapt the UTeach model in creating CalTeach and pledges to quadruple its math and science teacher output from 250 to 1,000 annually by 2010.

STRATEGY #4: Support accountability measures tied to funding for all providers of STEM teacher preparation and training

States should support accountability measures tied to funding for all providers of STEM teacher preparation and consider providing financial incentives to improve results based on the impact of STEM teachers and schools on students' achievement in STEM disciplines. Such financial incentives, combined with more robust state- and district-level accountability systems, should be used to document a causal link between specific professional development measures and students' learning outcomes using quantitative measures.

Education Week's *Quality Counts 2007: From Cradle to Career, Connecting American Education From Birth to Adulthood* measures accountability for teacher education programs using three different indicators: 1) publishing pass rates and rankings of teacher education institutions; 2) evaluating the performance of graduates of teacher education programs in a classroom setting; and 3) identifying low-performing teacher education programs. The Southern Regional Education Board[56] advocates for high standards for identifying at-risk or low-performing teacher preparation programs, as well as for assistance programs to improve the quality of the programs. This organization emphasizes the importance of accountability systems to maintain quality as states create an increasing number of alternate teacher certification programs.

Alabama has made good progress in improving its STEM education system, in part because it holds teacher preparation programs accountable for the performance of their graduates. In 2004, Alabama was one of eight states that held teacher preparation programs accountable using all three standards identified by Education Week's *Quality Counts 2004* as important indicators of accountability. Alabama's accountability system holds the teacher training programs and the university or institution accountable. Alabama produces report cards for each of its teacher-training institutions, which detail the quality of the programs on a variety of measures, ranging from the comprehensiveness of students' clinical experiences to evaluations of their performance once they enter the profession.

Louisiana also holds its teacher preparation programs accountable using the three measures identified by Education Week's *Quality Counts 2004*. The state has adopted a performance score that applies to both traditional and alternative programs. Teacher preparation programs gain points by improving aspiring teachers' scores on content area tests, the number of racial minorities who complete the programs, and numbers of graduates prepared to teach in shortage areas such as math and science. Louisiana also has a four-part corrective action plan that provides financial assistance, as well as external assistance, to address the problems within the program. The strict accountability system has been important in holding accountable the state's alternate certification programs, which account for many of the new incoming STEM teachers.

STRATEGY #5: **Support market- and performance-based, differentiated compensation for STEM teachers, particularly in underserved schools**

Given the shortage of K–12 teachers in STEM fields (as well as in English as a second language/bilingual areas), states should consider adopting differentiated compensation schedules for STEM teachers, particularly in underserved schools. A majority of states offer financial incentives to address subject-area shortages, including math and science. A number of diverse approaches to teacher compensation have begun to emerge, among them plans to tie compensation to teaching performance and evaluation in all content areas, including math and science.[57] All 50 states and more than 500 districts currently have policies and regulations in place to recruit, reward, and retain teachers in all content areas that are certified by the National Board for Professional Teaching Standards.[58] **Texas** and **Florida** have recently required school districts to establish performance based compensation systems for teachers in all content areas. Florida's system links raises and bonuses for teachers to students' standardized-test scores. Several school districts, including Houston, Texas, and Denver, **Colorado**, have established their own performance-based, differentiated compensation plans. Some states and districts are adopting the Teacher Advancement Program that includes a pay-for-performance element. The federal Teacher Incentive Fund provides funding for school districts and states to create financial incentives for teachers and principals who raise student achievement and close the achievement gap in high-need schools.

New York City offers teachers in high-need content areas, including math and science, and in underserved schools a $14,600 housing subsidy. Under the terms negotiated with the city's teacher's union, the city will pay as much as $5,000 up front plus a $400 monthly housing stipend. An aggressive marketing campaign is being used to try to lure STEM teachers from other parts of the country. Although the cost to the city is relatively minor, education officials believe the program value will far outstrip its costs. Teachers can bundle the housing stipend with a state-funded tuition reimbursement program that was developed by former Governor George Pataki. The city of Chicago, **Illinois**, and the state of **California** offer housing subsidies to teachers as well.

STRATEGY #6: **Create STEM centers to support improved teaching and learning across the state and between states through work on alignment, policy, and implementation**

States can establish state-level STEM education centers to help build statewide capacity for improved STEM teaching and learning. State-initiated STEM centers can act as a nexus for innovative partnership development and to increase local capacity in areas of STEM education. Individual STEM centers may focus their work on different aspects of STEM education, such as redesigning teacher preparation and supporting alternative models for STEM education delivery. STEM centers are an important way to develop, implement, and test professional development programs for teachers. A group of STEM centers may chose to work on more common aspects such as developing new STEM curricula, benchmarking state standards, and aligning assessments.

STEM centers should have a number of common elements. First, they should focus on exploring, testing, and propagating best practices in STEM education. Second, they should focus on improving all aspects of STEM education, including increasing the visibility of "T and E". STEM centers also should focus on drawing inspiration and guidance from across a wide array of sources, including partnerships with businesses, organizations that provide extra learning opportunities, and especially strengthening communication between the different levels of education.

Texas Governor Rick Perry was instrumental in building the Texas Science, Technology, Engineering, and Math Initiative (T-STEM) as a public-private partnership that is central to the Texas High School Project. The T-STEM initiative was launched with $20 million in state funds and $55 million in private funds, and has created six STEM centers to support 35 specialized STEM academies. The STEM centers are located at universities, regional service centers, and other nonprofit organizations and support the STEM academies with professional development, teacher recruitment and retention, curriculum development all in STEM education. The STEM centers are a foundation of the statewide, best practices Texas High School Project Network to share the work of the academies and the centers with all Texas middle and high schools as well as the nation.

The Charles A. Dana Center at the University of Texas at Austin demonstrates the expertise that university mathematics and science departments can provide to improve STEM education in a state through policy assistance, research, and professional development for teachers. The Dana Center helped formulate state standards for mathematics and science and now conducts research, provides research- and standards-based curriculum materials, and assists classroom teachers and higher education faculty involved in teacher preparation (e.g., UTeach at UT-Austin). The Dana Center's professional development support includes online lesson plans aligned to the state standards and assessments, ongoing assessments, and institutes for schools and districts. The Dana Center is a T-STEM partner center as well.

North Carolina Governor Mike Easley launched the North Carolina New Schools Project in 2004 through a public-private partnership to create small high schools with an economic development theme and a focus on STEM fields. Ten schools opened in 2005, with a concentration on fields and occupations experiencing economic growth, such as health and life sciences, engineering, biotechnology, and information technology. The New Schools Project focuses on assisting district- and school-level staff in the process of opening the school and the first years of implementation. The New Schools Project will help open 75 small new high schools and 100 Learn and Earn early-college high schools (one in each county) by 2008.

The Merck Institute for Science Education (MISE) in **New Jersey** was founded in 1993 with a mandate to improve student performance and participation in science. Focusing on students in kindergarten through eighth grade, the Institute focuses on forming partnerships between educators, parents, Merck employees, and policy makers through policy work at the state level and intensive school reform at the district level. MISE is an example of an industry sponsored STEM center that has achieved the goals of uniting all education stakeholders including industry, improving STEM education at multiple levels, and sustaining long term progress. MISE has also faced the challenge of scaling up its initial efforts from four to seven school districts and offering itself as a model for other organization while not diluting itself from its initial success and quality.

STRATEGY #7: **Support STEM education outside the classroom via expanded learning opportunities that develop and maintain student interest**

Providing governors the policy tools to help their STEM education systems create early student interest in STEM and then maintain that interest is critical. Education officials and funding organizations have looked to the success of expanded learning opportunities, such as afterschool and summer learning programs to see what is possible in STEM education. These programs can complement what students learn during the school day by giving them experiences with enrichment projects and access to community resources and sparking interest in STEM-related activities.

The Smith Summer Science and Engineering Program (SSSEP) in **Massachusetts** is a precollege summer program for young women of high school age. It brings together girls from all over the country to participate in intensive, integrated STEM coursework during the summer. The Smith program, which was started in 1990, seeks out girls who are traditionally underrepresented in the STEM professions and has been successful in maintaining them in the STEM pipeline. More than 75 percent of the Smith program's graduates say the program increased their interest and confidence in STEM. States can support programs like SSSEP as part of a comprehensive approach to engaging youth in the STEM fields.

Arizona State University's Women in Science and Engineering (WISE) program attracts junior and senior high school girls to explore STEM careers and college majors during the summer on the campus of ASU. WISE is a multi-tiered program that brings together diverse populations of students, their teachers, and parents to gain first-hand experience with the latest imaging technology. Besides presenting opportunities for scientific study, experiment design, and independent research, WISE also deals positively with gender bias issues in the classroom. WISE participants learn strategies and practices for neutralizing the classroom culture that can discourage the pursuit of advanced classes in mathematics and science and consequently participation in well paying and satisfying careers in science and technology. University of Arizona's College of Medicine MEDCAMP program brings high school students together to learn about careers and college majors in medicine, nursing, pharmacy, and biomedical research during the summer.

States have also focused on increasing students' access to real world experiences in STEM through support for design and innovation competitions such as the Intel International Science and Engineering Fair, Science Olympiad, and the FIRST Robotics series. These competitions provide students with real world STEM challenges and allow students to build, tinker, design, and problem solve while learning deep content understanding of the problem at hand. Other competitions, such as the Young Naturalist Awards, offer students a more inquiry and narrative style competition that reflects upon the scientific processes that allow students to explore the natural world. Governors can look to these rigorous real world experiences to gain knowledge into alternate evaluation methods, guidance in creating relevant, interesting STEM programs, and incentives to encourage districts to participate in these activities.

RECOMMENDATION #3: Support innovative models to find best practices in STEM education and bring them to scale

Looking to find examples of best practices in STEM education, it does not take long to identify promising and emerging practices from outside the traditional education world. Although there are some emerging best practices, there are few models with a research base for governors to look to. The existing models provide potential inspiration but there is a need for innovation that is tied to assessments that help inform what works and why. This is partially due to the cross disciplinary nature of STEM that brings together education and economic development. It is also due, in part, to the plethora of successful nontraditional educational models that have begun to flourish. From charter schools to business models, States are at a time in which they can no longer afford to only look inward to existing educational structures for models of effective STEM education. Governors should look internally to find the success stories from within their state, converse with other states to identify and localize their best practices, and look internationally to see how other countries continue to show progress.

STRATEGY #1: **Establish and/or expand specialty STEM middle and high schools, including "early colleges," charter schools, district charter schools, and other models**

Although this initiative maintains an important focus on improving STEM education for all students, the innovation economy also requires an increase in the number of STEM professionals. Specialty programs and schools provide students with the opportunity to specialize in STEM-focused studies. Such programs (e.g., day or residential, charter schools, magnet schools, in-district public schools, and precollege programs) have been shown to lead to much higher rates of postsecondary attendance and graduation in STEM fields. These STEM-focused schools have been show to be effective in increasing and maintaining student interest in STEM. For example, **Arizona** is home to a recently created Bioscience High School that will educate students in a small school environment. The school is located just minutes from Arizona's bioscience hub and will connect students with tools, resources, and experts from across the country.

Many states and districts have created specialty STEM schools. Thomas Jefferson High School for Science and Technology in Northern **Virginia** is one of the first and one of the most successful. Other top schools include the **Illinois** Math and Science Academy in Aurora and the Eleanor Roosevelt High School in Greenbelt, **Maryland**. Hi-Tech High, a wired school in San Diego, **California** has received national attention. The National Consortium of Specialized Secondary Schools of Math, Science, and Technology maintains a network of specialized STEM schools around the country that shares successful curricula and professional development programs. The National Academies Foundation is supporting a number of new STEM-focused schools.

Texas Governor Rick Perry has supported the design and implementation of whole-school changes in STEM. He helped launch the T-STEM initiative, which is creating 35 specialized STEM academies that are a mix of charter schools, traditional district schools, and early-college high schools. The academies will provide a rigorous STEM curriculum to 25,000 mostly low-income and minority students, beginning in the sixth grade, and will graduate 3,500 students each year with the preparation to pursue study and careers in STEM-related fields. The T-STEM initiative is part of the Texas High School Project, which is designed to increase high school graduation and college enrollment rates in every Texas community.

States can use also policies to expand access to early-college high school models focused on STEM disciplines and careers that directly connect the high school experience to postsecondary education and training, with the goal of supporting students moving from one level of the system to the next. **New York** is one of many states that have created an early-college model. The Early College High School Initiative is a collaborative effort between a number of school systems, including in **Georgia** and **Ohio**, to build a new model of high school that includes college courses. The **Maine** state legislature passed regulations and policies to grow that state's early-college program. Nine new programs were opened in January, bringing the total number of programs to 230 across the state. Through the NGA Honor States grant funding, the Great Maine Schools Project has created a network to support this expansion with substantial ongoing technical assistance.

North Carolina Governor Mike Easley launched the Learn and Earn early-college high schools initiative in 2004 as part of the NC New Schools Project. Learn and Earn high schools allow students to graduate in five years, with a high school diploma and an associate's degree or two years of college credit. The Learn and Earn schools are expected to recruit first generation college attendees and students who perform poorly in the traditional high school. For example, the Learn and Earn site at North Carolina Central University in Durham focuses on both curriculum and work experiences in partnership with biotech companies in Research Triangle Park. The governor plans to have Learn and Earn sites serving students in all 100 counties by 2008.

STRATEGY #2: Support emerging work on standards, assessments, and curriculum on the "T" and "E" (technology and engineering) of STEM

A key strategy to increase the relevancy of STEM to students' lives is to increase student exposure to the "T" and "E" of STEM — technology and engineering. Both subjects focus on describing the human-made world in which students increasingly live in and include hands-on manipulation, design activities, and real-world problem solving experiences as core components of learning. Few states or school districts include engineering — the study of how new technologies are developed — as part of the core curriculum.

Standards for Technological Literacy, developed by the International Technology Education Association, have been adopted by a majority of states who continue to work on implementation and assessments. A collaborative effort is currently underway to develop model K–12 engineering standards that will soon be available for state adoption. States should adopt or develop technology and engineering standards, assessments, and curriculum. Teaching young students about engineering can help attract women, English language learners, and underrepresented minorities into the field as well.

The College Board is working with Strategies for Engineering Education K–16 to develop a pre-AP engineering pathway course of study that will be piloted in several districts in 2008. The course, designed to attract students from all levels, will be inclusive and provide the kind of education needed for high school students to enter an AP program in engineering. This work will create a gold standard by which states can align their engineering education coursework and continue to increase the "E" in K-12 schooling.

Massachusetts has led the way among states in developing the "T" and the "E" in STEM. It recently required that, by 2010, all students must pass a Massachusetts Comprehensive Assessment System (MCAS) in Science and Technology/Engineering to graduate. This is a result of seven years of design work in Massachusetts' Framework that functions as the state's standards in STEM disciplines in K–12. Massachusetts has supported efforts on "T" and "E" by the Museum of Science in Boston that include the creation of the National Center for Technological Literacy (NCTL). The NCTL is designed to build K–12 curricula, standards, and professional development for technology and engineering education. The NCTL has reached out to state departments of education throughout the nation to support their work in designing standards in technology and engineering disciplines. **New Hampshire**, 36 other states, and a number of countries, are at various stages of work with the Museum of Science in Boston to develop "T and E" standards.

PTC, a global software company, has partnered with **Minnesota** Governor Tim Pawlenty, the University of Minnesota and the Minnesota High-Tech Association, to design and establish the world's first statewide Global Engineering Education Program. The Program is designed to prepare teachers across the state to use computer aided design tools, and connect schools with local design and manufacturing companies, and develop business partnerships, through Minnesota's High-Tech Association. Governor Pawlenty provided support for teacher professional development so that teachers could be trained before the school year began in September. The Minnesota Department of Education became a member of the PTC-MIT Consortium, a coalition of key stakeholders across the United States, focused on addressing the national technology and engineering workforce needs.

STRATEGY #3: Support the development of high-quality STEM curricula, aligned to state standards and assessments, for voluntary use by teachers and schools

States can partner with districts, organizations, and private entities to create high-quality STEM curricula that is aligned with state STEM standards and available for voluntary use by districts. The examples below demonstrate three ways to create and market curricula that are aligned with state STEM standards.

The state of **Washington** performed a review of mathematics instructional materials in 2006. The resulting report provided school districts in the state with comprehensive and comparative information regarding the alignment of mathematics instructional materials to Washington's K–10 math standards with an eye towards international standards. Although the materials were produced by private companies, the report serves to measure the degree of conformation with core lessons, assessments, and general program design.

In 2006, **Georgia** adopted a new series of math standards. The state developed "optimal teaching sequences" that provide unit and lesson plans that are aligned to the standards and assessments. The new program, entitled Georgia Performance Standards, has produced a series of lesson plans, activities and assessments for grades K–9 mathematics and will complete grades 10–12 in mathematics prior to the spring of 2008. A comparable science series is under development and its anticipated completion date is spring of 2008.

The publication of the **Massachusetts** Science and Technology/Engineering Curriculum Frameworks motivated districts to implement curricula, assess student learning and identify gaps in teaching. Working with the National Center for Technological Literacy at the Museum of Science, Boston, districts have implemented curriculum materials in elementary, middle, and high school to satisfy the new state standards. At the high school level, the courses fulfill the freshman-year Technology/Engineering framework, provide ample opportunity to teach math skills, and prepare students for engineering offerings in subsequent grades. The partnership between the state, local districts, and an outside organization has created a rigorous, innovative curriculum that satisfies state standards.

States can also learn from and support districts supporting professional development for STEM teachers; the Chicago, **Illinois** Public Schools Math and Science Initiative is offering curricula and other support materials in all of the district's high schools and is reaching down to elementary and middle school as well.

STRATEGY #4: **Reinvigorate Career Technical Education (CTE) as an option for all students with the same postsecondary pathways readiness expectations as for non-CTE students, particularly in its training for high-wage, high-skill occupations in STEM fields**

Aligning instruction to the career cluster knowledge and skills creates a fundamentally different type of instruction where academic and technical instruction is blended and transitions among learner levels are seamless. Within the CTE community there is a two-fold goal to support this strategy to inject rigor and relevance into both existing and emerging programs.

A Career Cluster is a grouping of occupations and broad industries based on commonalities. The 16 career clusters provide an organizing tool for schools, small learning communities, academies, and magnet schools. **Arizona** conducted a comprehensive review of its CTE curriculum during which specific program standards were written and programs were updated to include reinforcement of state academic standards. As a result, in 2004, CTE graduates who took two or more CTE courses outperformed the general high school student population taking all three of Arizona's high-stakes academic tests (AIMS). The state's next step will be to look at CTE curriculum and identify the STEM standards embedded within current CTE courses and to add STEM standards where gaps exist.

Maine is integrating career and technical education (CTE) into the state's overall academic framework. As a result, Maine's CTE Centers are increasingly emphasizing numeracy and literacy. The state has also launched a P–16 demonstration project that locates two high schools, the CTE Center, a community college, and a university on the same site. **Kentucky** has developed a series of interdisciplinary CTE courses that meet academic course requirements. For example, two courses, computer aided drafting and construction are structured so that they cover all 23 state standards for geometry.

Project Lead The Way (PLTW) is a four-year program of study designed to introduce high school students to engineering. Students participate in core STEM courses build around national STEM standards. More than 80 percent of PLTW graduates are going to college, and 68 percent of the college-bound PLTW graduates have decided to major in engineering. PLTW also engages teachers in a two-week summer workshop that models project- and problem-based STEM courses. PLTW has developed a complete engineering program, including curricula, assessments, standards, and professional development. PLTW is supported by the **Indiana** Department of Education and the National Aeronautics and Space Administration and hopes to eventually reach 5,000 or 20 percent of the nation's high schools. The program offers opportunities to earn early college credit and has recently announced its community college "Pathways to Engineering" program. Governor Rod Blagojevich of **Illinois** has invested more than $1.2 million in PLTW across the state as a part of his *Opportunity Returns* regional economic development strategy.

7. Putting It Together

A number of states are beginning to implement comprehensive K–12 STEM education reforms. **Rhode Island**, **Minnesota**, **Massachusetts**, and **Indiana** have all adopted these reforms as part of the NGA Honor States Grant work.

Rhode Island is revising the sequence of its high school science instruction; aligning standards and performance-based assessments to postsecondary expectations; expanding dual enrollment options; and creating a K–16 longitudinal data system that is linked to workforce data. Governor Donald Carcieri has taken an active role in establishing the state's P–16 Council as a focal point for STEM education reform as part of the state's high school redesign efforts.

As part of its STEM initiative, Rhode Island launched a new and innovative curriculum sequence for its high school science students called Physics First. The course sequence is rearranged to begin with physics and then move to chemistry and finally biology, under the belief that this sequence more accurately builds upon prior knowledge. Six schools (representing 10 percent of the state's high schools and 15 percent of the high school students) were selected as Physics First pilot sites to undergo summer professional development for teachers. Participating teachers also receive ongoing, job-embedded professional development during the school year.

In addition, Governor Carcieri worked with legislative leaders to secure over $16 million in additional funding for STEM education, including $15 million for upgrading teacher training programs and state information systems in the K–12, postsecondary, and adult education systems, and $200,000 for the creation of a statewide science curriculum.

Minnesota is emphasizing STEM education as it strengthens high school graduation requirements and aligns those with postsecondary expectations; expands dual-enrollment options; funds assessments of early-college readiness in eighth and 10th grade; creates a higher education accountability system; creates new school-level models to strengthen the academic rigor of career technical education; funds new instructional approaches; and increases public emphasis on STEM through professional development for teachers and outreach to the public.

Governor Tim Pawlenty's efforts are focused upon supporting teachers and schools in providing new instructional approaches in STEM. Teachers in Minnesota are learning to infuse digital content into their pedagogy. Twenty Lighthouse Schools received funding to improve student achievement and STEM teaching capacity. In addition, Minnesota has developed a new induction and mentoring program for math, science, and career and technical education teachers. Other developments in Minnesota include the following:

- The state recently gave grant awards allowing 20 high schools to develop model programs in digital content, technology and engineering, and math/science remediation.
- The state solicited guidance from teachers and community leaders through 12 regional forums to develop the state's STEM initiative.
- Minnesota's efforts are bolstered by a coordinated STEM-focused communication campaign. A Web site, print collateral, and public service messages generate media attention.

Indiana is focusing its high school redesign work on STEM by seeding promising STEM redesign models; forming STEM networks and creating a K–12 STEM Resource Center; developing a statewide curriculum to train math teachers; and enacting legislation to support high school redesign. Governor Mitch Daniels has developed a bottom-up, community-driven redesign process to complement the state's Core 40 curriculum (a college preparatory sequence that requires every student to pass algebra II and either chemistry or physics). A November 2006 conference highlighted STEM and high school redesign. An estimated five new-tech high schools and four early-college high schools will open by 2007. Supporting this work are the Indiana K–12 STEM Center and the new regional and thematic networks. The K–12 STEM Center's first project is to improve the teaching of middle school algebra, a key gatekeeper for student success in high school. In addition to the NGA High School Honor States grant, Governor Daniels raised $1 million in state dollars to support redesign planning. Through this outreach, Indiana's communities are examining different models to create effective STEM high schools.

Massachusetts is focusing on STEM education in strengthening its high school standards and aligning those standards to postsecondary expectations; creating a college/work ready curriculum; developing an end of course assessment in algebra II; enacting a dropout prevention strategy; increasing AP and dual-enrollment options; and building a K–16 longitudinal data system. The Massachusetts governor's office worked in close partnership with the state board of education and the commissioner of education to implement the following:

- By 2010, all students must score above the proficient level on the math MCAS and a discipline specific science, technology/engineering MCAS.
- The state board of education revised its state standards to further promote technology and engineering standards.

- There is now a single, comprehensive list of standards, including specific scientific inquiry and math skills.
- The Commonwealth has sought input from all education stakeholders, including business, to define work readiness and align its standards to those expectations as part of the American Diploma Project.

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