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THE PROGRESS OF Education Reform

# Secondary STEM Education

## "Designed by Apple in California, Assembled in China"

Etched into the back of tens of millions of iPods, these words are a highly visible symbol of the ever-increasingly interconnected global economy. Creative engineers in the United States designed a revolutionary device that went from obscurity to ubiquity in less than five years, impacting companies, culture and entire industries in its wake. Not only did these highly-skilled workers in the United States change the world of consumer electronics, their innovations led to the to the creation of lower-skilled manufacturing jobs in a developing country, a phenomenon likely to continue as nations leverage their comparative advantages to improve the economic lot of their citizens.

America's advantage has historically been its people's creativity, flexibility and entrepreneurship. But just as painters need to be proficient in technique and theory to produce great masterpieces, the next generation of Americans will likely require a solid grounding in mathematics and science for their creativity to be maximized in a world increasingly dependent on technological advances for prosperity and security.

Beyond economic concerns, ensuring quality mathematics and science education has other equally important goals. The citizenry must have a solid grounding in these subjects to make informed decisions. An aging infrastructure will require a new generation of engineers to repair bridges, roads, tunnels and subways, and a public that understands the need for funding this unglamorous and expensive work. A national energy policy requires not only creative minds to come up with alternative sources of energy and effective environmentally-friendly methods for extracting existing resources, but also a public knowledgeable enough to weigh the pros and cons of proposed courses of action.

The challenge is not to simply increase the number of students graduating with college degrees in the STEM fields; it is to lift the overall understanding of science, technology, engineering and mathematics among the rest of the population as well. As the majority of Americans do not earn a postsecondary degree, it is essential that students be given this solid grounding during the elementary and secondary years.

What's Inside


- An Evolving Reform: Mathematics and Science Graduation Requirements
- The Costs of Implementing Lab-Science Requirements
- An International Preparation Gap: Middle School Mathematics Teachers
- Mathematics and Science Teacher Attrition


Education Commission of the States

## The More Things Change: STEM Education in America

> *The economic growth of California and the nation will depend in a large part upon its ability to remain competitive with other states and with foreign nations. Maintaining our preeminence will be dependent upon persons who have a solid foundation in science.*
>
> *There is growing concern about science illiteracy within the state's adult population. A National Science Foundation Report shows that less than half of all high school juniors and one-third of high school seniors take a science course. As a result, American high school students receive only one-half to one-third the exposure to science as their counterparts in other developed countries, such as Japan, West Germany, East German and the Soviet Union. (Cal. Educ. Code § 52951)*

Were it not for the references to a divided Germany and a now-fallen Soviet Empire, the above legislation could well have been written in 2008, instead of 1987. The nations that the United States perceives itself as competing against may have changed, but Americans have long placed a high value on increasing achievement in mathematics and science.

**One of the most visible actions states have taken is raising high school graduation requirements for mathematics and science.**

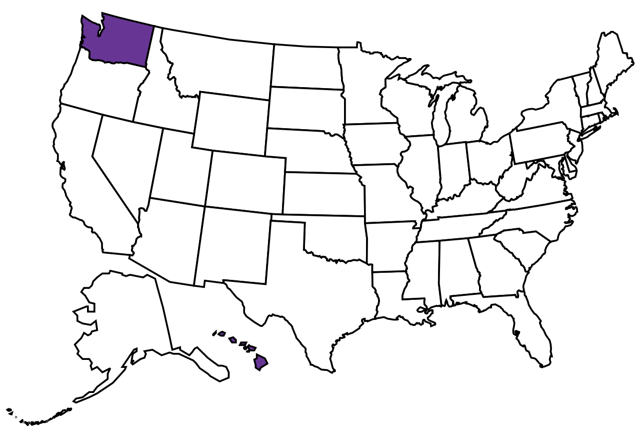
### So, Has Anything Changed in the States?

#### An Established Reform

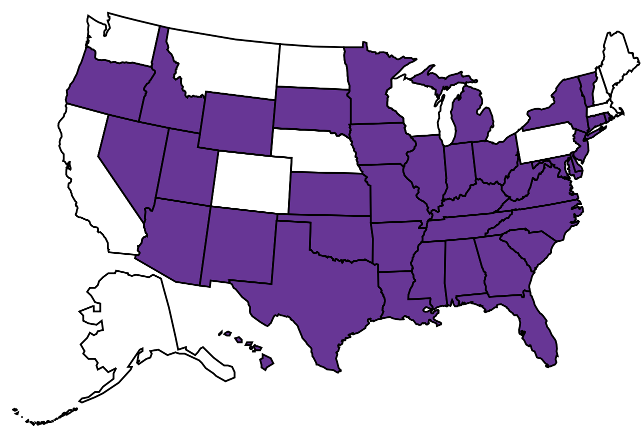
One of the most visible actions states have taken is raising high school graduation requirements for mathematics and science. The hugely influential 1983 report, *A Nation at Risk*, recommended as part of its "Five New Basics" that during high school every student take three years each of mathematics and science. Three years prior to the report, only two states' graduation requirements lined up with these recommendations in mathematics and only one state met the goal in science.[1]

Partly in response to the recommendations in the report, by 1990, 31 states had increased their graduation requirements, with 11 states requiring three units of mathematics and four states requiring three units of science. This trend continues to this day, as 39 states currently require or are phasing in requirements for students to complete at least three units of mathematics, and 36 states have or are phasing in similar requirements for science.[2]

**Three units Mathematics: 1980**

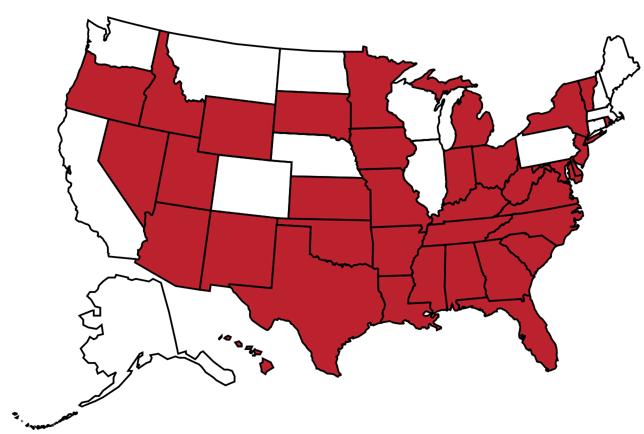


**At least three units Mathematics: by class of 2012**



**Three units Science: 1980**

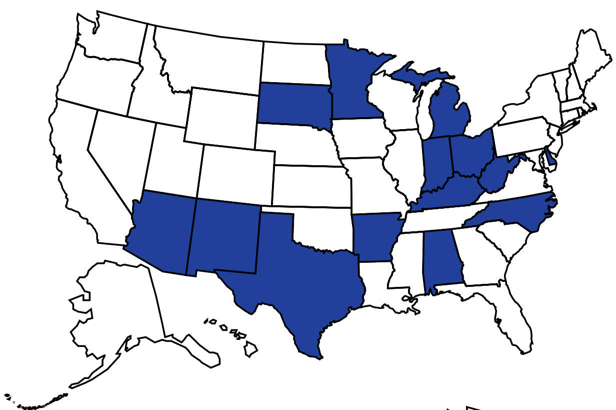
**At least three units science: by class of 2013**

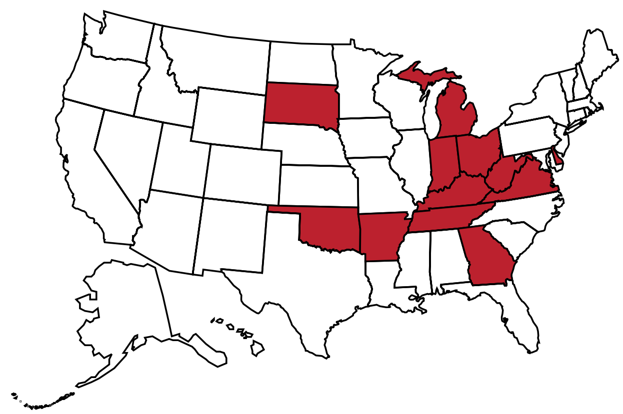


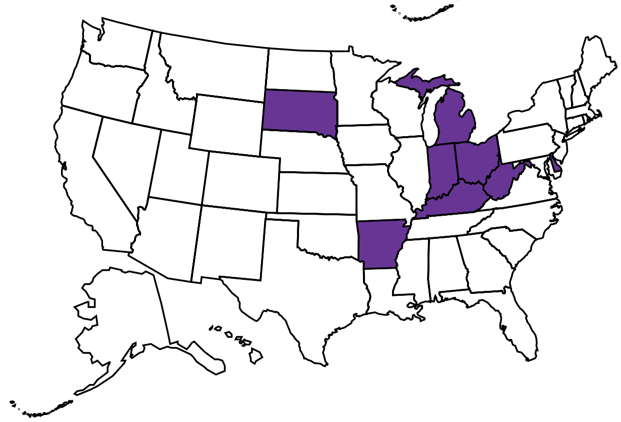
### An Emerging Reform

While raising the number of mathematics and science courses has proven popular across the states, research has found that students are better prepared for college or work if they are required to complete specific courses, rather than increased numbers of mathematics and science courses. Based on research by ACT and Clifford Adelman's 1999 *Answers in the Toolbox* report and the 2006 follow-up, *The Toolbox Revisited*, ECS considers three units of mathematics culminating in Algebra II or higher, and three years of laboratory science to be rigorous.[3] Requiring this course sequence has become more popular with states in recent years.

Currently, only Texas requires at least three units of mathematics culminating in Algebra II or higher. By 2015, that number will rise to 14 states (shown in blue). Similarly, only four states (Georgia, Tennessee, Virginia and West Virginia) currently require at least three units of laboratory science. By 2015, this number will rise to 12 (shown in red). When these requirements are fully phased in, eight states will require rigorous graduation requirements in both science and mathematics (shown in purple).







## One Caveat

Calling a course "Biology" or "Algebra I" does not ensure a common level of content from one classroom to the next. For example, 56% of the students who completed the rigorous "A-G" high school curriculum and subsequently entered the California State University system still required remediation upon postsecondary entry.[4] Policymakers should consider statewide end-of-course assessments as one means of evaluating the rigor of content in high school courses across a state.

## Additional Considerations

While establishing the expectation that all students complete challenging mathematics and science coursework is a good step, it cannot be the only step. States need to ensure that:

- Measures are in place — early in the school year — to identify students who are struggling to meet course expectations, and targeted, high-quality remediation is provided.
- Pre-service programs expect certification candidates to possess the higher-level mathematics and science content knowledge and related pedagogical skills they will need for students to be successful in rigorous courses.
- In-service teachers receive high-quality professional development to ensure their pedagogical skills and knowledge are up to date.[5]

**Two factors for policymakers to consider when implementing rigorous graduation requirements:**

- Dollars and cents: The costs of lab sciences and their alternatives (page 4).
- Laying the groundwork for high school success: How to best prepare middle school teachers (page 5).

## What Policymakers Need to Know About the Cost of Implementing Lab-Based Science Course Requirements

(Mike Griffith, Education Commission of the States, June 2008)
http://www.ecs.org/clearinghouse/74/64/7464.pdf

An increasing number of states require high school students to complete lab-based science courses to graduate from high school. To inform state policymakers of the financial impacts of these requirements, this ECS Policy Brief examines the costs associated with fitting schools with science labs and alternatives to traditional labs.

### Costs

#### Safety Equipment

Equipping an effective science lab requires that thought be given to the safety of students and teachers. Common examples of safety expenditures include:

- Goggles ($4-8)
- Eyewash station ($200-350)
- Ductless fume hood ($1,400+).

#### Facilities Costs

In addition to safety concerns, policymakers need to be aware of the capital, equipment and maintenance costs unique to science labs. This includes the proper construction of the physical lab, purchasing chemicals and proper training of staff.

### Alternatives to Traditional Labs

#### Joint Lab/Classroom Space

A shared space can serve as a traditional classroom when not being used as a lab.

- Pro: Doesn't require schools to build a stand-alone science lab.
- Con: Room will still need to meet minimum health and safety requirements.

#### Shared Lab Space

Schools can share lab space with other schools.

- Pro: Can generate revenue for host site and alleviate costs for visiting school.
- Con: Transportation-related issues for visiting students. Scheduling and coordinating difficulties.

#### Portable Labs

Such labs typically are contained in truck trailers and transported from school to school.

- Pro: Provides easy access to a lab.
- Con: Limited lab time for students, limited space, difficulty coordinating school curriculum with pre-set mobile lab program.

#### Virtual Science Labs

- Pro: Increased accessibility and decreased costs.
- Con: No conclusive evidence yet on their effectiveness compared to traditional labs.

### The Future of Science Labs

Practical considerations regarding finite financial resources, staff and space may limit traditional lab offerings, particularly in small or lower-resource schools. Virtual labs hold great promise for expanding their availability. The accessibility and lower associated costs are already attractive assets. Additionally, at least some research has found that virtual labs can be just as effective as traditional ones.[6] Rapid advances in software and hardware would seem to indicate a near-future in which virtual labs are every bit as effective as — and much more cost-efficient than — traditional labs.

## Other Resources

Coming Soon!

***Dispelling the Myths About Raising High School Graduation Requirements:***
State efforts to increase the number and rigor of courses required for a high school diploma have resulted in heated debates. This policy brief will counter the "myths" frequently raised by opponents of more rigorous high school graduation requirements — particularly mathematics and science requirements — and provide guiding principles for best policy in establishing more challenging high school curricular expectations for all students.

***Keeping America Competitive: Five Strategies to Improve Mathematics and Science Education***
After a brief overview of the importance of mathematics and science education to U.S. global competitiveness and the performance of U.S. students on recent national and international tests, this paper provides five key strategies to policymakers, university leaders, education researchers, and mathematics and science educators.
http://www.ecs.org/clearinghouse/62/19/6219.pdf

***High School-Level STEM Initiatives:***
This ECS database examines 10 areas of state action relating to STEM education at the high school level, including mentoring programs, after-school and extended learning opportunities, and targeted teacher recruitment and professional development.
www.ecs.org/hsdb-stem

***Recent State STEM Initiatives:***
This ECS *StateNote* examines recent action in 17 states that have recently undertaken statewide initiatives to improve education in the STEM subjects.
http://www.ecs.org/clearinghouse/70/72/7072.pdf

## The Preparation Gap: Teacher Education for Middle School Mathematics in Six Countries

(William Schmidt, Maria Teresa Tatto, Kiril Bankov, Sigrid Blomeke, Tenoch Cedillo, Leland Cogan, Shin Il Han, Richard Houang, Feng Jui Hsieh, Lynn Paine, Marcella Santillan and John Schwille, Center for Research in Mathematics and Science Education, Michigan State University, 2007)
http://usteds.msu.edu/MT21Report.pdf

### Background

Although elementary students in the United States appear to do well in mathematics, a drop in achievement begins in the middle school years. The "mile wide and an inch deep" curriculum common in U.S. middle schools is a primary factor behind poor achievement. This is in sharp contrast with the more rigorous curriculum found in top achieving nations on international assessments such as the Programme for International Student Assessment (PISA) and the Third International Mathematics and Science Study (TIMSS). A key step in implementing a rigorous curriculum is ensuring the proper preparation of middle school teachers.

This report seeks to identify how six nations (Taiwan, South Korea, Bulgaria, Germany, Mexico and the United States) with varying degrees of success on PISA and TIMSS prepare their future middle school teachers. Future math teachers' mathematics knowledge and course-taking — both in mathematics and pedagogy — and their beliefs about mathematics are examined.

### Selected Findings

Not only is there a curriculum gap between the United States and other nations, there is a "preparation gap" as well. Owing to their high performance on PISA and TIMSS, the authors use Korea's and Taiwan's pattern of future teacher course experiences as an international benchmark. Measured against those standards:

- Future U.S. teachers study a much lower percentage of advanced topics than their Taiwanese and Korean peers.
- Mathematics pedagogy is covered less extensively in the United States.

Differences were found among outcomes of the three major types of teacher preparation programs found within the United States. Teachers moving through:

- Secondary programs tend to have better knowledge of mathematics than their peers moving through elementary or middle school programs
- Elementary school programs tend to have a stronger preparation in pedagogy than their secondary program peers
- Middle school programs tend to get less training in pedagogy than elementary program teachers and take less advanced courses than those moving through secondary programs.

Owing to certain limitations of the study, the authors caution against applying its lessons too broadly. They point to future research in this area and plan to await the results of that study before providing specific recommendations for policymakers.

### Endnotes

[1] Melodye Bush, *Minimum High School Graduation Requirements: Standard Diplomas (Changes from 1980 to 1990)*, Education Commission of the States, July 1990. http://www.ecs.org/clearinghouse/78/20/7820.pdf

[2] ECS High School Policy Center databases on high school graduation requirements in science: http://mb2.ecs.org/reports/Report.aspx?id=900; Mathematics: http://mb2.ecs.org/reports/Report.aspx?id=902

[3] Mike Griffith, *What Policymakers Need to Know About the Cost of Implementing Lab-Based Science Course Requirements*, ECS' Policy Brief, June 2007. (See page 1 for a summary of relevant research.)

[4] E-mail correspondence with Michael Kirst, Feb. 2008.

[5] Excerpted from presentation by Jennifer Dounay, Education Commission of the States, May 2008. http://www.ecs.org/html/clearinghouse/MathandScienceGradReqts-5.13.08.ppt

[6] Marcel Satsky Kerr, Kimberly Rynearson and Marcus Kerr, "Innovative Educational Practice: Using Virtual Labs in the Secondary Classroom," *The Journal of Educators Online*, 2004. http://www.thejeo.com/Kerr%20Final.pdf

## Attrition of Public School Mathematics and Science Teachers

(Gillian Hampden-Thompson, William Herring and Gregory Kienzl, National Center for Education Statistics, May 2008)
http://nces.ed.gov/pubs2008/2008077.pdf

This report examines the trends and characteristics of public school mathematics and/or science teachers who leave the profession. The brief looks for any apparent trends in these "leavers" over a period of 16 years and compares their characteristics with those of public school teachers of subjects other than mathematics or science.

### Trends

There was no measurable trend toward either an increase or decrease in the number of mathematics/science teachers leaving the profession.

- The percentage of mathematics and science teachers leaving fluctuated from 5.1% at the beginning of the study in 1988-89, to a high of 8.2% in 2000-01 before falling to 6.4% during 2004-05.
- The percentage of teachers of other subjects leaving the profession rose from a low point of 5.2% in 1991-92 to a high of 8.7% in 2004-05.

### Characteristics

Characteristics of those leaving the profession are examined, including: teaching experience, age, base salary, sex, teaching status (full- vs. part-time), certification type and school level taught.

- Mathematics/science teachers with no full-time teaching experience were much more likely to leave than those who had at least one year of experience.
- Mathematics/science teachers earning less than $30,000 were much more likely to leave than those making more than $30,000. They were also more likely to leave than teachers of other subjects who made less than $30,000.
- Mathematics/science teachers with regular state certification were less likely to leave than those with some other form of certification. ("Other certification" includes provisional or temporary certificate and waiver or emergency certificate.)

### Reasons

Those who left teaching rated selected factors behind their decision to leave the profession. There were some similarities among the reasons that all teachers gave for leaving. For example, 34% of mathematics and science teachers cited retirement as very or extremely important in their decision to leave teaching, compared to 31% for teachers of other subjects. Differences cited for leaving include:

- Almost twice as many mathematics and science teachers cited the possibility of a better salary or benefits as their reason for leaving the profession (25% percent of mathematics/science teachers compared to 13% for other teachers).
- A higher percentage of mathematics and science teachers were also dissatisfied with teaching as a career or with a previous school or teaching assignment.

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