StateNotes
Mathematics and Science

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Mathematics and Science Education in the States

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Introduction

The early part of the 21st century sees the United States competing in an increasingly globalized, high-tech economy that highly prizes those individuals with quality mathematics and science educations, and bestows economic and other benefits on the nations and regions in which they live and work. Nations around the world – recognizing the importance of an educated workforce for their future development, prosperity and security – are producing a growing number of college graduates with mathematics and science degrees, challenging the United States' historic lead in these fields.

Acknowledging the challenge that lies ahead, a number of groups have published reports in recent years proposing actions to address the unique – yet interrelated – demands that mathematics and science education place upon schools.[1] Proposed actions commonly include boosting the number of U.S. students graduating with college degrees in mathematics and science. Accomplishing this goal would have two beneficial effects: (1) introducing highly qualified workers into high-tech fields, thereby helping to ensure economic competitiveness; and (2) enlarging the recruiting pool of highly qualified mathematics and science teachers, which holds the promise of further improving education in these subjects.

In order to accomplish this goal in the coming years, schools must address the needs of teachers and students now. As many students as possible should be given access to a quality, academically intense secondary curriculum, a strong predictor of student completion at the postsecondary level.[2] Additionally, students must know what will be expected from them academically at the postsecondary level and be provided with opportunities to address deficiencies as early as possible. Effectively delivering this curriculum means that teachers must be recruited and properly prepared. Scholarships, loan forgiveness programs, professional development opportunities and identifying motivated individuals willing to teach in hard-to-staff schools are all tools that can help to accomplish this.

So, which actions should policymakers implement first – those that seek to better prepare students, or those that prepare and recruit teachers? The answer: both.

This report identifies the types of state policy activities most likely to positively impact teachers and students under the following categories:

Teachers:
- Recruiting new science and mathematics teachers
- Strengthening the skills of existing teachers.

Students:
- Increasing the number of students who take AP and IB science and mathematics courses
- Raising the minimum number of credits high school students need to complete in mathematics and science, and requiring students complete specific mathematics and science courses most likely to prepare them for postsecondary coursework
- Reducing the need for remediation at the postsecondary level
- Establishing programs aimed at improving achievement by low-income and minority students.

Teachers

Recruitment of Science and Mathematics Teachers

Recruiting teachers is a common challenge in many states, and recruiting quality science and mathematics teachers is an especially acute challenge. At least 31 states currently have financial incentives to address subject-area shortages – which commonly include science and mathematics – with scholarships or loan forgiveness contingent upon completion of a minimum number of years of service in the public schools as common approaches.[3]

In addition to recruiting teachers in mathematics and science, it is also important to make sure that qualified and dedicated teachers reach the students that need them most. Students attending high-poverty schools are far more likely to be taught by a teacher without proper credentials, especially in the subjects of mathematics and science. Currently, 17 states offer incentive programs designed to attract teachers to hard-to-staff schools.[4] Delaware and Illinois are representative of typical approaches.

Delaware (2004)
First preference for loans awarded through the Delaware Teacher Corps program is given to students who intend to teach middle and high school mathematics and science.[5] Participating students are provided with loans that will cover the costs of tuition at a public university in Delaware. Loans are forgiven at a rate of one year of teaching in a Delaware public middle or high school for one year of loan. Loans are renewable for up to three additional years with at least a 2.75 GPA. High school seniors must rank in the upper half of graduating class and have a combined score of 1570 on the SAT. Although the program is not based in statute, it is modeled on the Christa McAuliffe Scholarship program.[6]

Illinois (2004)

Illinois' Grow Your Own Teacher program is designed to "prepare highly skilled, committed teachers who will teach in hard-to-staff schools and hard-to-staff teaching positions and who will remain in these schools for substantial periods of time."[7] The goal of the program is to recruit 1,000 teachers by 2016, and to retain these teachers for an average of seven years, as opposed to the current rate of 2.5 years for teachers in hard-to-staff schools and in hard-to-staff teaching positions.

The initiative is designed to stimulate the development of consortia – composed of institutions of higher education with accredited teacher preparation programs, targeted schools and districts and community organizations – that will identify and recruit parents, community leaders and paraprofessionals to become certified as teachers. Hard-to-staff teaching positions are those in which data compiled by the state board indicates a multi-year pattern of substantial teacher shortage or that has been identified as a critical need by the local school board (e.g., special education, mathematics and science). The program is designed to provide support through forgivable loans for a cohort of candidates until they complete their preparation as teachers. This support includes tuition, fees and other expenses directly related to the candidates' ability to participate in the program, which may include child-care. Loans are forgiven upon completion of five years teaching in either a hard-to-staff school or in a hard-to-staff teaching area.

For more information, see *REQUEST FOR PROPOSALS: Grants for Transitional Projects under the "Grow Your Own" Teacher Education Initiative*.[8]

Strengthen the skills of existing teachers

While recruiting teachers is a necessary aspect of any state policy, strengthening the skills of existing teachers is also crucial. Approaches implemented in the states include: (1) summer institutes where teachers hone their skills by receiving specialized training and equipment; (2) master-teacher programs that similarly provide specialized training and financial incentives to participating teachers; (3) special training and support for teachers of AP and IB courses; and (4) professional development opportunities for teachers in high-needs districts that may include a combination of the above.

Alabama (2002)

The Alabama Math, Science and Technology Initiative – commonly referred to as AMSTI – is the state department of education's initiative to improve math and science teaching statewide.[9] The initiative provides three basic services: (1) professional development, (2) equipment and materials and (3) on-site support. Schools become official AMSTI Schools by sending all of their math and science teachers and administrators to two-week summer institutes for two summers where teachers receive grade and subject specific professional development. AMSTI calls for the establishment of 11 support sites across the state, called AMSTI sites, to implement the state's initiative within the 11 geographical Regional Inservice Center areas. Three AMSTI sites are currently in operation, serving 72 official AMSTI schools. AMSTI has trained approximately 1,800 teachers through its summer institutes and is currently serving 42,000 students.

Established in 1995, the Alabama Science in Motion (ASIM) program is a state-funded program that serves as the high school science component of AMSTI.[10] It provides high school teachers with research-grade equipment, inquiry-based discipline training and classroom support needed to run effective science laboratory programs.

The first evaluation of student achievement – measured by standardized test scores – found that AMSTI-school scores were higher than non-AMSTI schools in math and science on all tests, and scores in reading and writing appeared to have increased as well.[11]

Texas (2001 and 2003)

In 2001 and 2003, the Texas Legislature directed the state board of education to establish a master teacher certificate for both mathematics and science at the elementary, middle and high school levels.[12] Additionally, the state commissioner of education was directed to establish grant programs to encourage teachers to become certified as master mathematics or science teachers.[13] The policies are designed to ensure a supply of teachers with special training to work with other teachers and with students in order to improve student performance in both subjects.

Eligible teachers must have at least three years of teaching experience and complete a knowledge-based course of instruction on the science of teaching children mathematics or science that includes training in mathematics or science instruction and professional peer mentoring techniques that have been proven effective through scientific testing. These courses are to be developed by the state board in consultation with mathematics and science faculty members at institutions of higher education.

Districts may apply for funds to pay stipends of up to $5,000 to teachers who: (1) hold the appropriate master-teacher certificate, (2) teach at a high-need campus, (3) have primary responsibilities of teaching science or mathematics and serving as a teaching mentor to other teachers, and (4) satisfy any other requirements established by the commissioner.

Minnesota (2001)

Recognizing that ongoing AP/IB-approved teacher training is critical to schools' educational success, this policy directs the commissioner of education to provide support programs during the school year for teachers of AP or IB courses.[14] Support programs are to provide teachers with opportunities to share instructional ideas with other teachers. The policy authorizes the state to pay the costs of participating in the support programs, including substitute teachers and program affiliation costs.

Additionally, for 2006 and 2007, at least $500,000 each year is to be directed towards enabling teachers to attend subject-matter summer training programs and follow-up support workshops approved by the AP or IB programs, with the commissioner of education determining the payment process and the amount of the subsidy.

However, recruiting and training teachers to effectively provide rigorous mathematics and science content – be it AP, IB or state-developed curricula – is only part of the solution. State policies must also encourage more schools to offer these challenging courses, help schools cover costs for course materials and student test fees and eliminate other obstacles to successful participation for all students. The section that follows provides details on how states are overcoming such obstacles in their AP and IB programs.

Students

Increasing the number of students who take Advanced Placement and International Baccalaureate science and mathematics courses

Advanced Placement (AP) and International Baccalaureate (IB) courses consist of rigorous curricula, have the capacity to prepare students for college-level coursework, and allow them to earn college credit while still in high school, saving parents and students money – and students time – in completing postsecondary degrees.

Advanced Placement
Advanced Placement, launched in 1955 as a program to offer college-level coursework to gifted high school students, has seen an expansion of its mission in recent years to provide a challenging curriculum to a greater proportion of the high school student population. AP courses and exams are currently available in the following mathematics and science disciplines:

Biology	Calculus AB	Calculus BC	Chemistry
Computer Science A	Computer Science AB	Environmental Science	Physics B
Physics C: Electricity and Magnetism	Physics C: Mechanics	Statistics	

AP courses and exams are also available in disciplines that, while related to mathematics and science, are more commonly categorized in the social sciences rather than applied or pure sciences:

- Economics: Macro
- Economics: Micro
- Psychology

Barring state or district policies to the contrary, students may elect to complete the AP course without taking the exam, sit for the exam without taking the related course, or complete both the course and related AP exam at the end of the school year.

AP exams are graded on a 1-5 scale, with 5 being the highest possible score. Postsecondary institutions generally determine the amount of credit awarded for each AP exam score, with many universities offering credit for scores of 3 or higher. While completion of AP courses and exams does not guarantee that students will “ace” college-level content, scoring at a level of 3 or above does seem to indicate that students are among the elite in science and mathematics disciplines internationally, and that students will enter college well-prepared to tackle postsecondary material in related classes.

A 2001 report relays the results of a second administration of the Third International Mathematics and Science Study (TIMSS) Advanced Mathematics and TIMSS Physics test to a national sample of students enrolled in AP Calculus AB or BC and AP Physics B or C.[15] The authors note that “the AP Calculus students significantly outperform all students in other countries in the TIMSS 1995 assessment except for students in France” and that those who scored a 3 or higher performed even better. AP Physics students taking the TIMSS Physics test placed fourth behind their peers in Norway, Sweden and the Russian Federation, with students scoring 3 or above on the AP exam performing better than students in these countries. “[I]n the areas of Mechanics and Modern Physics, the AP Physics students performed significantly higher than the international average….”

Another study, while finding very little relationship between the number of AP *courses* a student took in high school and the student’s grades or persistence in completing a first or second year of college, found that AP *exam* scores were a very strong predictor of college success; in fact, a stronger predictor than any indicator except high school grades.[16] Further, among all the major fields students had chosen, researchers found the strongest correlation between AP exam scores and college grade-point averages among those majoring in math and the physical sciences, with the second-strongest correlation among students majoring in biological sciences. Findings from a yet-unpublished study by Philip M. Sadler at the Harvard-Smithsonian Center for Astrophysics and Robert H. Tai, assistant professor of science education at the University of Virginia, indicate that students who scored a 5 on an AP exam in biology, physics or chemistry averaged a college grade of 90 in the related college introductory course (the mean college grade for all students was 80.)

Because of the positive benefits to students completing well-designed AP programs, the 2006 report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* proposes Advanced Placement training programs as one of the four mechanisms to improve the skills of 250,000 U.S. math and science teachers (page 112 ff).[17]

Only Arkansas, however, has a comprehensive set of policies in place to support the offering of AP courses (for further information about Arkansas' AP policies and other issues related to AP courses and exams, see the ECS February 2006 policy brief, "*Advanced Placement.*")[18]

Among the important policy questions to consider is, "Are schools and districts mandated or strongly encouraged to offer AP courses in math and science?" A summary of the Arkansas policies responding to this question is provided below.

Arkansas

ARK. CODE ANN. § 6-16-1204 mandates that districts begin phasing in AP courses in the 2005-06 school year so that, effective with the 2008-09 school year, all *districts* offer at least one advanced placement course in each of the four "core areas of math, English, science, and social studies for a total of four courses." Additionally, all Arkansas *high schools*, effective with the 2008-09 school year, must "offer a minimum of four advanced placement courses by adding at least one core course each year to the list of courses available to high school students." Alternative high schools, dropout recovery programs, and high schools offering the International Baccalaureate Diploma Program, (another rigorous curriculum with end-of-course subject exams), are exempted from this provision.

International Baccalaureate

The International Baccalaureate (IB) program, administered by the International Baccalaureate Organization, was created in 1968 to allow the children of diplomats to receive easily transferable high school and college credit when traveling from nation to nation.[19] IB in fact consists of three programs, a Primary Years program for students ages 3-12, a Middle Years program for students ages 11-16, and the Diploma program for students ages 16-19. Just as with AP, IB has expanded beyond its initial mission. One or more of the three programs are now offered in 623 U.S. schools, and the Diploma program is offered in 479 American high schools.

Unlike the AP program, in which students can choose which courses and/or assessments they wish to take, students in an IB Diploma program complete a curriculum of six subject areas: (1) Language A1 (study of literature in the student's native language, including world literature); (2) Second language; (3) Individuals and societies; (4) Experimental sciences; (5) Mathematics and computer science; and (6) The arts. Students take exams in all these subject areas. In the United States, individual postsecondary institutions determine whether and how much credit will be awarded for scores on IB exams, although universities that award credit for IB assessment scores usually recognize scores of 4 or higher (out of 7).

IB has been recognized as a means of improving students' achievement in mathematics and science. Although relatively little research exists on the impact of IB completion on student high school and postsecondary success, the aforementioned report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* likewise proposes IB training programs as a mechanism to improve the skills of 250,000 U.S. math and science teachers (page 112 ff.)

Fewer state policies exist on IB than on AP, perhaps due to the fact that fewer high schools in the country offer the program. However, Arkansas stands out for its 2005 legislation, which extends to IB the comprehensive set of policies governing AP programs in the state – providing funds for IB course materials and exam fees, teacher professional development, and more.

However, if states require or incentivize advanced courses, but are not prepared at a level necessary to succeed in these courses, unresolved issues remain. The following section on high school graduation requirements suggests sequences of math and science courses most likely to prepare students for AP and IB material in 11th and 12th grades.

Raising the minimum number of credits that high school students need to complete in mathematics and science

A growing body of research is developing on the sequences of mathematics and science coursework associated with students' admission to and completion of postsecondary programs. Cliff Adelman at the U.S. Department of Education found in both his 1999 report *Answers in the Toolbox: Academic Intensity, Attendance Patterns and Bachelor's Degree Attainment*, and in the 2006 follow-up to this report, *The Toolbox Revisited: Paths to Degree Completion from High School Through College* that those students who had completed a 4-year degree took at least 2.5 Carnegie units of science *or* more than 2.0 Carnegie units of core laboratory science (biology, chemistry, and physics) and 3.75 Carnegie units in high school math, with either calculus, precalculus, or trigonometry being the highest level of high school math completed.[20]

Two recent reports by ACT – *Crisis at the Core* and *Courses Count: Preparing Students for Postsecondary Success* – reach similar conclusions.[21] In sciences, ACT's recommended course sequence includes biology, chemistry and physics. In mathematics, the gold standard is Algebra I, II, geometry, trigonometry and calculus, with 74% of students completing this sequence meeting ACT's college algebra readiness benchmark. However, similar to Adelman's findings, *Crisis at the Core* notes that any mathematics above the level of Algebra II (such as trigonometry) is more likely to prepare students for college. In fact, according to the report, only 13% of students who completed just Algebra I, II and geometry met the college algebra benchmark – the same result as students who took fewer than these three courses.

The American Diploma Project (ADP), an arm of the nonprofit organization Achieve, Inc., has brought together members of the business community and college faculty to identify the skills and knowledge students need in high school English and math to succeed after high school – regardless of whether students' plans include going directly into the workplace or to a 2- or 4-year postsecondary institution. Unlike Adelman and ACT, however, the ADP has sought to designate content-area benchmarks, rather than Carnegie units, most likely to lead students to post-high school success; though the benchmarks "reflect content typically taught in Algebra I, Algebra II and Geometry, as well as Data Analysis and Statistics."[22]

Clearly, as a group, states are moving towards requiring students to earn more units in both mathematics and science in order to earn a high school diploma. Information graphed below depicts the minimum science and mathematics units required for high school graduation through the class of 2011. The graphs do not address the requirements being implemented for differentiated diplomas in some states.

Table 1: Mathematics Requirements

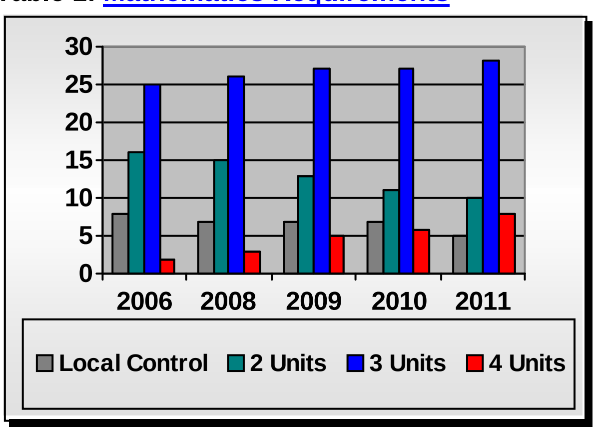
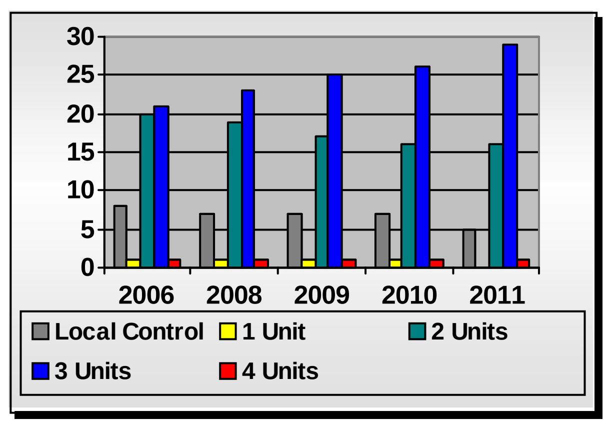


Table 2: Science Requirements



No state requires all students to complete the mathematics *and* science credits recommended by Adelman and others. That is to say, while 2 states (Alabama and South Carolina) currently require all students to complete 4 units of math and 24 states and District of Columbia require 3 units of math, these states do not specify that students complete a math sequence ending in a course above Algebra II, such as trigonometry. It is nevertheless promising that a handful of states will require all students to complete the Algebra I, II geometry sequence – Texas effective with the Class of 2008; Arkansas, Oklahoma and South Dakota in 2010; Indiana and Michigan in 2011; and Kentucky effective with the Class of 2012.

As for science, 21 states and the District of Columbia require all students to complete at least 2.5 units. In addition, ECS has identified 4 states – Georgia, Indiana, Tennessee and Virginia – that require all students to complete at least 3 units of laboratory science. This number will increase to 7 in 2010, when Arkansas, Oklahoma and South Dakota require 3 lab sciences and to 8 with Kentucky's requirement for the Class of 2012.

Still, it is not enough merely to raise the number of credits that a student must complete. The course content must also be rigorous. For more information on ensuring rigor, please see the ECS Policy Brief: *Ensuring Rigor in the High School Curriculum: What States are Doing*.[23] (For more detailed information concerning each state's graduation requirements for mathematics and science, click here. Requirements for all subject areas, both now and for future graduating classes, are available here.)

Reducing the need for remediation at the postsecondary level

Readiness assessments allow students to identify any deficiencies prior to graduation and enrollment in a postsecondary institution. Identifying areas that a student needs to improve prior to leaving high school allows them the opportunity to address them while still enrolled in high school, thus reducing the incidence of remediation at the postsecondary level, which has been shown to reduce a student's likelihood of graduating on time. Kentucky policy represents a promising state approach.

Kentucky (2000)

The Kentucky Early Mathematics Testing Program (KEMTP) utilizes a Web-site-based testing system to inform primarily high school sophomores and juniors about their skill level in mathematics compared to standards required for community college-, technical college- and university-level math courses.[24] KEMTP is aligned with the American Diploma Project (ADP) mathematics benchmarks in algebra and geometry.[25] KEMTP is also aligned with ACT mathematics benchmarks, and starting in 2006, the test will provide students with diagnostic feedback relative to new Kentucky 11th grade Core Content for Assessment standards, which will be aligned with both ADP and ACT standards.

Participation in the program is voluntary and a postsecondary education institution may not use test scores during the admissions process. Students may specify up to three participating postsecondary institutions be sent information regarding their performance, and the policy encourages the chair of the mathematics department or the academic dean of each identified institution to send a personalized letter to students either: (1) encouraging them to take additional high school mathematics courses to address identified deficiencies or (2) congratulating them for doing well on the test and encouraging continued study in mathematics.

Recent research indicates the predictive value of the KEMTP.[26] For example, 1,119 students took the KEMTP before enrolling in University of Kentucky's 2003 and 2004 spring college algebra. Of those students who scored greater than 70% on the KEMTP, 78% earned either an A, B or C, with 43% earning an A.

Establishing programs aimed at improving achievement by low-income and minority students

The U.S. population is in the midst of a profound demographic change. Census Bureau projections predict that the population will increasingly be comprised of citizens from racial or ethnic groups that are historically underrepresented in mathematics and science fields and who have historically underperformed on mathematics and science assessments.[27] Low-income students are faced with many of the disadvantages that minority students face – including under-qualified teachers and a lack of access to high-quality curriculum and lab experiences – and unsurprisingly share many of their educational outcomes. If the nation is to compete, it is important that states successfully reach out to these groups and improve their representation and performance.

Texas (2005)

The Texas Science, Technology, Engineering and Math (TSTEM) Initiative is designed to improve access to science, technology, engineering and mathematics education for low-income and minority students. The $71 million public-private partnership will establish 35 small academies that offer focused teaching and learning opportunities in STEM subject areas and five to six STEM Centers to develop high-quality teachers and schools.

Components include:

- The creation of science, technology, engineering and mathematics academies throughout the state, to improve student college readiness
- The creation of a system of college readiness indicators, including the reporting of higher education remediation rates on public high school report cards
- The development of a series of voluntary end-of-course assessments in science, mathematics – and other subjects – currently assessed by the 11th grade Texas Assessment of Knowledge and Skills (TAKS), to measure student performance; and provide for a potential alternative to the 11th grade TAKS
- The creation of a pilot financial assistance program for economically disadvantaged students taking college entrance exams, such as the SAT and ACT.

The 35 academies are expected to include a mixture of charter schools, traditional public schools and schools operated in conjunction with an institute of higher education. All academies will start the program in 6th grade and focus on the most challenged school districts and the most disadvantaged students across the state.

Mathematics, Engineering and Science Achievement (MESA)

MESA is a college-preparation program designed to increase the number of minority and female students who pursue course work, advanced study and possible careers in mathematics, engineering and science areas. Programs are based on a common co-curricular academic enrichment model that includes academic planning, community service, family involvement, academic enrichment, hands-on engineering activities, career advising, field trips, competitions and workshops.

Eight states currently participate in the MESA program, and pilot programs have been established in a number of other states. (MESA USA Web site.[28]) Initial establishment ranges from state to state. For example, MESA was established via statutes in Washington, and in administrative code in Utah – however, Utah law dictates that at-risk funds are to be used to fund the program – while in other sates it exists as a partnership between institutions of higher education, industry, state departments of education, local districts or schools.[29]

In 2000-01, MESA students received 74% of engineering baccalaureate degrees awarded to underrepresented students in California.[30] In Colorado over the last 10 years, consistently more than 90% of MESA graduates matriculated into the college of their choice, with almost 86% of these students majoring in a science or math based field.[31]

Conclusion

Improving mathematics and science education in the United States is a vitally important task, one that will only be accomplished if state policymakers and interested stakeholders work together to meet the needs of both teachers and students. The current high level of interest provides an ideal opportunity to implement policies that have the potential to ensure that the United States remains as competitive in the 21st century as it was in the 20th. The examples listed in this document are in no way meant to be exhaustive, however they do provide policymakers with an idea of a variety of approaches that have been successfully implemented in other states.

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Helping State Leaders Shape Education Policy