Learning about Science, Technology, Engineering, and Mathematics

Assessing the State of STEM Education in Colorado

Center for Education Policy Analysis

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The Center for Education Policy Analysis

The Center for Education Policy Analysis provides research and analysis on issues affecting the quality of P-20 education in Colorado and nationwide. CEPA is housed at the School of Public Affairs, University of Colorado Denver.

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Stem Education: What Is It, Why Is It Important, And How Are We Doing?

"STEM education" is shorthand for the education of students in the subjects of science, technology, engineering, and mathematics (hence, STEM, taking the first letters of each subject). In the past, this area was known more commonly as "math and science education," and sometimes that term is still used. The STEM acronym is a new way to acknowledge the separate importance of the engineering and technology disciplines, as well as traditional math and science, and to emphasize the interconnectedness of all of these disciplines.

STEM education is a hot topic today for a lot of reasons. First, as the complexity of work processes increases, the likelihood that a worker will need to be familiar with STEM concepts has grown exponentially. Math and science are not just for mathematicians and scientists anymore, and technology is omnipresent. As the National Science Foundation recently stated in a national call to action:[1]

In the 21st century, scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. To succeed in this new information-based and highly technological society, all students need to develop their capabilities in science, technology, engineering, and mathematics (STEM) to levels much beyond what was considered acceptable in the past. A particular need exists for an increased emphasis on technology and engineering in our Nation's education system.

In addition to knowing the basics of STEM concepts, the ways in which problems are approached and solved in STEM education invoke skills that are necessary in today's world. In science, for example, students practice using scientific inquiry: preparing a hypothesis and testing it against available data. This creates a "habit of mind," a disciplined inquiry process that is applicable to many non-scientific endeavors. In math, students wrestle with abstract concepts, again a habit of mind that is useful outside the specific discipline. The study of technology is both a subject and a process of adapting ever-changing tools to new problems in ways that are beyond the imagination of prior generations.

Finally, responsible citizenship today requires a basic understanding of STEM concepts. Voters and their elected representatives are faced with making decisions on issues such as stem cell research, the evidence for evolution, and individual privacy rights in a technological society. As the issues addressed in our democracy become more complex, so too must the knowledge of our citizenry.

The federal government is taking steps to address STEM education. Colorado Rep. Mark Udall is a co-founder of the STEM Education Caucus, a bipartisan caucus with over 100 members formed to educate Congress on STEM issues. President Bush recently signed into law the America COMPETES Act, a congressional response to reports by the National Academies and the Council on Competitiveness that criticize America's readiness to compete globally. The act, which authorizes $33.6 billion over fiscal years 2008-2010 for STEM programs across the federal government, includes a number of provisions intended to strengthen STEM education from preschool through higher education.

So how is Colorado doing in preparing its students in STEM disciplines? In K-12 education, when we compare ourselves to other states, Colorado students do relatively well overall. However, when we parse the numbers, we find gaps in achievement among different student groups that are larger than other states. We also see that the decentralization of Colorado's educational system means that significant statewide incentives and resources for improving STEM education are few and far between.

When we look at postsecondary education, it is clear that there are a lot of robust STEM programs around the state. Schools like the Colorado School of Mines, the University of Colorado, and Colorado State University feature strong baccalaureate and graduate programs in STEM disciplines such as engineering and physics. Community colleges offer a variety of career and technical education programs that serve STEM employers, such as engineering technology, process technology, and health professions. However, the financial state of Colorado's higher education institutions has been precarious since the 2002-04 recession. This threatens the ability of the state to maintain world-class STEM programs, which are equipment- and space-intensive and which must keep up with rapid technological changes.

We are well-positioned to continue thriving in the new economy, but only if we pay attention to our challenges and act quickly to find and implement solutions. Other states and countries recognize the opportunities of STEM and are acting to improve STEM education. If we stand still, we fall behind.

Our High-Tech State: The Economic Demand For Quality STEM Education In Colorado

Colorado's economic future depends in large part on its ability to attract and retain STEM-based industries and occupations. We have had great success in building one of the nation's leading high-tech economies. For example, Colorado enjoys the following national rankings:

- Highest concentration of private aerospace workers[2]
- 2nd in the overall education attainment of the workforce
- 2nd in entrepreneurial activity
- 2nd in the number of patents issued per 1,000 employees
- 3rd in number of high-tech workers as a percentage of the workforce
- 9th overall on the New Economy Index
- 10th in the number of scientists and engineers as a percentage of the workforce
- 10th in "knowledge jobs"[3]

JOB TITLE	% ANNUAL GROWTH
Network systems and data communications analysts	5.2
Plumbers, pipefitters, and steamfitters	5.0
Electricians	4.7
Computer software engineers, applications	4.6
Home health aides	4.6
First-line supervisors and managers of construction trades	4.5
Operating engineers	4.4
Computer software engineers, systems software	4.3
Construction managers	3.9
Computer support specialists	3.0
Accountants and auditors	3.0
Registered nurses	2.6

Source: Colorado Department of Labor

According to current projections, there will be no slowing in the demand for STEM-educated workers. The most recent projections from the Colorado Department of Labor[4] report the following STEM-related occupations as among the top 50 fastest-growing occupations in the state, as the chart below shows.

The Metro Denver Economic Development Corporation has targeted the following six industries for recruitment to the area: aerospace, aviation, bioscience, energy, financial services, and information technology – software. Industries targeted for retention include beverage service production, broadcasting and telecommunications, and information technology – hardware.[5] All of these industries rely heavily on a quality STEM-educated workforce.

However, as has been pointed out in numerous other reports, Colorado imports more of its STEM workforce than is "homegrown."[6] Our workforce is one of the most highly educated in the country, but our high school graduation rate and the rate of students continuing on to higher education are only average. This phenomenon, known as the Colorado Paradox, has caused Colorado's STEM industries and policy makers to contemplate the future with some alarm.

According to the Metro Denver Workforce Innovation in Regional Economic Development (WIRED) initiative, "in stark contrast to the past successes in attracting skills, Colorado's high school graduation and college completion rates are abysmally low. Scores in math and science are so low that recruitment for high paying jobs is often more active beyond state lines than within Colorado. The state cannot expect to continue to rely on this model for growth." [7] Businesses surveyed by WIRED reported that 74 percent of their employees are in occupations requiring at least some post-secondary education. Sixty-eight percent of occupations require a bachelor's degree or higher. Entry-level positions are usually hired locally, but as positions require more specialized skills and experience, industries must look further outside the region to find qualified candidates.[8]

> *"A knowledge-based economy cannot flourish without a public and private education system that consistently produces high-quality graduates with skills that offer the highest potential for employment."*
>
> Metro Denver Economic Development Corporation

If Colorado wants to maintain and grow its current prosperity, our state must ensure that students graduate from our high schools and colleges with STEM knowledge and skills. Recognizing this, the state has taken several huge steps in the past year by leveraging external funding sources to improve STEM education. For example, the Metro Denver WIRED initiative received a $15 million grant from the U.S. Department of Labor to focus on education and workforce issues in four target industries in the metro area: energy, aerospace, bioscience, and information technology. The National Science Foundation has funded several major grants in Colorado, including the Colorado Alliance for Minority

Stem Education in Our K-12 System

Our High-Tech State: The Economic Demand For Quality Stem Education In Colorado *continued*

Participation, which seeks to increase minority interest and participation in STEM subjects, and the Rocky Mountain Middle School Math and Science Partnership to improve middle school teacher instruction in math and science.

In July 2007, Colorado received $500,000 from the National Governors' Association (to be matched by state and local sources) to create state and regional networks of STEM education stakeholders and work for improvements in STEM education policies. The Governor's Office will be working in partnership with the Center for Education Policy Analysis at the University of Colorado at Denver, the Colorado Children's Campaign, the Colorado Mathematics, Science, and Technology Education Coalition (COMSTEC), the Metro Denver WIRED Initiative, and College in Colorado (a project of the Colorado Department of Higher Education) to accelerate Colorado's STEM education systems. As Governor Ritter stated in announcing the NGA grant:

Every day, economic competition among states and foreign countries grows more and more intense. Focusing on rigorous STEM education will allow us to better prepare Coloradans for a 21st century workforce that will serve the industries of the future. It also will help us achieve our goals of cutting high school dropout and achievement gap rates in half within 10 years and doubling the production of postsecondary certificates and diplomas.

Colorado's K-12 education policy environment is unique. "Local control" of education is mandated by both constitutional provision and tradition. While there is much ongoing debate about the legal scope of this provision and the meaning of "local control" in Colorado, K-12 education in Colorado is relatively decentralized as a matter of history and current practice.

Reflecting this, Colorado's statewide governance structure related to education is unique in its fragmentation. The State Board of Education, which is responsible for the oversight of K-12 schools, is chosen through a general election. The State Board of Education appoints the Commissioner of Education, who heads up the state Department of Education. Policy related to higher education is established by the Colorado Commission on Higher Education, staffed by an executive director appointed by the governor. The legislature appropriates funds for education and can also make policy related to both K-12 and higher education. Until the recent executive order creating the P-20 Council, there was no single body responsible for viewing the education system as a whole. As a result of all these factors, compared to other states, critical education policy making happens in Colorado both at the local and state level and in a variety of agencies. This decentralization and fragmentation affects STEM education in Colorado.

Not only is Colorado education decentralized, but it is also extremely diverse. The state has 178 school districts serving nearly 800,000 students. Most districts serve less than 1,000 students, and ten serve less than one hundred students. Many districts have a majority population of students from traditionally minority ethnic backgrounds. Hispanic students make up 27 percent of the total student population. The state is geographically diverse, ranging from the heavily populated Front Range and the resort towns of the mountains to the more sparsely populated northwestern, southern and eastern areas to the Western Slope.[9] Different communities have different views about the importance of STEM education and different levels of access to STEM resources.

Colorado also does not invest large amounts of state money in education compared to many other states. Our spending on education ranks 25th on a per-pupil basis (just slightly below the national average), but we rank much lower when spending on education is viewed as a percentage of state per capita income.[10] We have relatively little discretionary money available in our General Fund for investing in education due to the restrictive tax and expenditure limit (known as the Taxpayer's Bill of Rights, or TABOR) placed in the state constitution by voters in 1992. The state department of education is among the smallest in the country, and in the past few years has served mainly as a distribution and enforcement mechanism for federal education funds. As a result, there are relatively few state-level resources available for districts looking to improve STEM education.

What Do Colorado's K-12 Students Learn About Science, Technology, Engineering, and Mathematics?

What students learn about STEM subjects is governed by a number of state-, district- and school-level requirements and opportunities. At the state level, students in grades 3-10 are tested by the Colorado Student Assessment Program (CSAP) in reading, writing, and mathematics, and in science in grades 5, 8, and 10. Schools and districts are held accountable for student scores. As a result, schools and districts focus much of their math and science education on the subjects that will be tested by the state, which are contained in the Colorado Model Content Standards.

Because of our decentralized education system, there are no statewide high school graduation requirements or state-level curriculum requirements. School districts generally have coursework requirements for graduation from high school, and these requirements obviously influence coursetaking in high school. Some districts also have standard curricula that schools and teachers are required to use. Beyond required courses, many schools and districts offer a variety of other opportunities for students to explore interests in STEM disciplines. The breadth and availability of these opportunities, however, vary across the state.

Discussions about the sufficiency of what students are learning, whether in STEM disciplines or other subjects, often are driven by differing views on what the learning should be used for. Many recent policy initiatives have been driven by the viewpoint that K-12 learning is intended to prepare students for postsecondary education, particularly a four-year traditional college experience. Others argue that K-12 learning is intended to allow students to explore their own interests and make their own choices, and what may be right for one student is not right for another. STEM subjects have been the crucibles for these arguments in Colorado.

K-12 Mathematics Learning

Recently, international assessments have allowed the United States to compare student learning in our country with the performance of students from other developed nations. For example, the Program for International Student Assessment (PISA) measures the reading, mathematics, and science literacy of 15-year-olds around the world. In 2003, the mathematics performance of American 15-year-olds was lower than the average performance of 15-year-olds in other developed countries, and American scores were also lower than average on each mathematics content subscore. In terms of numerical scores, American 15-year-olds ranked 24th out of 29 developed countries, on par with Poland and Hungary, and scoring well below countries such as Korea, Japan, Australia, and Canada.[11] Results such as these, combined with the increasing globalization of the world economy, have led to a renewed focus on mathematics nationally and at the state levels.

Math content standards

Colorado students take state CSAP mathematics tests annually in grades 3-10. These tests are based on the knowledge and skills contained in the Colorado Model Content Standards for mathematics. The six mathematics standards, which are very general, are supplemented by curricular frameworks appropriate for grade-level groupings in grades K-2, 3-5, 6-8, and 9-12.[12]

1. Students develop number sense and use numbers and number relationships in problem-solving situations and communicate the reasoning used in solving these problems.
2. Students use algebraic methods to explore, model, and describe patterns and functions involving numbers, shapes, data, and graphs in problem-solving situations and communicate the reasoning used in solving these problems.
3. Students use data collection and analysis, statistics, and probability in problem-solving situations and communicate the reasoning used in solving these problems.
4. Students use geometric concepts, properties, and relationships in problem-solving situations and communicate the reasoning used in solving these problems.
5. Students use a variety of tools and techniques to measure, apply the results in problem-solving situations, and communicate the reasoning used in solving these problems.
6. Students link concepts and procedures as they develop and use computational techniques, including estimation, mental arithmetic, pencil-and-paper, calculators, and computers, in problem-solving situations and communicate the reasoning used in solving these problems.

Frameworks allow for the appropriate grade-level application of each standard. For example, the application of Standard 4, the use of geometric concepts, properties, and relationships, looks very different in grade 3 than in grade 10. One of the geometry tasks for 3rd-graders is to be able to recognize and describe geometric shapes, while 10th-graders are expected to be able to apply the Pythagorean theorem to solve real world problems.

Because the subjects emphasized by CSAP testing are intended to influence what teachers teach in the classroom, the quality and relevance of our content standards is critical. Colorado's mathematics standards were adopted in 1995, and have not been amended since their initial adoption. A 2005 review by the Colorado Department of Education concluded that the math standards and assessments were aligned and grade-appropriate, and recommended that no changes be made.[13] However, new Education Commissioner Dwight Jones and the State Board of Education recently released a strategic plan for education that includes revisiting state standards and assessments.[14]

The state's mathematics standards were reviewed for their rigor during the tenure of the Colorado Educational Alignment Council, in 2006.[15] The Council asked Achieve, Inc., a national organization with expertise in benchmarking standards, to review Colorado's math standards. Achieve reported the following deficiencies:

ACHIEVE ASSESSMENT OF COLORADO MATH STANDARDS

Area	Omission
Number sense and numerical operations	No specific expectations for high school students to compute with rational numbers fluently and without a calculator
Algebra	No specific expectations for students to add, subtract, multiply, divide and simplify rational expressions; solve quadratic equations in one variable; and graph exponential functions and identify their key characteristics
Geometry	No specific expectations for students to state and prove basic theorems in geometry; describe a line by a linear equation; and find the distance between two points using their coordinates and the Pythagorean Theorem
Data interpretation, statistics, and probability	No specific expectations for students to recognize when arguments based on data confuse correlation with causation; explain the differences between randomized experiments and observational studies; and explain how the law or large numbers can be applied in simple examples

The Fund for Colorado's Future, which staffed the Alignment Council, also conducted interviews with Colorado subject-area content experts to determine their opinions of the relative strengths of Colorado's math standards, as compared with college readiness standards developed by ACT and college and workforce readiness benchmarks developed by the American Diploma Project. The experts ranked the standards on a scale of 1-10, with 10 indicating extremely high quality. In math, the content experts gave the Colorado standards a ranking of 7.2. This was higher than the ranking assigned to the ACT college readiness standards (7.0) but well below the ranking assigned to the ADP standards (8.1).

STEM Learning Begins in Early Childhood

The natural curiosity of a child leads to early understanding of STEM concepts. Children begin their study of mathematics by filling cups with sand in the sandbox, comparing heights on a growth chart, and wondering why the blocks fell down at a certain point. Researchers and early childhood educators now recognize that "high-quality, challenging, and accessible mathematics education for 3- to 6-year-old children is a vital foundation for future mathematics learning. In every early childhood setting, children should experience effective, research-based curriculum and teaching practices."[16] Observing, asking questions, and debating answers all begin a child's development in scientific investigation. Colorado's content guidelines for early childhood programs include mathematics and science, and activities meeting these standards are required in the state-funded Colorado Preschool Program.[17]

Math coursetaking

Unfortunately, Colorado does not keep statewide records on student coursetaking, which greatly hampers our ability to advance the debate on this issue. What records on coursetaking we have come from student responses to a survey administered as part of the mandatory 11th grade ACT test. According to that information, 63 percent of Colorado's high school students take what ACT considers to be the "minimum core" curriculum necessary to be ready for college math: at least Algebra I and II and Geometry. Seventeen percent of Colorado's students take two or fewer years of high school math.[18]

Other evidence of coursetaking comes from district high school graduation requirements. As noted previously, districts set their own graduation requirements, and they vary widely across the state. If a district requires a certain amount of math coursework for graduation, it is a pretty safe bet that most of the students will take that coursework. A recent analysis of district graduation requirements by the Fund for Colorado's Future showed that most districts require three or more years of high school level math for graduation. However, one-quarter required less than three years.[19]

Responding to ACT's research on the relationship between high school coursetaking and college success, in 2003 the Colorado Commission on Higher Education decided to require applicants to the state's four-year colleges as of 2010 to have taken four years of mathematics, Algebra II and higher, as of 2010. These Higher Education Admission Requirements, or HEAR, were seen by many K-12 educators as an effort to dictate what was being taught in the K-12 schools, and were met with a great deal of opposition. While the HEAR requirements addressed other subjects in addition to math, the vast majority of opposition centered around the new math requirements as well as a new foreign language requirement. School districts expressed concern not only about their own ability to offer a complete math curriculum, but also about the ability and motivation of all students to meet the new requirements.[20]

Simultaneous with these discussions, the field of career and technical education had been undergoing changes intended to include explicit academic content along with the teaching of technical content and skills. Opponents of the new HEAR argued that the mathematics learned in CTE courses would not count towards HEAR, even though for many students it was their preferred way of learning. After much debate, CCHE revisited the HEAR requirements and voted in July 2007 to provide that the fourth year of mathematics does not need to be at an advanced level. This allows courses such as accounting and statistics to count towards the HEAR requirements.

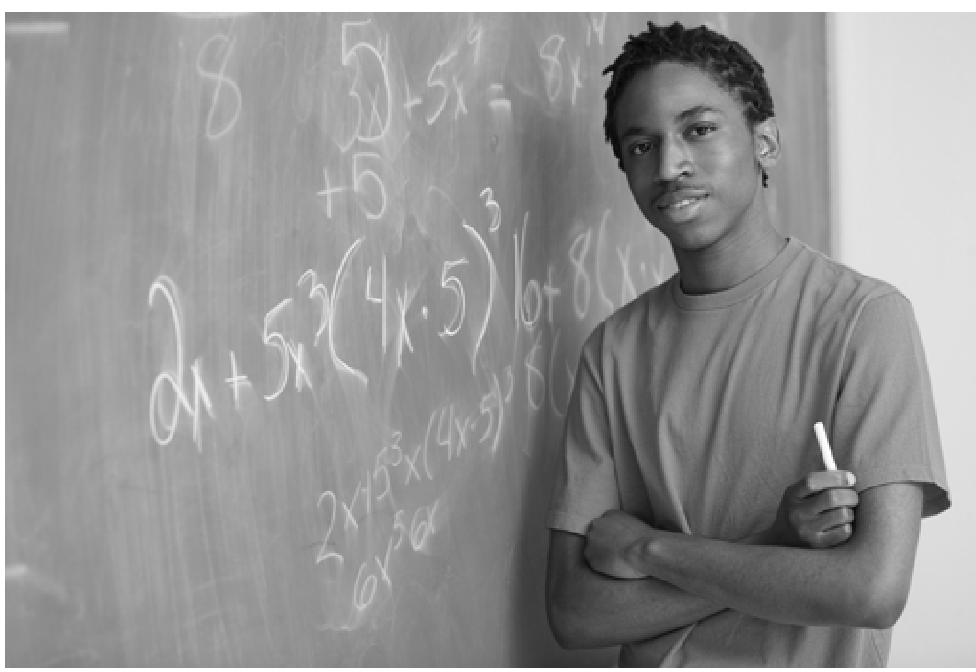
Other opportunities for K-12 math learning

Students in highly-populated areas tend to have a wide array of math courses and math-related extracurricular activities available to them, as do students in wealthier schools. For example, Smoky Hill High School in the Cherry Creek School District offers 25 different math courses to its approximately 2,600 students, ranging from Math Lab to both Advanced Placement (AP) and International Baccalaureate (IB) calculus.

Smoky Hill students who want to delve more deeply into mathematics can join clubs like the Math Club and MESA (Math, Engineering and Science Achievement). Students at high schools like Smoky Hill in metro areas have easy access to out-of-school math activities such as classes held at the Denver Museum of Nature and Science and university-sponsored math camps.

On the other hand, the Fremont School District in Cotopaxi, with 316 students in grades K-12, offers 6 high school level math classes, going up to Pre-Calculus. Soroco High School, in the northwest corner of the state, has two math teachers and no courses beyond a geometry level. Many smaller high schools in Colorado, such as Wray High School, Creede Junior/Senior High, and Rocky Ford High School, have just one math teacher.

Many rural districts are turning to online and distance learning for advanced mathematics coursework. For example, Colorado Online Learning partners with school districts across the state to offer online courses such as AP Calculus. School districts on the Eastern Plains can use the Video Network for Educational and Training Services (VNETS), an interactive multipoint videoconferencing system, to effectively share classes such as college-level algebra. In the future, VNETS plans to offer conferencing with resources across the country, including NASA.



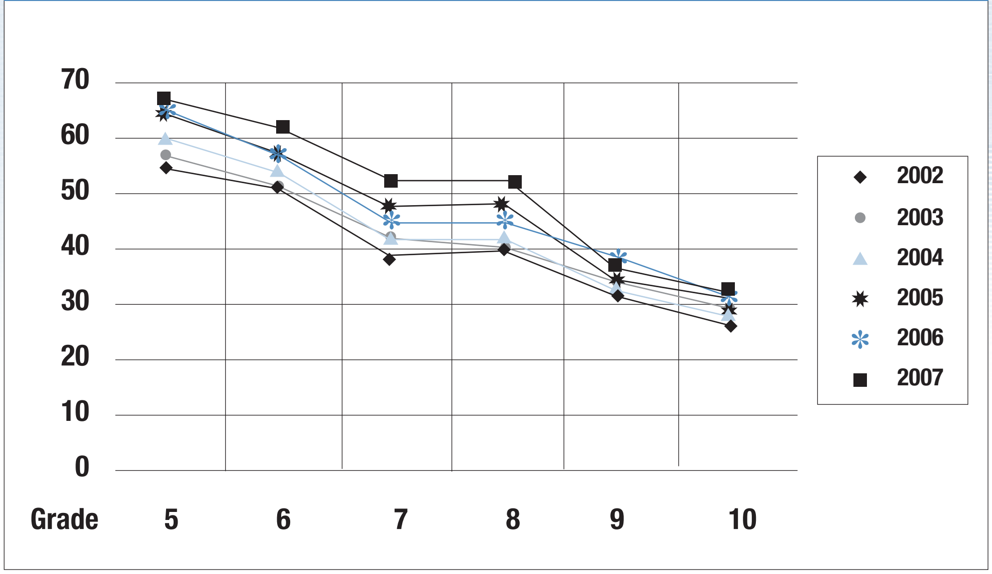
Looking for results: Mathematics outcomes

A variety of assessments measure how well Colorado students understand math. These include CSAP, for grades 3-10; ACT, for grade 11; and the National Assessment of Educational Progress, or NAEP, which is a nationwide test for grades 4 and 8. The CSAP is a Colorado-specific test, while ACT and NAEP are administered nationwide and allow for comparisons between states.

As can be seen in the chart to the right, math proficiency as measured by CSAP is much higher in the early grades, and decreases steadily by grade. Interestingly, much progress has been made in increasing proficiency over the last five years in grades 5-8, while increases in proficiency for grades 9 and 10 are much more incremental.

Many explanations are offered for the persistently weak showing of 10th graders in math. In its 2005 report, CDE stated that the math standards and assessments are appropriate and aligned, and the poor showing is caused by educators who are not familiar with the standards and by schools and districts who choose not to offer the level of math courses tested by the 10th grade CSAP.[21] Many educators, on the other hand, believe that the 10th grade CSAP math assessment is simply not a valid assessment of the standards. Other factors might include the fact that more advanced mathematics courses are increasingly abstract and tend to be taught as wholly abstract concepts, and that some adolescents may view themselves as not capable in math and set up self-fulfilling prophecies with respect to math assessments.

CSAP MATH PROFICIENCY, 2002-2007

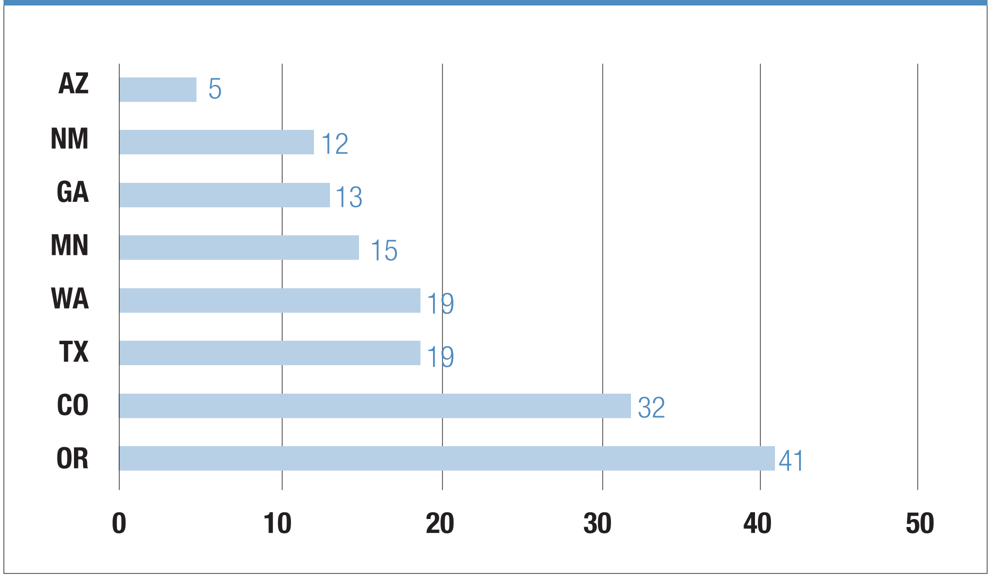


Source: CDE

The precipitous decline in math proficiency between early and later grades is not unique to Colorado. However, Colorado's drop is abnormally high compared to peer states. The following chart tracks the "drop-off" that occurred in 2007 state math assessments between grades 3 and 10 for Colorado and peer states.

Keep in mind that absolute scores are not comparable, as each state assessed students using its own standards and tests. While all states experience a drop in math proficiency, Colorado's is abnormally high compared to all peer states except Oregon.[22] This suggests some factor unique to Colorado's assessment may be at work.

DROP IN STATE MATH PROFICIENCY FROM 3RD TO 10TH GRADE, 2007



Note: Georgia and Minnesota results are from 3rd through 8th grade.

Comparing Colorado's 2007 math NAEP scores to those of our peer states and the nation is also instructive. The state's 4th-graders tested at about the same level as the national average, with a scale score of 240 compared to the national average of 239. Our 8th-graders, however, scored above the national average.[23] While proficiency levels tend to dip nationwide between 4th and 8th grade, Colorado's dip of four percentage points is actually lower than the national average of eight percentage points.

Colorado is only one of two states that require all 11th graders to take the ACT. In the vast majority of states, the ACT is taken only by those students who choose to take it for purposes of college entrance. As a result, it is not appropriate to compare Colorado's scores (which represent the state's entire 11th grade population) to those of most other states (where the scores represent only the college-going population). We can, however, compare Colorado's scores to the three states in which student participation is greater than 90 percent: Illinois (100%), Mississippi (96%), and Tennessee (96%). Colorado ranks second among this group, with the average math score at 20.1. Illinois students score higher, with an average math score of 20.4, while Tennessee and Mississippi score lower, with average math scores of 19.9 and 18.1, respectively.[24] ACT considers a math subscore of 22 to indicate college readiness.[25]

Another way to measure K-12 performance in mathematics is to see what percentage of college-bound students are considered ready for college-level mathematics. In Colorado, state law provides that students who score below certain levels on mathematics, reading, and/or writing assessments must take remedial coursework before they are deemed ready for college-level work. In mathematics, students must score at or above these levels on one of the following tests: 19 on the ACT math subtest; 460 on the SAT math subtest; or 85 on the Accuplacer elementary algebra subtest. The state's most recent report on remediation rates indicates that 29.8% of incoming college students need remedial coursework, and more than four out of five of these students are deficient in mathematics. In FY 2006, 24.8% of entering post-secondary students required remedial coursework in mathematics.[26]

2007 NAEP – MATH

	Scale Scores		% of Students Scoring Proficient and Above	
	4th	8th	4th	8th
U.S. Average	239	280	39	31
Arizona	232	276	31	26
Colorado	240	286	41	37
Georgia	235	275	32	25
Minnesota	247	292	51	43
New Mexico	228	268	24	17
Oregon	236	284	35	35
Texas	242	286	40	35
Washington	243	285	44	36

Source: NCES

How can we improve K-12 math outcomes?

In 2005, staff from the Colorado Department of Education traveled around the state to visit schools and ask teachers and administrators about math performance. Across the state, teachers and administrators agreed that students at all levels were mostly unable to solve math problems with any degree of proficiency. However, they did not know how to improve these results. "There was an honest confounded quality as to how to tackle math deficiencies and where to begin … There was overall confusion about which students were 'stuck' and why and how these students ought be engaged." CDE staff observed that less than half of the 58 districts visited were "firmly clear about math standards." Suggestions from the field for improvement included the need for more money and addressing issues of urban and rural poverty. In addition, "[e]very city or district addressed the need for stronger teacher development in math and for higher education to align their work to K-12 needs. This was especially true for elementary and middle school teachers."[27]

CDE's analysis of schools that performed well in math during the years 2002-2004 revealed the following common features:

- Teachers know the standards and the mathematics
- Quality curriculum supplemented with procedural or conceptual practice
- Both explicit instruction and inquiry in the four essential math domains (arithmetic, concepts, reasoning and problem-solving)
- Teacher collaboration focused on student outcomes
- Student progress monitoring and adjustments made based on data

Based on its findings and current research, CDE made the following recommendations for improvement for schools and districts:

1. Be clear about the math topics that Colorado students are expected to know at each grade level.
2. Be clear about what specific proficient student work looks like in math at each grade level.
3. Check school and teacher beliefs about how many students can and should know math.
4. Ensure that coherent approaches to math instruction are based on current research on math cognition and learning.
5. Teach students efficient and accurate methods for computing and using computational algorithms and math facts, and provide the necessary practice to build automaticity.
6. Teach students the ways that numbers behave and help students build their understanding of math concepts and vocabulary.
7. Teach mathematical reasoning skills.
8. Teach students to use knowledge of arithmetic, conceps, and reasoning to solve math problems.
9. Diagnose what your students understand about the lesson of the day.
10. Recruit and develop teachers with knowledge of math concepts, learning, and instruction.

Sadly, although CDE has established a math website with some helpful links to external resources, there is no statewide initiative to assist schools and districts with the implementation of these recommendations. As a result, implementation will depend upon the will and resources available to local schools and teachers.

K-12 Science Learning

Science content standards

Colorado's science standards were first adopted in 1995, and were modified in 2007 after a year-long investigation by CDE resulted in recommendations for changes. Colorado has five science standards, again supplemented by more detailed grade-level benchmarks:

1. Students apply the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
2. Physical Science: Students know and understand common properties, forms, and changes in matter and energy. (Focus: Physics and Chemistry)
3. Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment. (Focus: Biology – Anatomy, Physiology, Botany, Zoology, Ecology)
4. Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space. (Focus: Geology, Meteorology, Astronomy, Oceanography)
5. Students understand that the nature of science involves a particular way of building knowledge and making meaning of the natural world.

For example, Standard 1 expects students in grades K-2 to "use their senses to make and describe careful observations," and to "ask questions and make predictions." The same standard expects students in grades 9-12 to "ask questions and state hypotheses using prior scientific knowledge to help design and guide development and implementation of a scientific investigation," and to "select and use appropriate technologies to gather, process, and analyze data and to report information related to an investigation."

Science coursetaking

A review of coursetaking in science using information collected by ACT shows that 58 percent of Colorado's students take what ACT considers to be the minimum science coursework necessary for college readiness. Thirty-two percent of Colorado's students take biology, chemistry, and physics in high school, while 26 percent take general sciences, biology, and chemistry. Twenty-two percent report taking less than three years of natural science.[28]

The new HEAR requirements require students entering Colorado's four-year colleges to have taken at least three years of natural sciences, including at least two years of lab-based courses. This part of the HEAR requirements does not seem to be particularly controversial for school districts, even though a review of district graduation requirements in 2005 showed that more than one-third did not have this requirement in place.

Other opportunities for K-12 science learning

Again, opportunities for science learning vary from district to district and from school to school. Some districts offer entire schools that are focused on science learning, such as the Denver School of Science and Technology and the Discovery Canyon Campus in Colorado Springs. Large comprehensive high schools, like Bear Creek High School in Jefferson County with 1,900 students, can offer a multitude of science courses such as Physics Principles, Anatomy and Physiology, Oceanography, and AP Environmental Science. Littleton High School offers Forensic Science. Thunder Ridge High School, in the Douglas County School Districts, offers Genetics, Astronomy, AP Chemistry, Chemistry for the Community, and Science Technology.

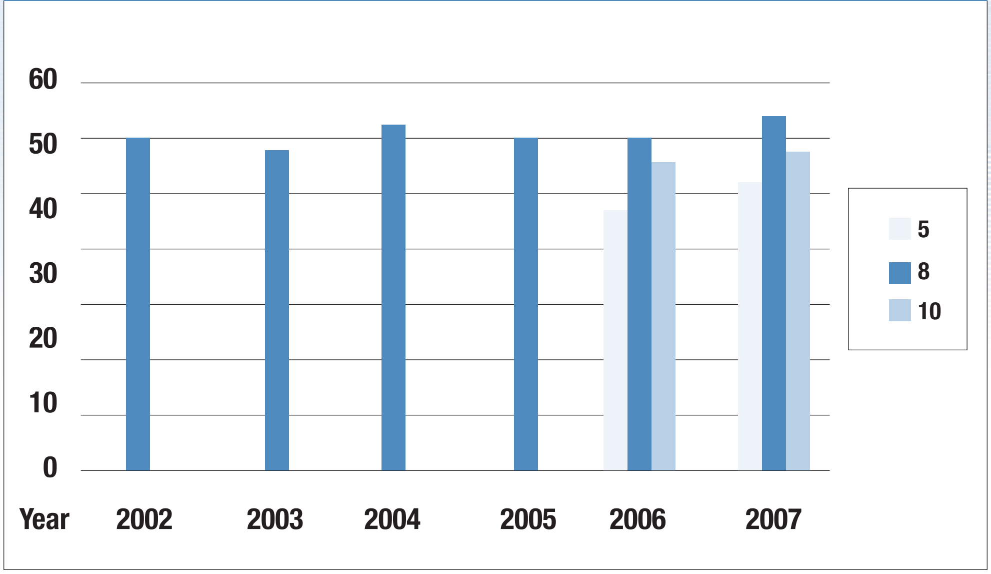
Fairview High School in Boulder offers Advanced Physics and IB Biochemistry. After-school clubs at Thunder Ridge High School include a Science Club and a Sports Medicine Club. Bear Creek students can get involved in the Astronomy Club and the Pre-Medicine/Pre-Veterinarian Club.

Smaller and more isolated schools need to be more inventive in offering science courses and experiences. Many are partnering with local community colleges. For example, the Bennett School District offers high school students the ability to take college-level biology courses at Morgan Community College, earning high school and college credit simultaneously.

There are a variety of nonprofit and government organizations that supplement formal K-12 science learning. For example, the Denver Museum of Nature and Science, the Denver Zoo, the Discovery Science Center in Fort Collins, and the Western Colorado Math & Science Center in Grand Junction are extremely valuable resources for their communities, offering hands-on student learning and resources for teachers. Federal agencies such as the Forest Service, the U.S. Geological Survey, the National Renewable Energy Laboratory, NASA, and the National Center for Atmospheric Research offer K-12 resources. Colorado's higher education institutions also provide a number of opportunities for informal science learning. For example, the Science Discovery program at the University of Colorado – Boulder offers hands-on after school and summer science programs, traveling science programs that visit K-12 schools, and summer wilderness camps.

For a comprehensive listing of Colorado organizations offering STEM enrichment activities, download the Pre-Collegiate Services Directory, published by College in Colorado and available at www.collegeincolorado.org under Statewide Resources.

CSAP SCIENCE PROFCIENCY IN GRADES 5, 8 AND 10, 2002-2007



Source: CDE

Looking for results: Science outcomes

Colorado tested only 8th graders in science until 2006, when 5th grade and 10th grade tests were added. Scores for 8th graders have remained remarkably flat, and scores for both 5th and 10th graders are lower, probably reflecting the relative lack of emphasis on science in previously untested grades.

The last NAEP science test was given to U.S. 4th and 8th graders in 2005. Colorado's students did relatively well in science compared to the rest of the country, although given the uniformly low scores across the country this is not much to cheer about. The state with the highest proficiency levels in 4th grade, Virginia, had just 40 percent of its students scoring proficient or above. North Dakota had the highest scores in 8th grade, with 42 percent of its students scoring proficient or above.

2007 NAEP – SCIENCE

	Scale Scores		% of Students Scoring Proficient and Above	
	4th	8th	4th	8th
U.S. Average	149	147	27	27
Arizona	139	140	18	20
Colorado	155	155	32	35
Georgia	148	144	25	25
Minnesota	156	158	33	39
New Mexico	141	138	18	18
Oregon	151	153	26	32
Texas	150	143	25	23
Washington	153	154	28	33

Source: NCES

On the 2007 ACT test taken by all of Colorado's 11th-graders, Colorado students scored an average of 20.4 on the science subtest. This compares to the national science subtest score of 21, and the following scores for states with greater than 90 percent participation in the ACT: Illinois and Tennessee at 20.4, and Missippi at 18.7. ACT considers a science score of 24 to indicate readiness for a college-level biology class.

How can we improve K-12 science outcomes?

In 2006, the Colorado Department of Education investigated the state of science education in Colorado. CDE's report on Colorado's science standards, like its previous report on math standards, involved interviews and classroom visits around the state. Based on the report, it appears that science classrooms are widely divergent. In 2000, the state began requiring only 8th graders to be tested on their science knowledge by CSAP. As a result, many schools and districts placed a lesser emphasis on elementary-level science, which was not something for which they were accountable to the state. In 2006, state-mandated science testing was expanded to include 5th and 10th grade as well as 8th grade. While educators are pleased that more emphasis is being placed on science, there is a widespread sense that the science curriculum and science teachers in some locations are not quite ready for this change. There is a perception that elementary school science teachers need more training in content, and secondary school science teachers need more training in how to teach the content.[29]

Common features of Colorado schools with high science achievement in 8th grade:

- Recruit and retain teachers with expertise and confidence in science who continually seek professional development opportunities
- Engage their community and parents in science activities, and benefit from science-minded and/or supportive administrators
- Know and use the state standards and assessment frameworks to align curriculum and pacing of instruction
- Use both teacher-directed and guided inquiry methods of instruction in earth, life, and physical science topics
- Actively integrate the science topics into other aspects of the curriculum

Based on its findings and current research, CDE made the following recommendations for improvement:

1. Identify what pre-conceptions and misperceptions students bring into the classroom about the nature of the scientific world around them.
2. Be clear about the science topics that Colorado students are expected to know at each grade level.
3. Build a focused and intentional district curriculum of concepts, knowledge, and skills to avoid a shallow and excessively broad span of topics each year.
4. Guarantee that all students, each year, are deeply engaged in rigorous and developmentally appropriate life, physical, and earth/space science instruction.
5. Be clear about what specific proficient student work looks like in science at each grade level.
6. Insist on a balance of explicit teacher-directed science instruction and teacher-guided student inquiry into science.
7. Diagnose what your students understand about the lesson of the day with lab-based activities, writing tasks, and proofs.
8. Check school and teacher dispositions and beliefs about how many students can or should know science.
9. Recruit and develop teachers with knowledge of science concepts, learning, and instruction.
10. Ensure that other subjects are reinforced and used in science instruction.

Again, no statewide resources were made available to assist districts and schools in implementing these recommendations, nor does the CDE website contain extensive information about how to implement the recommendations.

Engineering, which essentially involves applied mathematics and science, is not treated as a different subject by Colorado education policy. There are no state engineering standards or content tests. Instead, engineering concepts are either embedded in mathematics courses, or are contained in separate engineering electives. In general, only larger high schools located in more populated areas are able to offer any courses related to engineering.

One pre-engineering curriculum that has received a great deal of attention lately is Project Lead the Way (PLTW). This curriculum, developed initially for grades 9-12, requires students to take three foundation courses (Introduction to Engineering Design, Principles of Engineering, and Digital Electronics), specialization courses (Computer Integrated Manufacturing, Civil Engineering and Architecture, Biotechnical Engineering, and Aerospace Engineering), and a senior year course involving a capstone project. PLTW students also take college-preparatory coursework in math.[30]

PLTW programs are in place in all but four states. In Colorado, 14 high schools have certified PLTW programs. All certified PLTW high schools are located either in the Denver or Colorado Springs metro areas. Another six Colorado high schools, including high schools in Montrose and Loveland, use the PLTW curriculum.

Beverage Container Design Problem – PLTW Introduction to Engineering Design:

Design a beverage container that will hold 12.5 fluid ounces, plus or minus 0.25 ounces. Prior to using the container, sketch the top and front view using the correct dimensions to acquire the required volume. Show all your math calculations. Using the computer design tool, apply good design criteria of function and aesthetic value to solve this problem.

A regional alternative to PLTW is the Partnership for Engineering Education in the Rockies, which operates in Fort Collins. PEER is a partnership founded by Colorado State University, Front Range Community College, the Poudre School District, and Hewlett-Packard. Fort Collins high schools offer pre-engineering courses which are designed to lead to postsecondary coursework, and industry employers such as Intel provide instructors, resources, and internships.[31]

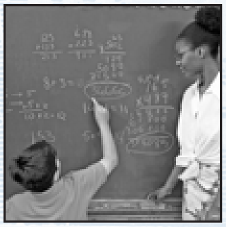
K-12 Technology Learning

The federal No Child Left Behind law requires states and districts to develop a plan for all 8th-graders to be technologically literate. "Technological literacy" is defined by Colorado as "the ability to responsibly use appropriate technology to communicate; solve problems; and access, manage, integrate, evaluate, design, and create information to improve learning in all subject areas and to acquire lifelong knowledge and skills in the 21st century."[32] The Colorado Department of Education recently adopted technology model content standards in August 2007 in response to district requests for assistance in developing mandated technology plans.[33] Each district is responsible for meeting or exceeding these standards, and CDE reviews progress on district technology and information literacy plans as part of the district accreditation process.

1. *Creativity and Innovation.* Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology.
2. *Communication and Collaboration.* Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.
3. *Research and Information Fluency.* Students apply digital tools to gather, evaluate, and use information.
4. *Critical Thinking, Problem-Solving and Decision-Making.* Students use critical thinking skills to plan and conduct research, design and manage projects, solve problems, engineer solutions, and make informed decisions using appropriate digital tools and resources.
5. *Digital Citizenship.* Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.
6. *Technology Operations and Concepts.* Students demonstrate a sound understanding of technology concepts, systems, and operations.

Districts need to collect information on the number of students assessed for technological literacy, the number of students technologically literate by the completion of 8th grade, and the type of assessment used. The ability of districts to create and implement meaningful technology plans that meet the above standards is likely to vary widely by district. Teachers in a few districts are using the latest instructional technology such as class websites, blogs, podcasts, Webquests, computer-simulated environments, probeware, and the like. Teachers in other districts are just learning how to use e-mail. State funding for district technology improvements is miniscule, and subject to a competitive grant process that does not begin to address the need.

Education Week publishes an annual report on the state of technology education in the states. Colorado, for all of its status as a high-tech economy, received a grade of C- for technology learning, one of the lowest scores in the country. Just 40.5 percent of our students had a computer in their classroom in 2005, compared with 63 percent of students in Virginia and 60.5 percent of students in Ohio. An average of 4.1 students in Colorado share access to a high-speed Internet-connected computer, compared to 3.4 students in Massachusetts and 1.9 students in Maine. Colorado also does not offer computer-based assessments, unlike 23 other states. Only four states regularly test students on technology literacy, and Colorado is not one of them.[34]



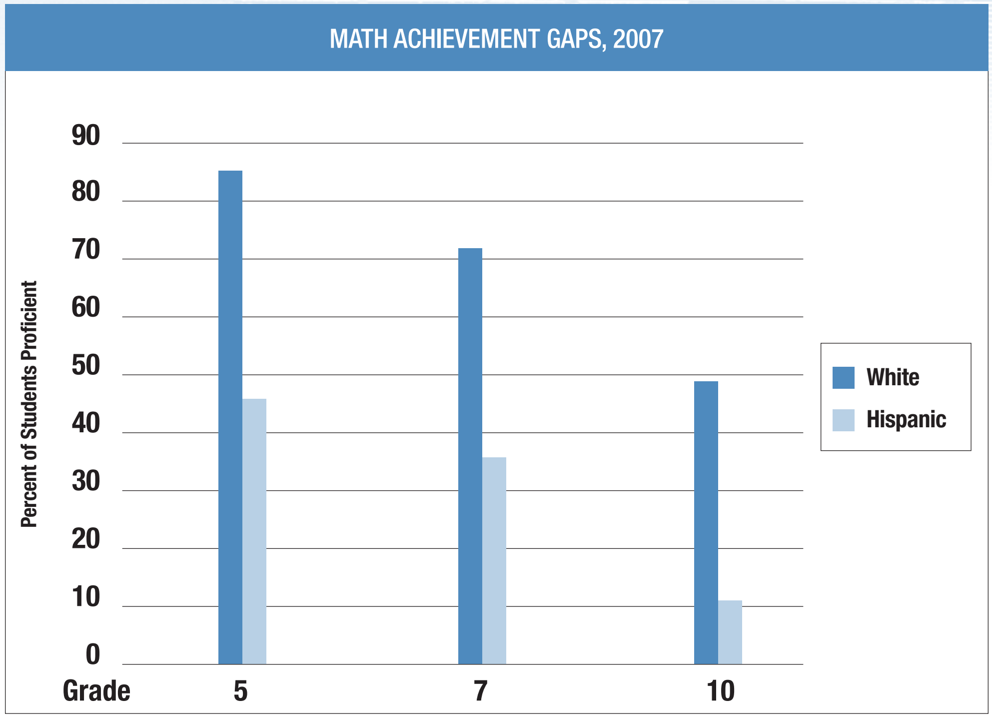
Issues in K-12 Stem Education

Achievement gaps

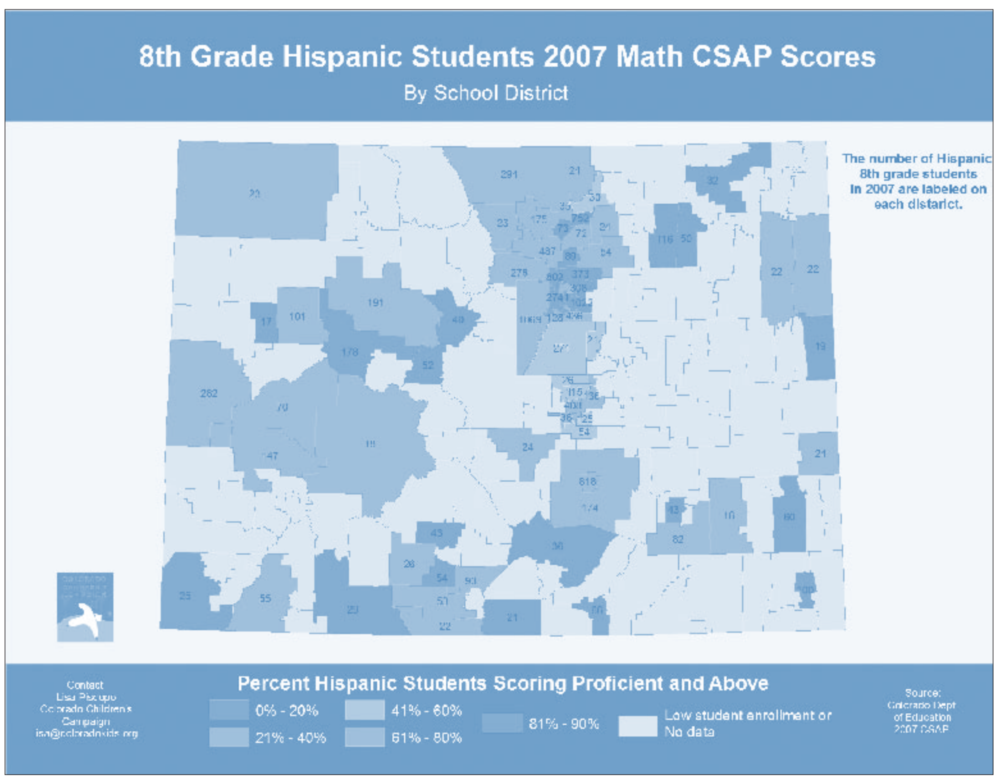
There are enormous gaps in achievement among Colorado's student groups, and the most immediately pressing gap in economic terms is the gap between Hispanic students and white/Asian students. Although all achievement gaps demand urgent attention, the demographics of our population make this gap the one that will have the most significant impact on Colorado's STEM economy. As noted previously, Hispanic students make up 27 percent of the total K-12 student population, and represent the fastest growing student group.

The chart on the right shows achievement gaps on the 2007 math CSAP assessments between white students and Hispanic students. These gaps have persisted for years.

Of all of Colorado's school districts with significant Hispanic student populations, only one (Cheyenne Mountain in Colorado Springs) saw a majority of its Hispanic 8th graders score proficient or above on the 2007 CSAP. While nearly all states see a gap in performance between white students and minority students, the NAEP test shows that Colorado's gaps are larger than average. For example, the national proficiency gap between white and Hispanic students is 26 percentage points. In Colorado, that gap is 35 percentage points -- our white students score higher than the national average and our Hispanic students score lower than the national average.[35]



Source: CDE



Teacher quality and quantity

Teacher quality is the most important school-based determinant of student achievement. In STEM subjects, teacher content knowledge has been shown to correlate with student achievement scores. For this reason, drafters of the federal No Child Left Behind act generally require teachers of secondary content areas to have majored in the subject area and to have passed a subject-area competency test in order to be considered "highly qualified." However, not many college students who major in STEM subjects consider teaching as a profession. The average salary for a high school teacher in Colorado is $46,000, while the average salary for aerospace engineers and mathematicians is $88,000, the average biochemist earns $78,000, and the average computer systems analyst earns $74,000.[36] Unfortunately, STEM majors can do the math.

A recent analysis by the Alliance for Quality Teaching found that of the 47,358 teachers in Colorado, nine percent taught math and six percent taught science. Due to relatively low enrollment in math preparation programs, "[m]ath is the subject where supply from Colorado preparation institutions may not be adequate."[37] As of 2004, Colorado had 19 traditional teacher preparation programs and 40 alternative preparation programs. Together, these programs enrolled close to 9,800 teacher candidates. Just four percent of teacher candidates were preparing for mathematics education, and just four percent were preparing for science education. As a state, Colorado does not keep data on the percentage of teacher preparation program graduates finding employment in Colorado, in STEM fields or otherwise, and there is no systematic collection and analysis of data that would allow the state to track and predict current and future STEM needs. Complicating the picture, many of Colorado's teachers are prepared out of state – 58 percent of all new teachers in 2005.[38]

There are several promising programs for recruiting teacher candidates to STEM fields. The University of Colorado at Boulder is actively integrating its education and sciences departments, both to improve science learning and to recruit teacher candidates from undergraduate science classes. For example, the Learning Assistants program at the University of Colorado at Boulder recruits undergraduates with proven success in science courses and an interest in teaching to assist science faculty in making their classes more interactive and student-centered. About 50 learning assistants are hired each semester for courses in six departments. Recruitment of science teacher candidates into the education program at CU-Boulder increased after the Learning Assistants program was implemented.[39] PhysTEC at CU-Boulder encourages physics majors to go into teaching by partnering with the School of Education to offer courses such as Teaching and Learning Physics.

Mid-career training for teachers is usually seen as a matter of local discretion in Colorado, although the state does require ongoing professional development as a condition of re-licensure for teachers. As a result, most professional development occurs at the local level, and is often governed by the individual teacher's choice (and often paid for by individual teachers). The Colorado Department of Education does use Title II-B funds from NCLB to administer funding for Mathematics and Science Partnerships. With these funds, high-needs school districts partner with institutions of higher education to enhance content knowledge and/or improve teaching skills of classroom teachers. Four Mathematics and Science Partnerships are currently funded in Colorado.

The Role of Career and technical education

Career and technical education (CTE), formerly known as vocational education, is in the process of revamping itself to integrate more rigorous academic content into applied learning situations. CTE is the forum for many of the most exciting innovations in STEM education today. For example, at Loveland High School, a math teacher and a CTE teacher are pairing to teach students geometry through construction. By the end of the course, students not only have learned the same geometry principles as in a traditional geometry class, but they have built an entire house themselves using these principles.[40]

Around the state, schools are beginning to explicitly incorporate biology principles into agriculture and health profession coursework; chemistry into process technology courses; and physics into automotive and motorcycle maintenance courses. STEM-based CTE is happening in schools as diverse as Denver's CEC Middle College (offering programs in architectural technology, forensics, and multimedia graphic design), Jefferson County's Warren Technical High School (biotechnology) and Colorado Springs' Mitchell High School (natural resource technology). Districts are also beginning to look into creating small CTE academies that can provide applied STEM education to students. CTE programs are also being designed to flow seamlessly into postsecondary education.

STEM Learning in Postsecondary Education

GRADUATES OF METRO DENVER-AREA COMMUNITY COLLEGE STEM PROGRAMS, 2006

	Discipline	Aims	Arap.	Red Rocks	Front Range	Aurora	Denver	Grand Total
Associate of Applied Science	Applied Tech					40	6	46
	Architectural & Construction Tech				8			8
	Computer Information Systems	28	6	11	35	12	13	105
	Construction Tech Cluster			24				24
	Electronics Tech		7		10			17
	Engineering Graphics Tech			13	7		10	30
	Horticulture & Landscape Technologies				21			21
	Water Quality Management Tech			6				6
Associate of Applied Science Total		**28**	**13**	**54**	**81**	**52**	**29**	**257**
Certificate (at least one but less than two years)	Architectural & Construction Tech				7			7
	Computer Information Systems	7		8				15
	Construction Tech Cluster			6				6
	Horticulture & Landscape Technologies				18			18
Certificate (1 but less than 2 yrs) Total		**7**		**14**	**25**			**46**
Certificate (less than one year)	Architectural & Construction Tech		26					26
	CAD/CADD Engineering Graphics Tech				11			11
	Communication Tech		20					20
	Computer Information Systems	50			30	16		96
	Construction Tech Cluster		8	32				40
	Engineering Graphics Tech			11	7			18
	Engineering Tech	7						7
	GIS Tech				17			17
	Manufacturing Tech			6				6
Certificate (less than 1 year) Total		**57**	**54**	**49**	**65**	**16**		**255**
Grand Total		**92**	**67**	**117**	**185**	**68**	**29**	**558**

Source: CCHE

According to Measuring Up, a national report on higher education statistics among the states, a Colorado 9th-grader's "chance for college" by age 19 is 40 percent.[41] While a large percentage (73%) of freshmen at Colorado's four-year colleges and universities return for their sophomore year, only a fair percentage (45%) of first-year students in community colleges return for their second year, a percentage that has declined substantially since 1992. Just over half (53%) of entering students will earn a bachelor's degree within six years.[42]

Once students are in Colorado postsecondary institutions, STEM areas enjoy a large share of degrees conferred. Colorado has the fourth-highest number of graduate students in STEM fields. In 2002-03, 38.1 percent of all higher education degrees conferred in Colorado were in STEM fields, compared to the national average of 29.7 percent. Colorado ranked first among all states in this measure. The National Science Foundation reports that there are 10.91 bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18-24 years old in Colorado, compared to the national average of 7.82. Similarly, there are 14.51 STEM graduate students per 1,000 individuals age 25-34 in Colorado, compared to the national average of 11.76. However, both of these ratios have dropped since 1993.[43]

Graduates of two-year, four-year, and graduate-level postsecondary programs are essential to a STEM workforce. The tables in this section provide a sense of the variety and size of community college and four-year STEM-related programs in the Denver metro area.

The primary challenge for Colorado's higher education system is funding. In its most recent report on Colorado's competitiveness, the Metro Denver Economic Development Corporation reported that it was "concerned with … the disconnect between the requirements of our high technology clusters and the low levels of funding provided for acquiring these skills. Most importantly, we are troubled by ongoing low higher education funding levels."[44]

GRADUATES OF METRO DENVER-AREA UNIVERSITY STEM PROGRAMS, 2006

Degree Level	Area of Study	UC Boulder	CSU	Metro State	UC Denver	UNC	UCCS	Mines	Grand Total
Bachelor's Degree	Agriculture		255						255
	Natural Resources	102	140	42					284
	Computer & Info Sciences	86	63	96	29		35	309	
	Engineering	431	276		103		63	438	1,311
	Engineering Technicians		178	33				211	
	Biology	513	282	97	104	32	94		1,122
	Mathematics	75	49	26	20	30	17	45	262
	Physical Sciences	83	33	33	9	61	51	15	285
Bachelor's Degree Total		1,290	1,276	327	265	123	260	498	4,039
Master's Degree	Agriculture		44						44
	Natural Resources	12	35		15				62
	Computer & Info Sciences	25	51		76		11	163	
	Engineering	300	98		70		21	120	609
	Engineering Technicians		19					14	33
	Biology	16	55		43				114
	Mathematics	25	14		11	9		20	79
	Physical Sciences	49	32					17	98
	Veterinary Sciences		10						10
Master's Degree Total		427	358		215	9	32	171	1,212
Doctoral Degree	Agriculture		6						6
	Computer & Info Sciences	12							12
	Engineering	64	16					12	92
	Biology	16	25		14				55
	Mathematics	6							6
	Physical Sciences	61	11						72
Doctoral Degree Total		159	58		14			12	243
Grand Total		1,876	1,692	327	494	132	292	681	5,494

Source: CCHE

Conclusion and Recommendations

There are several conclusions to be drawn from this discussion. First, Colorado K-12 students are doing relatively well in mathematics and science compared to the rest of the country, and our colleges and universities are producing relatively high numbers of STEM graduates. We can bask in that good news for only a little while, because the second conclusion is that our performance is not good enough given the workforce needs of our high-tech economy and reality of global competition.

Third, we are dragging our feet in addressing our most pressing issues:

- calamitous drops in mathematics achievement between the elementary and high schools levels;
- the fact that nearly one-quarter of college students educated in Colorado schools need remedial education in math;
- the fact that our K-12 science teachers admit that they are struggling to teach content well;
- the slow and uneven integration of technology into our schools;
- the huge achievement gap in STEM education experienced by our largest minority group;
- the gaps in educational experiences and opportunities among our highly diverse school districts; and
- the remarkably low funding levels for higher education in this high-tech state.

As Colorado investigates ways to improve the quality of its home-grown STEM workforce, it is important to understand that different areas of the state have different needs, both in terms of workforce and in terms of educational needs. While Colorado is one of the country's wealthiest states, communities on the Eastern Plains and in the San Luis Valley are struggling economically. A recent study analyzed economic, educational, and market conditions in each of Colorado's 58 counties. Analysts found that 25 of Colorado's counties are in the "most critical" or "critical" categories of an "Educational Needs Index." Colorado's challenges include a combination of rapid population growth and increasing diversity, together with depressed local economies and areas with low educational attainment. Report authors recommended that "[b]ecause of greater challenges facing certain regions of Colorado, policymakers should recognize that public policy regarding access to higher education, preparation for college, participation, and the economic demand for college-educated residents should not be uniformly applied from region to region."[45]

Colorado's proposal for the National Governor's Association STEM grant, funded in July 2007, may provide a model for the best way to improve education in our state. The project recognizes both our system of local control and the importance of state leadership in education reform by funding activities at two levels. At the state level, the project is funding work for the Governor's P-20 Council, identifying areas in which STEM education can be improved through greater state education alignment and coordination. At the regional level, the project is funding local STEM education compacts that will identify the STEM-related strengths and challenges of each region, making recommendations for state and local actions to improve STEM in ways that make the most sense for that region. This model allows for both local innovation and state direction and support – a necessary combination for Colorado to continue its role as a leading high-tech state.

Endnotes

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[23]By way of comparison, 58 percent of 4th graders and 51 percent of 8th graders in Massachusetts scored proficient or above.

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[25]ACT bases its college readiness math benchmark on scores that predict a 50% likelihood of earning a "B" or a 75% likelihood of earning a "C" in a college algebra class. Benchmarks in the various ACT subjects were derived from the actual performance of students in college.

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[38]Governor Ritter recently signed SB 07-140, establishing a commission to study the implementation of a statewide teacher identifier data system. Such a system would assist in the state's ability to track teachers and predict shortages.

[39]Otero, V., Finkelstein, N., McCray, R., Pollock, S. (2006). "Professional development: Who is responsible for preparing science teachers?" Science 28 July 2006, pp. 445-446.

[40]For more information, visit www.geometryinconstruction.org.

[41]National Center for Public Policy and Higher Education. (2007). "Measuring Up: The National Report Card on Higher Education." Retrieved October 1, 2007 at http://measuringup.highereducation.org/. "Chance for college" describes the probability that a 9th grader will graduate from high school in four years and immediately enter into postsecondary education.

[42]Ibid.

[43]National Science Foundation, Division of Science Resource Statistics (2006). Science and Engineering Indicators 2006. (Washington, DC: National Science Board).

[44]Development Research Partners (2007).

[45]Davis, H., Noland, B., and Kelly, P. (2006). "Colorado: Educational Needs Index State Report." (Educational Needs Index Project).

WHAT'S OUR COMPETITION DOING? STEM INITIATIVES IN OTHER STATES

According to national math and science assessments, Colorado is doing pretty well compared to other states. However, Colorado is struggling to close achievement gaps in STEM subjects, a serious problem given our rapidly growing Hispanic population. Colorado also spends relatively little state money on funding innovative new projects and statewide initiatives in education. Other states are able to move more responsively and effectively at a state level, meaning that if Colorado stays where it is, we are actually falling behind. This essay reviews STEM initiatives in other states, to give us an idea of how other states are thinking about STEM education and to inspire us to make sure we continue to stay near the top of the heap.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Alabama	18	n/a	24	n/a	3

Alabama, a traditionally poor state, starts with a disadvantage, and its NAEP scores tend to reflect this. The Alabama Math, Science, and Technology Initiative (AMSTI) provides selected schools with extensive professional development, all of the equipment and materials needed to engage students with hands-on, inquiry-based learning, and on-site assistance from content specialists. As a state-funded initiative, these benefits are provided at no cost to the schools. Evaluations show that AMSTI schools are outperforming other schools not only in math and science, but also in other subject areas. State funding for AMSTI in 2008 is $35.8 million, allowing the initiative to expand beyond the current 365 AMSTI schools.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Indiana	35	20	29	10	6

Biocrossroads, a market-driven public-private partnership dedicated to bringing life sciences industry to Indiana, recently coordinated the formation of the Indiana K-12 STEM Resource Network. Based at Purdue University, the I-STEM Resource Network will provide high-quality professional development for teachers, hands-on learning opportunities for students, and the creation of formal linkages between K-12 and higher education STEM teachers.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Massachusetts	51	19	41	9	13

Even with top math and science achievement scores, Massachusetts is concerned that it is not graduating enough STEM students to meet economic demand. The Robert H. Goddard Council, comprised of business, education, and government leaders, is charged with advising the state department of higher education and the legislature on STEM workforce issues. In 2003, the state established the "pipeline fund," directing $6.5 million in grants to local and regional STEM education improvement projects, including professional development, after school and summer STEM education, implementation of new curricula, and the like. By 2010, the state will require students to pass state assessments in science and technology/engineering to be eligible to graduate.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Minnesota	43	18	40	14	5

Minnesota, another top-scoring state, is aggressively pursuing STEM improvement efforts. A STEM roundtable convened by the governor made recommendations for improving the rigor of math and science in career and technical education programs. The state provides funds for districts to increase AP and IB offerings and provides extensive professional development for AP/IB teachers. State funds are available to help teachers infuse digital content into their instruction, and to fund Lighthouse Schools designed to improve STEM teaching and achievement. STEM toolkits have been provided to every school. Minnesota has also launched a public awareness campaign directed at students and families, and hosted a STEM summit in 2006 for students to network with STEM business representatives.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
North Carolina	34	23	22	13	8

The North Carolina New Schools Project was launched in 2004 through a public-private partnership to create small high schools with economic development themes that focus on STEM fields. The project received $11 million from the Bill and Melinda Gates Foundation. Ten schools opened in 2005 with themes such as health and life sciences, engineering, and biotechnology. Thirty-four redesigned high schools, 42 early colleges, and ten new STEM-focused high schools have opened as of the 2007-08 school year. The "Learn and Earn" early colleges provide both high school diplomas and associate's degrees to graduates.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Ohio	35	25	35	24	2

Ohio recently passed the Ohio Innovation Partnership, which will provide $100 million in scholarships for students who choose to study in or become teachers in STEM fields, and $50 million to recruit scholars tied to job creation in Ohio's regional economies. Ohio also recently allocated funds to support up to ten regional summer academies that prepare 11th- and 12th-grade students to enroll in college-level STEM courses and encourage them to pursue a teaching career in a STEM discipline. Students successfully completing these courses will earn dual high school and college credits.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Texas	35	23	23	12	45

In 2005, Texas announced the Texas Science, Technology, Engineering, and Math Initiative (TSTEM), an $80 million public-private partnership to improve access to STEM learning for low-income and minority students. The state is funding $20 million of this effort with state funds, and $10 million with federal funds. TSTEM is a part of the state's $180 million Texas High School Project. TSTEM is in the process of establishing 35 small schools that offer focused learning in STEM subjects in the most disadvantaged areas of the state and five to six STEM centers that will develop high-quality STEM teachers and schools. The STEM academies will be a mix of charter schools, traditional public schools, and schools operated in partnership with higher education institutions. All STEM academies begin in 6th grade and will feature partnerships with STEM employers.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Washington	36	13	32	9	14

Washington's new GET Ready for Math and Science scholarships will provide $28 million in public and private funds to encourage high school students who score well on the state's math and science assessments to major in STEM fields and work in the state after graduation. Washington also implemented LASER in 1999, an initiative that provides professional development, materials support, and technical assistance necessary to implement inquiry-based science learning that is aligned with the state's science standards. Recent evaluations showed that 5th-graders' science scores increased with the amount of the LASER curriculum to which they were exposed and the level of professional development experienced by teachers. Evidence also suggests that LASER works well with disadvantaged student populations.

STATE	% 8TH GRADERS PROFICIENT IN MATH	% HISPANIC 8TH GRADERS PROFICIENT IN MATH	% 8TH GRADERS PROFICIENT IN SCIENCE	% HISPANIC 8TH GRADERS PROFICIENT IN SCIENCE	HISPANIC STUDENTS AS % OF TOTAL STUDENT POPULATION
Colorado	37	13	34	12	27

So how is our state doing with major STEM initiatives? We have secured important grants from outside sources such as the National Governors' Association, the National Science Foundation, and the U.S. Department of Labor's WIRED initiative, but the state itself invests next to nothing.

In 2001, the legislature passed HB 01-1365, a bill providing for Science and Technology Education Center grants centered on "space simulation" activities to "ensure that all students are technologically literate for the dawn of the 21st century and equipped with the science, math, and critical thinking skills essential for enhancing learning and improving productivity and performance." No appropriations have been made for this program since 2002.

Recent legislation (HB 07-1243) encouraging the establishment of STEM-related after-school programs had no funds accompanying it. Instead, the legislation suggested that it would be funded through "gifts, grants, and donations." This phrase, common to Colorado legislation, is generally translated as "the state is not willing or able to pay for this, but we sure hope someone else will step up."

That's about it for Colorado-funded STEM initiatives. You do the math.

GET THOSE TEACHERS OUT OF THE CLASSROOM! OR WHY STEM TEACHERS NEED TO KNOW ABOUT THE REAL WORLD

Carole Basile, Ed.D.

Associate Professor, School of Education and Human Development

University of Colorado Denver

I know that a lot of diverse conditions need to be in place for students to successfully learn STEM content and skills. Through my work as a professor in the field of education, director of the University of Colorado Denver's math and science center, and co-principal investigator/director of a National Science Foundation Math and Science Partnership grant, I have found that these conditions include quality teachers, experiential learning, challenging courses, informal and extracurricular activities, viable social environments that promote math and science education, technological resources and materials, and scholarships and funding. All are important, but teacher quality stands as first among equals. As we look to improve STEM education in Colorado, we need to know that the traditional methods of preparing and training teachers will not provide the essential condition of teacher quality in STEM education.

Without teachers who have knowledge in content and skills in instruction, students will be hard-pressed to access any of the other conditions necessary for success. The federal No Child Left Behind law calls for "highly qualified teachers." However, being highly qualified doesn't necessarily mean being high quality. Teachers need both content and pedagogical content knowledge to be effective in the classroom. In addition, teachers also need to understand the workforce opportunities that exist for their students and how that changes what they teach and how they teach it. Except for second-career teachers who have recently moved into education from business and industry, most teachers do not understand issues of economic development, changing technologies, or the needs of industry sectors. All teachers can't know everything, but isolation from the workforce and dependence on standards and high-stakes test questions will not help prepare students for the future.

Through a number of current initiatives including those funded by the U.S. Department of Labor, National Science Foundation, and other local business and foundation support, we are seeing industries focusing on partnerships with P-20 institutions in order to understand more about the current education system and environment. They are developing opportunities for teacher professional learning that introduces teachers to workforce opportunity and provides outreach to their students through field trips, internships, and guest speaker forums. Also through these efforts, we can find universities that are teaching content courses specifically to teachers in order to build their content proficiency and exposing them to inquiry-based learning that allows them to connect content with real-world problems. Community colleges are aligning themselves with industry sectors and are recruiting teachers who are interested in exposing their students to these specialized programs. And there are K-12 districts looking at standards and essential learnings to try and understand what is important for workforce development, and reaching out to higher education and industry for partnerships that can provide classroom teachers with the professional learning they need to help students make the connections.

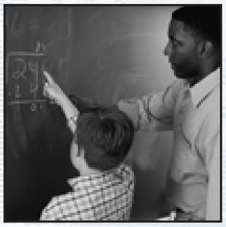
For example, a group of Colorado high school teachers representing a variety of disciplines recently spent a week with me exploring issues of economic development and the opportunities for students after they leave high school. The group visited community colleges and universities and spoke with industry and economic development representatives. When the week was over, the teachers commented on how in just one week, their eyes had been opened. They now understood why Colorado's content standards were important and how they related to the real world, and realized that they needed more exposure to what was going on in the world (and more than just reading "The World is Flat!"). The teachers concluded that what they had been doing in the classroom was not going to get their students where they needed to be. As a result, the teachers are now in the process of revamping curriculum and experiences for students so that the access points are available to all students.

In another project based in Colorado, K-12 teachers are learning more content through experiential learning. By visiting the National Renewable Energy Lab, United States Geologic Survey, Dinosaur Ridge, the Denver Museum of Nature and Science, the National Oceanographic and Atmospheric Administration and other scientific research sites along the Front Range, teachers are learning about the connections between disciplines, understanding how math, science, and social science fit together. The West Chamber Serving Jefferson County, an economic development group, is providing experiences for teachers to visit local businesses and industry and learn more about what people do, see first-hand the explosion of technological innovation, and work with businesses to create problem-based curricula that utilize examples from the workplace.

And finally, a major National Science Foundation grant is supporting Colorado teachers by providing courses that increase the content knowledge of teachers as well as their self-confidence to teach the content, with every course taught by professors in the sciences and education as well as colleagues in the K-12 sector. Many of the courses include experiential components and industry connections. Preliminary data indicate increases in teacher self-efficacy, student achievement scores, and the overall ability of teachers to become leaders in math and science instruction. Participating teachers say that because they are better able to make workforce connections, their students are able to grasp concepts more quickly: "It is very important for students to come up with their own questions and ways to solve them—it is a good way to promote critical thinking." One teacher stated that as a result of his new instructional strategies, he saw students more engaged and paying more attention. He believes that their learning "sticks much more than it used to."

What we're learning from these experiences about teaching and learning is important and critical for teachers and students. Unfortunately, these activities are episodic and based on external funding. They do not represent mainstream thinking about how to incorporate these learnings into the general education system for teachers so that it is part of teacher pre-service and professional learning. There isn't a teacher education standard for "relevance" and making connections with workforce issues, but maybe there should be. Staff developers in school districts should be giving these connections more thought and figuring out how it fits in the bigger professional learning plan. Industries and universities need to be reaching out to school districts to help them think about this work and determine where and when the best connections can be made. This may also have implications for state content standards, as we consider whether every standard should have a direct link to the broad workforce community.

The implications for preparation and professional learning of preservice and inservice teachers are clear. The isolation of teachers in the classroom, the school, the education system must stop. Teachers cannot use resources or make resources available to students if they do not know what they are or how to use them; and they cannot guide students or help them to understand why knowledge is important if they do not understand it themselves. Ultimately, teachers cannot be held accountable for not meeting the needs of our industry partners and provide generations of capable and competent employees if, after they have been exposed to the resources, they still do not have the funding to provide students with the access to challenging courses, experiential learning, scholarships, technology, materials, informal and extracurricular programs that we know are conditions of student success.



Did You Know...

Did you know ...
During the next eight minutes ….

60 babies will be born in the U.S.

244 babies will be born in China.

351 babies will be born in India.

Did you know . . .
China will soon become the number one English speaking country in the world.

2006 college graduates:

In the U.S. – 1.3 million

In India – 3.1 million

In China – 3.3 million

Name this country . . .
- Richest in the world
- Largest military
- Center of world business and finance
- Strongest education system
- Currency the world standard of value
- Highest standard of living
- *Great Britain. In 1900.*

The U.S. Department of Labor estimates that today's learner will have 10-14 jobs . . .
by the age of 38.

Many of today's college majors didn't exist 10 years ago
New media

Organic agriculture

e-business

Nanotechnology

Homeland security

What will they study 10 years from now?

Did you know . . .
Today's 21-year-olds have:

Watched 20,000 hours of TV

Played 10,000 hours of video games

Talked 10,000 hours on the phone

And they've sent/received 250,000 emails or instant messages.

More than 50% of U.S. 21-year-olds have created content on the web.

More than 70% of U.S. 4-year-olds have used a computer.

The Internet started being widely used in 1995 ...
One out of every eight couples married in the U.S. last year met online.

More than 230,000 new users signed up for MySpace …Today.

If MySpace were a country, it would be the eighth-largest in the world.

Did you know . . .
We are living in exponential times.

There are over 2.7 billion searches performed on Google each month...

To whom were these questions addressed B.G.? (Before Google)

The first commercial text message was sent in December 1992.

The number of text messages sent and received every day exceeds the population of the planet.

There are about 540,000 words in the English language . . .About five times as many as during Shakespeare's time.

More than 3,000 new books are published . . . Daily.

It's estimated that a week's worth of New York Times . . . Contains more information than a person was likely to come across in a lifetime in the 18th century.

It's estimated that 40 exabytes (that's 4.0 x 1019) of unique new information will be generated worldwide this year. That's estimated to be more than in the previous 5,000 years.

The amount of new technical information is doubling every two years. It's predicted to double every 72 hours by 2010.

Nearly 2 billion children live in developing countries

One in three never completes fifth grade.

The One Laptop per Child project is expecting to ship between 50 and 100 million laptops a year to these children.

Kids who have never held a textbook before will hold the world and be connected … to you.

Predictions are that by 2013 a supercomputer will be built that exceeds the computation capability of the human brain . . .

By 2023, a $1,000 computer will exceed the computation capability of the human brain . . .

And while technical predictions further out than about 15 years are hard to do . . .

Predictions are that by 2049 a $1,000 computer will exceed the computational capabilities of the human race.

What does it all mean?

We are currently preparing students for jobs and technologies that don't yet exist . . . in order to solve problems we don't even know are problems yet.

"We can't solve problems by using the same kind of thinking we used when we created them." – Albert Einstein

Ask your kids: Are you doing this in school?

Ask your principal: How are you helping my child become literate in the 21st century?

Ask your school board: Are you providing the resources and training necessary to prepare students to be successful in 21st century society?

Ask your elected representatives: Now that you know all this, what changes should be made to current education legislation?

What's your vision?
Shift Happens.
Now you know . . .

This text is adapted from text of a PowerPoint presentation first developed by Karl Fisch, Director of Technology at Arapahoe High School in Colorado's Littleton School District, with assistance from Scott McLeod. Fisch created the presentation in 2006 to challenge the thinking of 150 AHS teachers around technology and student learning. Since that time, the presentation has been enhanced by XPlane, posted on YouTube, and generally shared around the world.

To view various versions of this presentation, learn about its creators, find source materials, and join in a wiki conversation about Shift Happens, visit http://shifthappens.wikispaces.com/

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