

# STEM Performance

► Improving policy to enhance outcomes for students – and states

## Consider the following:

- On the 2009 PISA, U.S. 15-year-olds scored below the OECD average in math, and in the middle of the pack in science. The U.S. earned the dubious honor of racking up the largest gender difference in favor of boys in science (14 points).<sup>1</sup>
- On the 2007 TIMSS, American 4th graders scored below eight countries in math, and American 8th graders lagged behind nine other countries in science.<sup>2</sup>
- The 2009 National Assessment of Educational Progress (NAEP) science results indicate declining performance as students get older. Seventy-two percent of 4th graders, 63% of 8th graders and just 60% of 12th graders scored at or above the “Basic” level.
- In an analysis comparing “advanced” U.S. 8th grade NAEP math achievers against their international peers, “[t]he only OECD countries producing a smaller percentage of advanced math students than the United States are Portugal, Greece, Turkey, and Mexico.”<sup>3</sup>

Yet, according to the Bureau of Labor Statistics (BLS), jobs in computer systems design and related services — a field dependent on high-level math and problem-solving skills — are projected to grow by 45% between 2008 and 2018. Further, more than one in four (26%) of all new jobs created in the U.S. economy during this time will be in the healthcare and social assistance industry. And occupations with the fastest growth in the coming years — such as biomedical engineers, network systems and data communications analysts, medical scientists and physician assistants, to name just a few — will call for baccalaureate, master’s and doctoral degrees in STEM (Science, Technology, Engineering, and Mathematics) fields.<sup>4</sup> Students across the states simply must strengthen their skills in math and science.

### What’s Inside

- Recent research with implications for state-level STEM policy
- State efforts to advance the “Silent T” and “E” in STEM education
- Approaches to move a STEM agenda forward in tough economic times

This issue of *The Progress of Education Reform* identifies promising and research-based approaches for enhancing student interest and achievement in STEM disciplines, including approaches that come with a smaller state-budget price tag.



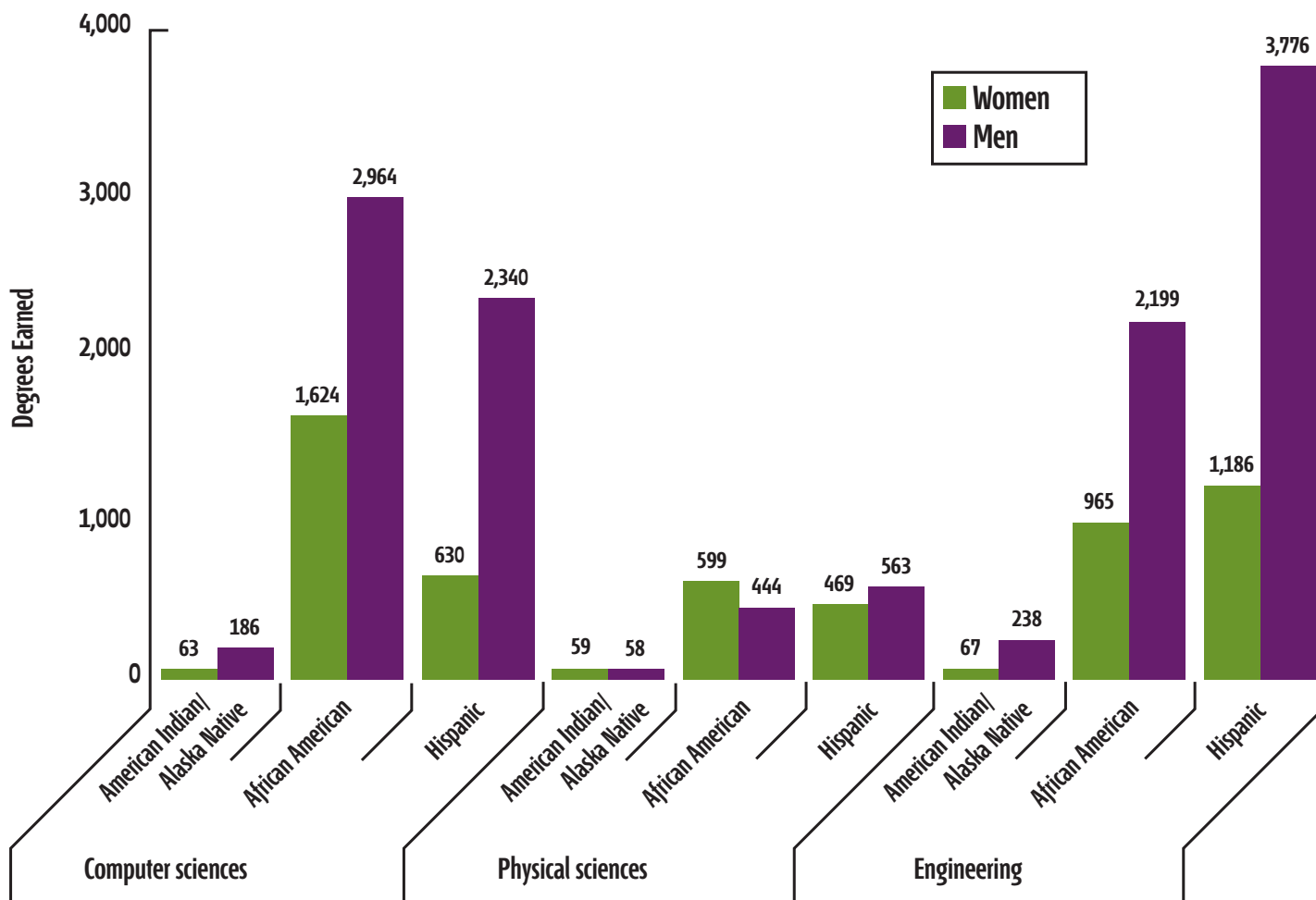
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FEBRUARY  
Vol. 12, No. 1

THE PROGRESS OF  
Education Reform



Education Commission  
of the States

## Bachelor's Degrees Earned by Underrepresented Racial-Ethnic Groups in Selected STEM Fields, by Gender, 2007



Note: Racial-ethnic groups include U.S. citizens and permanent residents only. Data based on degree-granting institutions eligible to participate in Title IV federal financial aid programs.

Data: National Science Foundation, Division of Science Resources Statistics, 2009, *Women, minorities, and persons with disabilities in science and engineering: 2009* (NSF 09-305) (Arlington, VA), Table C-14.

As published in: Catherine Hill, Ph.D. Christianne Corbett and Andresse St. Rose, Ed.D., *Why So Few? Women in Science, Technology, Engineering, and Mathematics* (Washington, D.C., AAUW, 2010) p.11.

### What does the research say?

In 2005, the landmark National Academies report *Rising Above the Gathering Storm* documented America's need to build upon its STEM investments — both in terms of financial investments in STEM innovation and human capital — to maintain its status as a world leader in innovation. In 2010, *Rising Above the Gathering Storm Revisited: Rapidly Approaching Category 5* was published, and as the title suggests, the situation has deteriorated since 2005: “So where does America stand relative to its position of five years ago when the *Gathering Storm* report was prepared? The unanimous view of the committee members participating in the preparation of this report is that our nation's outlook has worsened. While progress has been made in certain areas ... the latitude to fix the problems being confronted has been severely diminished by the growth of the national debt over this period from \$8 trillion to \$13 trillion. Further, in spite of sometimes heroic efforts and occasional very bright spots, our overall public school system ... has shown little sign of improvement, particularly in mathematics and science.”<sup>5</sup>

While data suggests that Asians, Caucasians and overseas talent comprise a large proportion of America's STEM workforce, recent research points to state policies with the potential to greatly enhance the pool of Latinos and African Americans holding a STEM credential.

One study analyzed data related to the Florida Class of 1997's high school coursetaking, college entry and college completion. The researchers found that while students who took Calculus, Chemistry II or Physics II in high school were substantially more likely to earn a bachelor's degree in a STEM discipline, Hispanic and Black students were grossly underrepresented in these courses. In fact, of the 18,701 Black students and 13,999 Hispanic students in this analysis, only **24 Black** and **24 Hispanic** students took Chemistry II or Physics II. When Black students took these rigorous courses, they were just as likely as their White peers to complete a STEM degree, and Hispanic students taking these courses actually significantly outpaced their White peers in STEM degree attainment.

However, women taking advanced high school courses are less likely to complete STEM degrees. Although female high school students were very well-represented in advanced math and science courses in the Florida study, and were 6.9% more likely than males to graduate from a Florida public four-year university, just 9.6% of females completed their baccalaureate in a STEM field, as opposed to 21.3% of the males. The authors propose that "university course-taking is a likely drop-off point off STEM pathways for women with high-level course-taking in high school."<sup>6</sup>

Please contact the author of this issue of *The Progress of Education Reform* for additional research with implications for improving STEM engagement and achievement at the K-12 level, and postsecondary STEM degree completion, particularly among women and traditionally underrepresented minorities.

"[H]igh school is a primary point for Black and Hispanic students to drop off STEM pathways because they do not take high-level courses at the same rate as their peers. ... it is critically important that schools find ways to offer opportunities for all students to enroll in the highest level courses in mathematics and science, for if they do, students taking these courses are more likely to persist in the STEM pathway regardless of race or ethnicity."

-Will Tyson, et al, *Journal of Education for Students Placed at Risk*

## How can my state advance STEM with no additional state funds?

In this tough fiscal environment, creating a new program from scratch may seem unrealistic. Yet there are programs that create cost efficiencies and/or embrace public/private partnerships to bring high-quality STEM educational opportunities to K-12 students. Below are just a few approaches.

### *The ACE Mentor Program*

ACE (an acronym for "architecture, construction and engineering") is a not-for-profit organization that connects professionals in these fields with high school students. It helps establish an ACE affiliate in a local community, pairing one or more teams of 15-25 students with an industry mentor to develop a mock design project after school over the course of the school year. Teams typically meet for 15 sessions, either at the school or in a business office. At the end of the year, teams "present their designs to other teams, their families, teachers, prospective mentors and the affiliate administrators" at a final presentation night. The ACE Mentor Program also awards scholarships to some participating students.<sup>7</sup>

According to a 2010 survey, "Female ACE ... participants enter college engineering programs at double the national rate of their non-ACE counterparts (29% versus 15%, respectively)" and "Nearly four times more Hispanic ACE alumni enter civil, mechanical and electrical engineering programs than their non-ACE counterparts", while "nearly three times more African American ACE alumni enter those fields than their non-ACE counterparts."<sup>8</sup> Clearly, the program has potential for increasing the numbers of female and minority STEM degree-holders.

### *Maryland Digital Library*

Established through 2009 legislation, the MDK12 Digital Library Project offers the opportunity for schools statewide to access high-quality digital content. The aim of the project is "to form a statewide purchasing consortium to ensure cost-effective access to appropriate electronic resources for all students."<sup>9</sup>

One of the resources available through the library is a database that serves as a one-stop secondary-level science resource, addressing such diverse areas as earth and life science, space, technology, math, and science history and biography. In fact, legislators had STEM in mind when they created the library. One of the stated purposes of the MDK12 Digital Library is to "Support effective teaching and learning by connecting digital content with the Maryland content standards, workforce development, and science, technology, engineering, and mathematics initiatives."<sup>10</sup>

### *STEMnet Teachers Hub*

Developed with \$2 million in Race to the Top funds and over \$300,000 contributed largely by private corporations, the STEMnet Teachers Hub will be launched this school year to provide STEM teachers across Maryland with opportunities to expand their instructional effectiveness. In the first phase of the project, three resources aligned with the Common Core Standards will be made available:

1. *The STEM Resource Clearinghouse*: Will offer online “STEM curriculum materials, lesson plans, webinars, tutorials, classroom-ready experiments, professional development and more.”
2. *Networking*: Teachers will be able to connect with fellow practitioners from the elementary through college and postgraduate levels, as well as with STEM industry professionals “to share knowledge and resources.”
3. *“STEM Specialists in the Classroom”*: Teachers will be able to tap “an impressive roster of STEM practitioners from federal agencies, industry and higher education to visit their classrooms and inspire and inform their students about real-world STEM work.”

Additional resources will become available in later phases of the project. The STEMnet Teachers Hub was designed based on market research with STEM educators across Maryland, who identified their areas of greatest need. These first three resources are aligned with the greatest needs identified by these teachers in focus groups and an online survey.<sup>11</sup>

## The Silent “T” and “E” in STEM Education

Many “STEM” education efforts often address only math and science. And, as pointed out in an article in *Today’s Engineer*, a 2009 report by the National Academy of Engineering and the National Research Council’s Center for Education found that “in practice the T — technology — often relates to computer technology, not technology education.”<sup>12</sup>

Yet the 2009 report argues that “The presence of engineering in K-12 classrooms is an important phenomenon, not because of the number of students impacted, which is still small relative to other school subjects, but because of the implications of engineering education for the future of [STEM] education more broadly. Specifically, ... K-12 engineering education may improve student learning and achievement in science and mathematics; increase awareness of engineering and the work of engineers; boost youth interest in pursuing engineering as a career; and increase the technological literacy of all students. The committee believes engineering education may even act as a catalyst for a more interconnected and effective K-12 STEM education system in the United States.”

Admittedly, some argue that the development of model K-12 engineering standards is not feasible or desirable.<sup>13</sup> Nonetheless, some states are making efforts to provide students — particularly in the late elementary and secondary grades — with meaningful opportunities to engage in engineering and pre-engineering learning experiences, and are establishing technology education programs informed by the Standards for Technological Literacy, developed by the International Technology Education Association.

The following are just a sampling of state approaches. Contact the author of this issue of *The Progress of Education Reform* for additional examples.

### *Problem-based, applied learning:*

Hawaii legislation creates the “Fostering Inspiration and Relevance through Science and Technology” (FIRST) Pre-Academy program for students in grades 4-8. By providing problem-based, applied learning experiences, the program aims to engage and motivate students in STEM.<sup>14</sup>

Another Hawaii effort is a robotics and problem-based, applied learning program administered by the University of Hawaii college of engineering. The program is intended to expand and strengthen STEM activities by working with established programs, including:

- ▶ **NASA Explorer Schools**
- ▶ **FIRST Robotics, Lego League and VEX challenges** or competitions
- ▶ **Botball educational robotics** programs
- ▶ **Underwater robotics challenges.**<sup>15</sup>

Engineering programs may be difficult to implement in resource-poor schools, so financial support can prove essential to creating and maintaining high-quality offerings. Kentucky policy offers a matching-grant program to help districts implement an energy technology engineering career track program in middle and high schools. Eligibility hinges on local implementation of several elements of a highly successful engineering education model — Project Lead the Way.<sup>16</sup> (See the “Resources” sidebar for more about the Project Lead the Way program.)

“The inadequacies of our system of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine.”

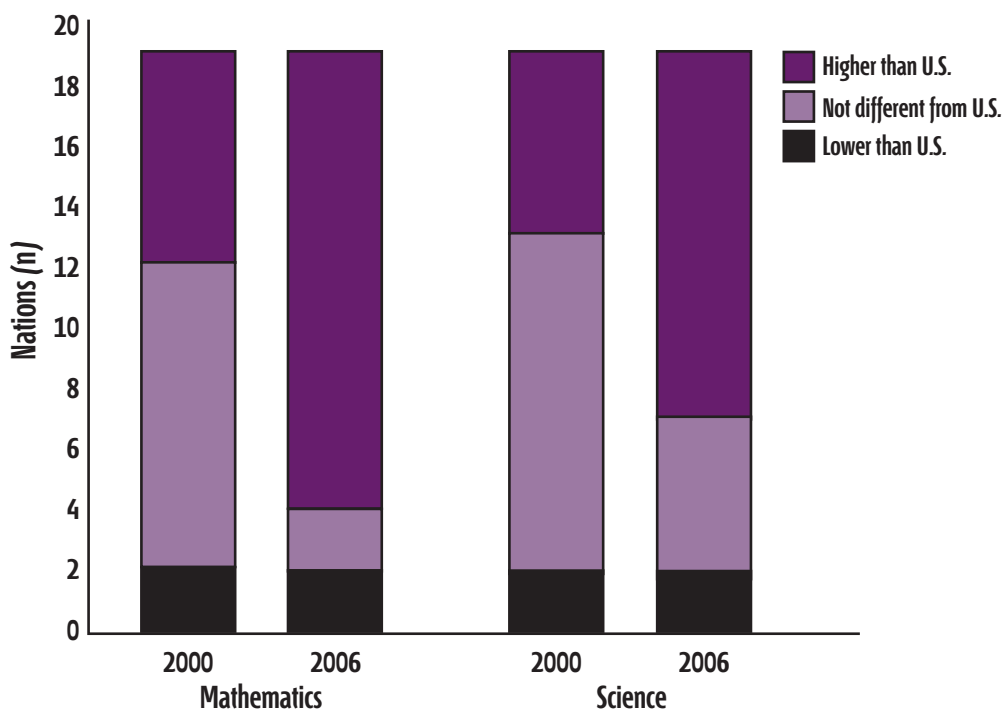
- *The U.S. Commission on National Security|21st Century, 2001*

### Supporting real-world learning opportunities for teachers:

Hawaii law also creates a "research experiences for teachers" program to support the development of middle school teachers' skills and knowledge, and the development of middle school curriculum materials in STEM subject areas, with a focus on wireless communications. The enabling legislation identifies nine types of activities the program must make available, including assisting teachers in adapting state-of-the-art engineering research into a meaningful classroom experience for students, and providing summer engineering workshops for teachers.<sup>17</sup>

As for technology education, policies in a few states — Louisiana, New Jersey and Rhode Island — explicitly call for content standards in technology to be informed by the International Technology Education Association's Standards for Technological Literacy.<sup>18</sup> These standards go way beyond teaching students to desktop and blog. The following are the five threads of the standards, and one example of a standard under each thread: (1) The Nature of Technology ("Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study."); (2) Technology and Society ("Students will develop an understanding of the cultural, social, economic and political effects of technology"); (3) Design ("Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving"); (4) Abilities of a Technological World ("Students will develop abilities to apply the design process"); and (5) The Designed World (students will "develop an understanding of and be able to select and use" seven different areas of technology, including in the areas of medicine, construction, transportation, and energy and power).

### Changes in selected nations' performance on PISA assessments of 15-year-olds, relative to U.S. performance: 2000 and 2006



PISA = Program for International Student Assessment

NOTES: All comparisons refer to the number of selected nations scoring higher or lower than, or not statistically different from, the U.S. for the same test (among those participating in both years.) The selected countries include Australia, Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Korea, Norway, Russian Federation, Spain, Sweden, Switzerland, and United Kingdom.

SOURCE: Baldi S., Jin Y., Skemer M., Green P.J., Herget D., *Highlights From PISA 2006: Performance of U.S. 12-Year-Old Students in Science and Mathematics Literacy in an International Context*, NCEES 2008-016 (2007).

Science and Engineering Indicators 2010

## ECS Resources

### High School Graduation Requirements Database

50-state information on math <http://mb2.ecs.org/reports/Report.aspx?id=900>, science <http://mb2.ecs.org/reports/Report.aspx?id=902> and computer/technology education <http://mb2.ecs.org/reports/Report.aspx?id=907> requirements in the states.

### Recent State Policies/Activities: Economic/Workforce Development – STEM

Summaries and links to newly enrolled and enacted state legislation and recently approved state board rules from across the states. Updated weekly. <http://www.ecs.org/ecs/ecscat.nsf/WebTopicView?OpenView&count=-1&RestrictToCategory=Economic/Workforce+Development--STEM>

### Recent State Policies/Activities: Teaching Quality – Recruitment and Retention – High-Need Subjects

Includes policies to recruit and retain teachers in STEM disciplines. Updated weekly.

<http://www.ecs.org/ecs/ecscat.nsf/WebTopicView?OpenView&count=-1&RestrictToCategory=Teaching+Quality--Recruitment+and+Retention--High-Needs+Subjects>

### High School-Level STEM Initiatives

50-state database on 10 indicators related to increasing student engagement and achievement in STEM disciplines. (2008)

[http://www.ecs.org/html/educationissues/HighSchool/highschooldb1\\_intro.asp?topic=stem](http://www.ecs.org/html/educationissues/HighSchool/highschooldb1_intro.asp?topic=stem)

## Other Resources

### Project Lead the Way (PLTW)

A highly successful initiative offering grades 6–12 engineering programs and 9–12 biomedical sciences program, PLTW provides project-based curricula, teacher professional development, and “partnership teams” that make available current classroom materials and the latest information in developing fields. <http://www.pltw.org/>

### Rising Above the Gathering Storm

Makes recommendations on improving STEM education and expanding the STEM workforce for federal policymakers that are equally actionable for state leaders.

[http://books.nap.edu/catalog.php?record\\_id=11463](http://books.nap.edu/catalog.php?record_id=11463)

### Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads

Identifies approaches federal, state and local leaders may use to enhance minority participation and success in STEM.

[http://www.nap.edu/catalog.php?record\\_id=12984](http://www.nap.edu/catalog.php?record_id=12984)

## Endnotes

- 1 *PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science* (Volume I) (OECD, 2010).
- 2 P. Gonzales, T. Williams, L. Jocelyn, S. Roey, D. Kastberg and S. Brenwald, *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context (NCES 2009–001 Revised)* (Washington, D.C.: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, 2008).
- 3 Eric Hanushek, Paul E. Peterson and Ludger Woessmann, “Teaching Math to the Talented,” *Education Next*, Winter 2011, vol. 11, no. 1.
- 4 Bureau of Labor Statistics, *Occupational Outlook Handbook, 2010-11 Edition* (Washington D.C.: United States Department of Labor.), <http://www.bls.gov/oco/oco2003.htm> (accessed January 28, 2011).
- 5 National Academy of Sciences, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (Washington, D.C.: The National Academies Press, 2010).
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- 7 ACE Mentor Program Web site. “About Us” and “ACE Scholarship Collaborative,” <http://www.acementor.org/495> and [http://www.acementor.org/wsc\\_content/pics/user\\_upload/ScholarshipColl6410.pdf](http://www.acementor.org/wsc_content/pics/user_upload/ScholarshipColl6410.pdf) (accessed February 3, 2011)
- 8 ACE Mentor Program, *ACE Mentor Program Releases Landmark Research Results: Participants Graduate High School at a Greater Rate & ACE Increases Diversity in Architecture, Construction, Engineering Program Enrollment*, June 17, 2010, [http://www.acementor.org/wsc\\_content/pics/user\\_upload/ACEResearchPressRelease.pdf](http://www.acementor.org/wsc_content/pics/user_upload/ACEResearchPressRelease.pdf) (accessed February 3, 2011). (Full survey results available from: <http://www.emcorgroup.com/ACE/ACEbrochureFinal.pdf>.)
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- 11 Maryland Business Roundtable for Education, *The Case for STEMnet Teachers Hub*, October 2010, <http://mbrt.org/wp-content/uploads/2010/11/stem-teachers-hub.pdf> (accessed February 3, 2011).
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- 13 Committee on Standards for K-12 Engineering Education, National Academy of Engineering of the National Academies, *Standards for K-12 Engineering Education?* (Washington, D.C.: The National Academies Press, 2010).
- 14 HAW. REV. STAT. § 304A-1861
- 15 HAW. REV. STAT. § 304A-1862
- 16 KY. REV. STAT. ANN. § 158.808; 705 KY. ADMIN. REGS. 4:250
- 17 HAW. REV. STAT. § 304A-1863
- 18 N.J. STAT. ANN. 18A:7F-4.2 and N.J. ADMIN. CODE tit. 6A, § 9-2.1; LA. ADMIN. CODE tit. 28, pt. LXXXI, § 1501 and ff.; RI ADC 21-2-53:G-13.1.6

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This issue of *The Progress of Education Reform* was made possible by a grant from the GE Foundation. If you have any questions about this issue, please contact: Jennifer Dounay Zinth, Senior Policy Analyst, Education Commission of the States, at 303.299.3689 or [jdounay@ecs.org](mailto:jdounay@ecs.org).



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