Taking the pulse of bioscience education in America:
A State-by-State Analysis

A Report Prepared by Battelle in Cooperation with Biotechnology Industry Organization (BIO) and the Biotechnology Institute

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Prepared by:
Battelle Technology Partnership Practice

In Cooperation with:
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May 2009

Acknowledgements

The project team wishes to thank BIO's state affiliates, contacts in State Departments of Education and others who provided input for this report. Thanks are due to the individuals who responded to our web surveys and to the state bioscience association staff who identified state education contacts and bioscience education programs, and reviewed draft profiles, often under tight timelines. Without their cooperation, this effort would not have succeeded. Thanks are also due to Battelle and BIO for their financial support of this effort.

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Executive Summary

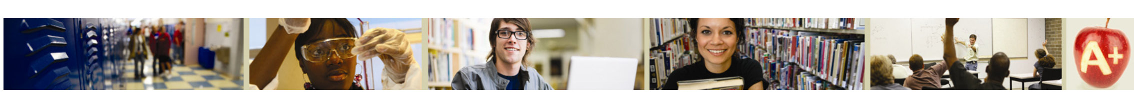
The severe economic downturn facing the nation and the world in 2009 makes it difficult to focus on issues beyond the short-term imperative of improving our economic footing and reversing the deep declines in jobs. But, just beyond today's economic ups and downs are warning signs that the United States is slipping in generating the skilled, educated workers needed to meet the demands for a highly trained, technical workforce in today's knowledge-based economy. As the National Academies warned in its 2005 report, *Rising Above the Gathering Storm*: "Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength."[1] In particular, the interest of students to pursue science, technology, engineering, and mathematics (STEM) skills and careers seems to be diminishing.

This trend poses particular challenges to growing economic drivers for the nation, such as the bioscience industry sector, which must maintain an edge against global competitors. In *Technology Talent and Capital: State Bioscience Initiatives 2008*, Battelle and the Biotechnology Industry Organization (BIO) reported that nearly all states have an economic specialization in one or more subsectors of the biosciences—so the bioscience industry is truly a large and fast-growing technology industry driver with a national footprint. For the bioscience industry, the prospect of the United States losing its competitive advantage—no less facing declining levels—in the educational attainment and resulting skills of our nation's workforce presents a considerable competitive challenge.

Bioscience workers are needed to conduct research; translate innovation into product development and improved health care techniques; and, ultimately, to manufacture biomedical and other bioscience-related products. Thus, ensuring the availability of an educated, skilled workforce is critical to developing and sustaining a highly competitive, robust bioscience cluster over the long term.

Yet, what makes the bioscience industry sector stand out is its application of a unique and growing body of knowledge on how humans, plants, and animals function. This, in turn, places unique demands on the skills and knowledge of bioscience workers, including understanding advanced molecular biology, operating specialized instrumentation, and interpreting biological data generated. In addition, the translation of biological knowledge to advancing health treatments requires specific regulatory oversight, rigorous clinical trials, and ongoing quality assurance unique to the bioscience industry sector.

[1] *Rising Above the Gathering Storm*. National Academies Committee on Science, Engineering, and Public Policy; 2005; page 4.



It is also critical for the American society that the public is well-informed about the promise and challenges of biotechnology. Recent national legislation on genetic testing is a harbinger of the complex issues that the biosciences will pose in the years ahead.

Such demands raise the question of just how well the future workforce is being prepared to supply the talent that will be needed. Specifically,

- How well are students being prepared in the biosciences in particular and in science and mathematics in general?
- How and to what extent are states incorporating the biosciences into school curricula?
- How well prepared are science teachers to teach students about the biosciences?
- To what extent are students exposed to the biosciences and made aware of career opportunities and educational requirements?
- To what extent have states recognized the need to incorporate the biosciences in K-12 education and how have they done so?

In an effort to begin to answer these questions, Battelle and BIO joined with the Biotechnology Institute to undertake this study of bioscience education in the 50 states, Puerto Rico, and the District of Columbia.

Using various sources of existing secondary data supplemented by data collected by Battelle focused specifically on the biosciences, the study team examined four aspects of state performance and activities in bioscience education at the middle and high school level:

- Student achievement in both the biosciences and broader science and mathematics education as measured by performance on national tests
- State standards and requirements with regard to the biosciences
- Bioscience teacher quality and preparation
- Bioscience experiential learning and career awareness.

Collecting these data was challenging as it is difficult to separate the biosciences from general science education. Also, many state Departments of Education were unable to provide information on topics such as how many of their high school graduates have completed biology courses or how many career and technical education (CTE) students are enrolled in specific bioscience courses. As a result, the data are not comprehensive. Thus, this report should be viewed as an initial step in a process to develop better indicators of the state of bioscience education in the United States.

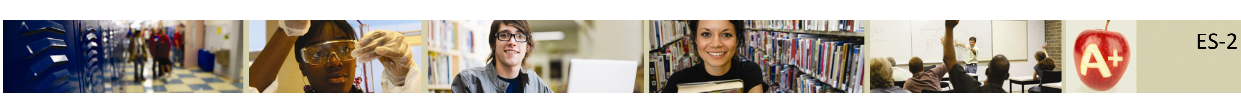
SOURCES OF ACHIEVEMENT DATA

The **National Assessment of Educational Progress (NAEP)** is the only nationally representative assessment of student knowledge across a variety of subjects administered in the United States for students in grades 4, 8, and 12.

Advanced placement (AP) tests are administered by the College Board and are used to give high school students college credit for advanced work.

The **American College Test (ACT)** is a standardized achievement exam for college admissions and is oriented toward measuring a student's knowledge.

The **Scholastic Aptitude Test (SAT)** is also a standardized exam for college admissions administered by the College Board and is oriented toward measuring a student's aptitude.



Key Findings

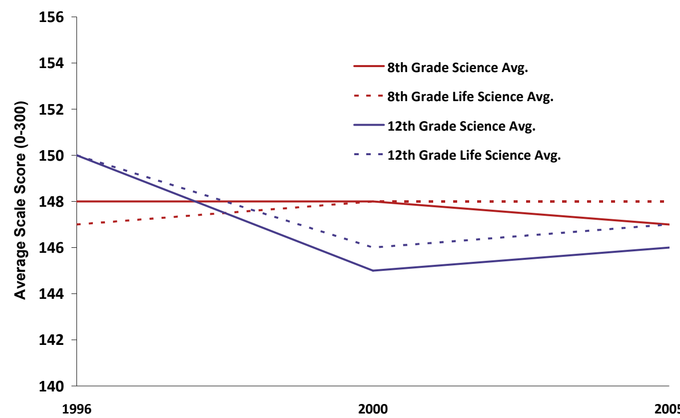
Measures of student achievement nationally suggest that states are not measuring up in terms of overall science and life science education.

Overall national data on life sciences achievement are spotty, but the indications clearly suggest that our nation is falling short.

8th and 12th grade students are performing poorly in science achievement and have shown no improvement over time according to the most recent results from the National Assessment of Educational Progress (NAEP). NAEP is the only nationally representative state-by-state assessment of achievement. The most recent NAEP science results were completed in 2005. Life sciences is a major portion of the overall NAEP science test and is broken out for 8th and 12th graders.

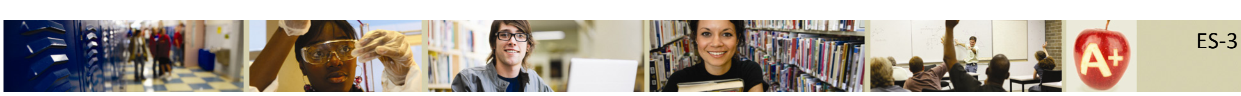
- Only 52% of 12th graders are at or above a basic level of achievement in the sciences, and for 8th graders only 57% are at a basic level of achievement.
- Average scores for 12th graders in the sciences and the life sciences have actually declined from 1996 to 2005 and shown no improvement for 8th graders both on overall science and the life science component.
- Even in states with the highest scores, fewer than half of 8th graders are "proficient" in science. The percentage of 8th graders in each state that tested as proficient in science on the NAEP test ranged from a high of 43% to a low of just 14% in 2005.[2]
- A significant gap exists in science achievement for low-income middle-school students, although it narrowed between 2000 and 2005. Only 37% of 8th grade low-income students reached even a basic level of science knowledge on the NAEP test, as compared with 57% of all 8th grade students. However, low-income students achieved a 5% improvement in science scores between 2000 and 2005.

Declining 12th grade science achievement and no improvement in 8th grade NAEP science scores.



High schools are not preparing students to pursue college-level science. The American College Test (ACT) is a national standardized test for college admission that is designed to draw subject-specific conclusions on the preparedness of high school exam takers for college-level coursework in a variety of subjects including biology. ACT has determined that those students who achieve a score of 24 in the science section of the ACT have a 50% chance of obtaining a B or higher in college-level biology. On average, only 28% of the high school students taking the ACT reached a score indicating college readiness for biology and no state reached even 50%.

[2] Six states and Puerto Rico did not participate in the NAEP: Alaska, Iowa, Kansas, Nebraska, New York, and Pennsylvania.



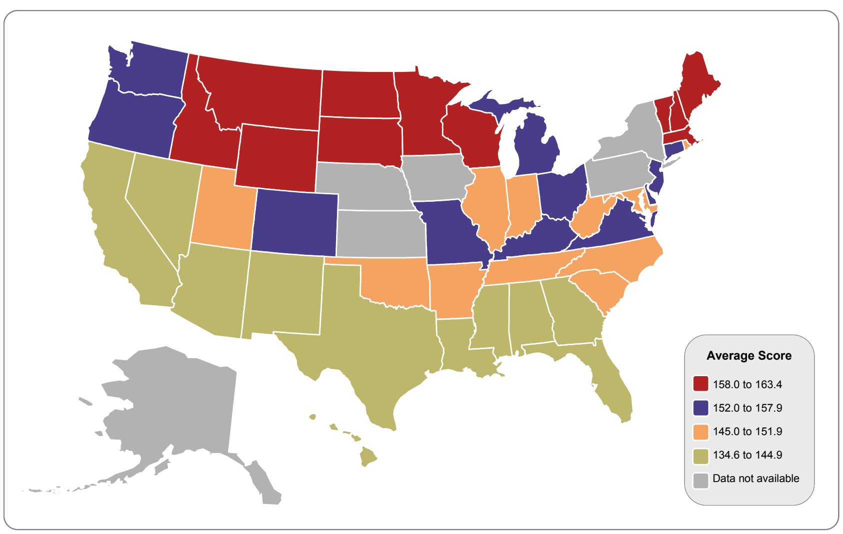
Wide disparities exist among states in student performance in the biosciences and broader sciences.

Bringing together four of the key student achievement measures in the biosciences, science, and math suggests that, even with the nationally lagging bioscience performance across all states, a number of states stand out as performing considerably better than others.

While it is difficult to give a single grade across states because of the limited quality and comparability of the student achievement data, the patterns of student performance across the measures displayed in Table ES-1 suggest the states fall into several broad categories.

- **Leaders of the Pack**
  (at least two in quartile 1, remainder in quartile 2): Connecticut, Massachusetts, Minnesota, New Hampshire, New Jersey, Ohio, Vermont, Wisconsin
- **Second Tier**
  (mix of quartiles 1–3, none in quartile 4): Colorado, Delaware, Idaho, Illinois, Maryland, Missouri, North Carolina, North Dakota, Oregon, Rhode Island, South Dakota, Tennessee, Utah, Virginia, Washington
- **Middling Performance**
  (mix of quartiles 2–4 with at least one in quartile 4): Alabama, Arizona, California, Hawaii, Indiana, Kentucky, Maine, Michigan, Montana, South Carolina, Wyoming
- **Lagging Performance**
  (quartiles 3 and 4 across all measures): Arkansas, Florida, Georgia, Louisiana, Mississippi, Nevada, New Mexico, Oklahoma, Texas, West Virginia
- **Not Rated:** States that did not participate in the NAEP science assessment in 2005 were not rated.

Table ES-1 (next page) shows student performance data by state. The color coding denotes the performance of each state relative to all 50 states and the District of Columbia



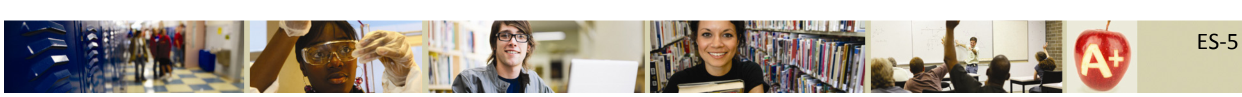
Striking Regional Differences in 8th Grade NAEP Life Science Average Scores for 2005 with Northeastern, Mountain and Upper Midwest regions standing out as higher performers.

Table ES-1. Student Performance in Bioscience and Math Indicators by State

Ranks in **top quartile** of states | Ranks in **2nd quartile** of states | Ranks in **3rd quartile** of states | Ranks in **lowest quartile** of states

State	8th Grade NAEP, Avg. Life Sciences Score, 2005	Percent of AP Biology Students Scoring 3 or Higher, 2008	Percent of ACT Tested Students Ready for College-level Biology, 2008	ACT-SAT Math Avg. Indexed Relative to the U.S., 2008*
U.S. Average	**148.2**	**49.8%**	**28%**	**1.00**
Alabama	141.6	50.4%	21%	0.94
Alaska	N/A	56.2%	31%	1.01
Arizona	141.2	45.0%	30%	1.03
Arkansas	145.4	21.4%	22%	0.97
California	136.3	50.9%	32%	1.02
Colorado	155.6	45.3%	25%	0.99
Connecticut	152.9	68.0%	40%	1.02
Delaware	152.1	51.3%	37%	0.98
District of Columbia	N/A	53.2%	21%	0.89
Florida	141.9	32.3%	19%	0.96
Georgia	144.7	43.7%	23%	0.97
Hawaii	137.1	46.3%	31%	1.00
Idaho	158.5	59.0%	29%	1.03
Illinois	149.2	57.1%	27%	1.00
Indiana	151.2	38.3%	32%	1.00
Iowa	N/A	57.3%	37%	1.06
Kansas	N/A	53.6%	33%	1.05
Kentucky	153.8	34.9%	25%	0.98
Louisiana	139.8	43.6%	20%	0.95
Maine	159.3	45.2%	37%	0.92
Maryland	147.0	50.6%	34%	0.99
Massachusetts	161.5	60.0%	40%	1.04
Michigan	154.4	56.8%	23%	0.95
Minnesota	159.2	49.9%	40%	1.09
Mississippi	134.6	15.0%	13%	0.88
Missouri	154.9	49.5%	31%	1.01
Montana	162.2	42.5%	33%	1.05
Nebraska	N/A	34.6%	35%	1.05
Nevada	137.8	32.0%	28%	1.00
New Hampshire	162.6	66.9%	39%	1.03
New Jersey	155.7	63.9%	35%	1.01
New Mexico	138.5	45.9%	22%	0.96
New York	N/A	56.7%	43%	1.01
North Carolina	145.2	50.6%	28%	1.00
North Dakota	163.4	43.4%	31%	1.04
Ohio	156.8	58.1%	33%	1.03
Oklahoma	146.2	30.7%	24%	0.96
Oregon	154.6	48.2%	29%	1.02
Pennsylvania	N/A	55.4%	34%	0.99
Rhode Island	147.7	54.1%	31%	0.98
South Carolina	146.7	55.0%	19%	0.96
South Dakota	161.9	48.9%	35%	1.05
Tennessee	146.6	51.2%	23%	0.97
Texas	143.7	40.0%	25%	0.99
Utah	151.7	46.4%	32%	1.01
Vermont	163.0	59.3%	38%	1.03
Virginia	157.9	48.1%	32%	1.00
Washington	154.6	45.6%	40%	1.05
West Virginia	147.7	31.5%	23%	0.94
Wisconsin	158.6	55.7%	38%	1.07
Wyoming	158.6	30.9%	27%	1.00

Table 1 Source: Battelle analysis of data from the U.S. Department of Education, National Center for Education Statistics; the College Board; ACT, Inc.
Note: NAEP = National Assessment of Educational Progress
*ACT-SAT Math Average is an index of state averages in both exams relative to the U.S. and weighted by the share of high school graduates in each state taking each exam (U.S. average = 1.00).



There is an uneven record across states in incorporating the biosciences in state science standards, supporting focused bioscience education programs and advanced bioscience courses, and ensuring well-qualified science and bioscience teachers.

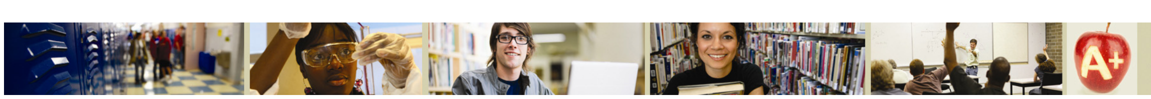
Thirty-one states reported that their science standards explicitly mention or define standards or applied laboratory or other instruction tools specifically for biotechnology or the biosciences. Some of these standards require that students be acquainted with career opportunities in the biosciences; others require that students be involved in hands-on activities. The vast majority, however, discuss the societal impact of biotechnology and the risks and benefits associated with its applications.

At least half the states have at least one school with a bioscience focus, and all of the states have schools with a focus on broader Science, Technology, Engineering, and Math (STEM) education. There is also a growing practice across states of advancing defined bioscience programs within existing high schools that link with advanced courses in biotechnology, offer hands-on laboratory experiences, and raise career awareness.

States do not seem to be succeeding at encouraging high school students to take upper-level science courses, although data on this subject are very limited. The vast majority of high school graduates, 92% nationally in 2005, take a basic course in biology during their high school years even though only half the states require biology for high school graduation. However, the level of advanced biology courses, which indicate the depth of bioscience learning in high school, is less widespread. One way to measure the extent to which high school students are taking more advanced biology courses would be to vet the level of participation in AP biology courses. Data on the number of students enrolled in AP classes are not available, however, as the College Board tracks only students who take the AP exam, not all course participants.

To get some feel for participation in AP biology, the study team examined the number of students taking the AP biology exam as a percentage of recent high school graduates. Nationally, on average only 4.6% of high school graduates have taken the AP biology exam as compared to 10.5% of students taking a science AP exam. Among states, the biology share ranges from 1.4% to 9.6%.

States continue to struggle with having a sufficient number of well-qualified science and bioscience teachers despite efforts to attract both undergraduates and mid-career professionals to science teaching. Nearly one in eight U.S. high-school biology teachers was not certified to teach biology. The average share of biology teachers who are certified in a given state ranged from 50% to 100% in data collected by the Council of Chief State School Officers (CCSSO), although 88% of teachers are certified nationally on average.



Still, nearly every state has professional development programs designed to provide middle and high school teachers with the training, equipment, supplies, and support to expose their students to biotechnology and the biosciences; but, these programs tend to be grant funded and often serve only a limited number of teachers. In most states, numerous workshops, conferences, and summer institutes are offered by colleges and universities, laboratories, and other science-related organizations to provide middle and high school teachers with the expertise to incorporate biotechnology into their science classes. In only a few states is there a systematic approach designed to reach all areas of the state and impact a larger number of teachers and thus students.

Experiential learning and career awareness programs are extremely widespread with colleges, universities, museums and other science-based organizations providing services that include field trips, on-site classes for school groups, summer camps, workshops and internships. There also are programs that provide research experiences for high school students and mobile bioscience laboratories that offer students and teachers the opportunity to conduct hands-on experiments. Every state has at least one experiential learning and outreach program in the sciences and the majority have programs focused on the biosciences. but such efforts are limited in the number of students they reach.

A study of outreach programs in the Bay area found that

- The majority of public school students are not served through the outreach programs of the region's science-rich educational institutions
- Most outreach programs are less than two hours in length
- Different types of programs tend to serve different populations. Summer camps do not tend to serve a very diverse audience, while out-of-school classes (in particular) and teen internship programs (to a degree) are able to serve a more diverse audience.[3]

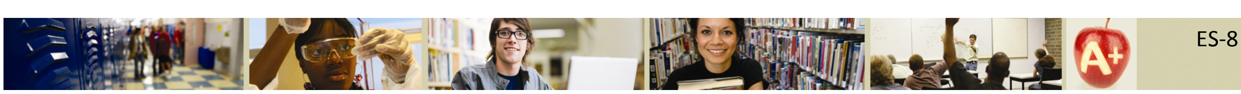
Table ES-2 (next page) provides data on state standards, requirements, and teacher quality.

[3] Maia Werner-Avidon, Rena Dorph, PH.D., with Scott Randol, Ph.D. *Assets and Capacities to Support Bay Area Science Learning Opportunities: Results from the Science-Rich Educational Institutions Asset Study.* University of California, Berkeley, December 2008.

Table ES-2: Indicators of State Commitment to Bioscience Education

	Standards Address Biotechnology	Scientists Provided Input	Dedicated State Science Standards Staff	Biology Required	AP Biology Exam Takers (% of all H.S. Grads)	Certified H.S. Biology Teachers (% of total)
Alabama		N/A	N/A	■	2.7%	N/A
Alaska					2.2%	75%
Arizona	■	N/A	N/A		2.2%	N/A
Arkansas	■	■	■	■	6.1%	95%
California	■	■	■	■	6.5%	84%
Colorado	■	N/A			5.0%	94%
Connecticut	■	■	■		5.8%	99%
Delaware	■	■		■	5.2%	92%
District of Columbia		N/A			9.6%	N/A
Florida	■	■	■		5.8%	N/A
Georgia		■	■	■	5.2%	92%
Hawaii	■	N/A	N/A		5.4%	50%
Idaho		■	■	■	2.4%	99%
Illinois		■			3.9%	79%
Indiana		■	■	■	4.2%	95%
Iowa		■	■		2.1%	N/A
Kansas		■	■	■	1.5%	97%
Kentucky		N/A	N/A	■	3.5%	N/A
Louisiana	■	N/A	N/A	■	1.4%	N/A
Maine		■	■	■	5.4%	92%
Maryland	■	■	■	■	6.9%	N/A
Massachusetts	■	■	■		7.1%	N/A
Michigan	■	■	■	■	4.5%	N/A
Minnesota	■	■	■	■	3.6%	100%
Mississippi	■	N/A	N/A	■	2.6%	N/A
Missouri		N/A	■	■	2.4%	100%
Montana	■	■	■		3.4%	N/A
Nebraska	■	■	■		1.8%	N/A
Nevada	■	■	■		5.0%	N/A
New Hampshire	■	N/A	N/A	■	3.7%	N/A
New Jersey	■	N/A	N/A		5.6%	N/A
New Mexico	■	■			2.5%	100%
New York	■	N/A	N/A	■	7.6%	91%
North Carolina	■	N/A	N/A	■	5.1%	90%
North Dakota	■	N/A	N/A		2.1%	100%
Ohio	■	N/A	N/A	■	3.3%	85%
Oklahoma	■	■	■	■	2.7%	99%
Oregon		N/A	N/A		3.3%	N/A
Pennsylvania	■	N/A	N/A		3.5%	98%
Rhode Island		■	■		4.7%	N/A
South Carolina		N/A	N/A		3.8%	N/A
South Dakota		■	■	■	3.5%	99%
Tennessee			■	■	3.3%	N/A
Texas		■	■	■	3.3%	72%
Utah	■	N/A	N/A		5.0%	90%
Vermont	■	■	■		5.9%	N/A
Virginia	■	■	■		5.6%	99%
Washington	■	N/A	N/A		4.0%	N/A
West Virginia	■	■	■	■	2.8%	95%
Wisconsin		■	■		4.4%	100%
Wyoming			N/A		2.3%	N/A
Puerto Rico		N/A	N/A	N/A	N/A	N/A

Table ES-2 Source: Battelle national surveys and analysis of state K-12 science standards; the College Board; Council of Chief State School Officers data on certification of biology teachers.
Note: N/A = data not available.



Nearly every state surveyed for this study identified a bioscience experiential learning and career awareness effort underway; but, such efforts are not yet at the required level nor are they reaching the vast majority of students.

These initiatives typically involve colleges, universities, museums, and other science-based organizations providing services ranging from field trips to on-site classes for school groups to summer camps to research experiences. This is particularly important since bioscience education needs to go beyond just learning facts and instead focus on understanding how bioscience is applied.

Nevertheless, an area of concern is that many of these programs are funded by grants and, as a result, often come and go as grants begin and end. Beyond their sustainability, there is also an open question on the scale and reach of these efforts—an area deserving more in-depth study in the years ahead.

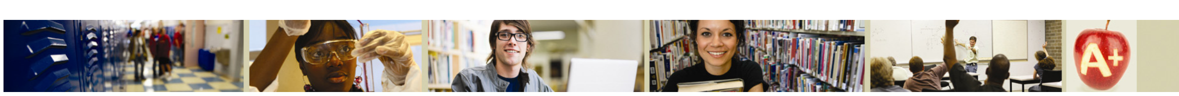
Conclusion

Clearly, more must be done to raise the level and quality of bioscience education if the United States is to remain globally competitive in the biosciences. There are many examples of the type of programs that work; but, they need to be replicated and states need to commit resources to them. This review of state activities in bioscience education suggests a number of actions that should be taken, including the following:

- States should incorporate biotechnology as they revise their science standards and should involve research scientists with expertise in the biosciences in their development.
- States must commit to improving student achievement in biology and the life sciences and ensuring that their high school graduates are ready to pursue college-level bioscience courses.
- States should do a better job of collecting and disseminating data to track student participation and performance in the biosciences and the broader sciences.
- States should take a more systematic approach to teacher professional development, experiential learning, and career awareness.

Desired State Participation and Performance Measurement Data

- Percentage of high school students taking AP biology or other advanced science classes, e.g., molecular biology, biochemistry, AP chemistry
- Number of students enrolled in CTE biotechnology career pathway courses
- Percentage of high school biology teachers certified in biology
- Percentage of middle-school science teachers who have completed professional development courses or workshops focused on biotechnology
- Percentage of middle school students who participate in experiential learning in the biosciences



Introduction

The Challenging Trend in U.S. Education

The severe economic downturn facing the nation and the world in 2009 makes it difficult to focus on issues beyond the short-term imperative of improving our economic footing and reversing the deep declines in jobs. But, just beyond today's economic ups and downs are warning signs that the **United States is slipping in generating the skilled, educated workers needed to meet the demands for a highly trained, technical workforce in today's knowledge-based economy** (refer to text box on "Warning Signs for Educational Attainment in the United States").

This trend poses particular challenges to growing economic drivers for the nation, such as the bioscience industry sector, which must maintain an edge against global competitors. The bioscience industry sector stands as a large sector of the economy, involving a wide range of manufacturing, service, and research activities. It spans across a diversified set of industry subsectors, including drugs and pharmaceuticals; medical devices and equipment; agricultural feedstock and chemicals; and research, testing, and medical laboratories. Nearly all states have an economic specialization in one or more subsectors of the biosciences—so it is truly a national technology driver.

Warning Signs for Educational Attainment in the United States

A report from the National Academies, *Rising Above the Gathering Storm*, warns: "Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength."*

Similarly, the Council on Competitiveness in its Competitive Index report explains: "Simply being an American does not guarantee a high-wage job anymore as companies allocate more of their activities across locations based on productivity relative to wages …we see rising inequality as the most educated prosper while those who lack education or skills struggle to keep pace."†

The warning signs for the United States are clear: While the United States still ranks among the top performers in the percentage of older adults (35 to 64) with an associate's degree or higher, it has slipped to seventh in the educational attainment of younger adults aged 25 to 34. The percentage of younger adults in the United States with at least an associate's degree falls well below that of Japan and Korea, and is marginally ahead of Spain, Ireland, and France.

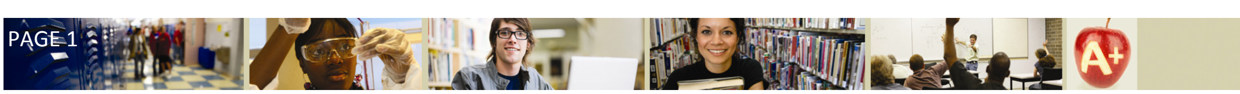
Unlike many other key competitor nations from both the developed and developing worlds, the educational attainment of the younger generation in the United States is at risk of falling behind that of the older generation it is replacing in the workforce.

On international education comparisons, the United States is falling behind other nations as well. In the most recent testing of science and math literacy for the Program for International Student Assessment (PISA), the United States stood below the average for Organization for Economic Cooperation and Development (OECD) nations in both science and math literacy. U.S. 15-year-olds scored lower than 16 of the other 29 OECD nations on science literacy and lower than 23 of the other 29 OECD nations on math literacy.§

* Rising Above the Gathering Storm. *National Academies Committee on Science, Engineering, and Public Policy; 2005*; page 4.

† Competitiveness Index: Where America Stands. *Council on Competitiveness*, 2007, pages 8 and 9.

§ Highlights From PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context. *National Center for Education Statistics*, 2007, pages iii and iv.



In the most recent economic growth cycle, the U.S. bioscience industry recorded strong job gains, increasing by 6.7% from 1.23 million jobs in 2001 to 1.31 million in 2007. The national bioscience industry has a total employment impact of 7.5 million jobs, taking into account the additional jobs created in the economy as a result of the sector's direct jobs.

The long-term growth prospects beyond the current recession are very bright for the bioscience industry. The U.S. Bureau of Labor Statistics forecasts bioscience industries to generate annual growth of 1% through 2016. What is particularly exciting for the biosciences going forward is that, along with major new opportunities in advancing applications of the biosciences to human health (in emerging areas such as tissue engineering, stem cell therapies, and personalized medicine), there are also significant opportunities today to advance the industrial applications of the biosciences (in such areas as agbio, bioenergy, sustainable development, and advanced materials).

The Bioscience Talent Demand: The Need for an Educated and Specialized Workforce

For the bioscience industry, the prospect of the United States losing its competitive advantage—no less facing declining levels—in the educational attainment and resulting skills of the nation's workforce presents a considerable competitive challenge. As a recent report commissioned by the Massachusetts Life Sciences Center on *Growing Talent: Meeting the Evolving Needs of the Massachusetts Life Sciences Industry* makes clear, the need for an educated workforce is particularly important for the bioscience industry.

"The majority of new life science jobs—more than 80 percent—will require at least a four-year degree. A steady stream of high-level talent is needed in the biological sciences to sustain the state's worldwide leadership position in biomedical research. While most life sciences jobs require higher education, the industry continues to offer opportunities for skilled technicians and manufacturing workers without a four-year degree, especially in the medical device sector."[1]

In a state with a more emerging bioscience industry sector, such as Arizona, similar findings on the need for postsecondary education across the spectrum of bioscience jobs emerge. A detailed survey of bioscience employers was completed for a study sponsored by Maricopa Community Colleges and other key stakeholders that revealed the broad demand for postsecondary education among bioscience employers.[2] While this is not surprising for research scientists or engineers, it is surprising how frequently employers are seeking a postsecondary degree for research lab technicians; engineering technicians; and management support occupations involving marketing/sales, quality assurance, and technical support (Figure 1).

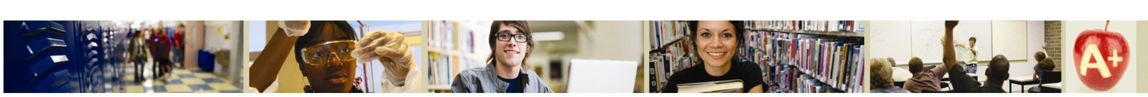
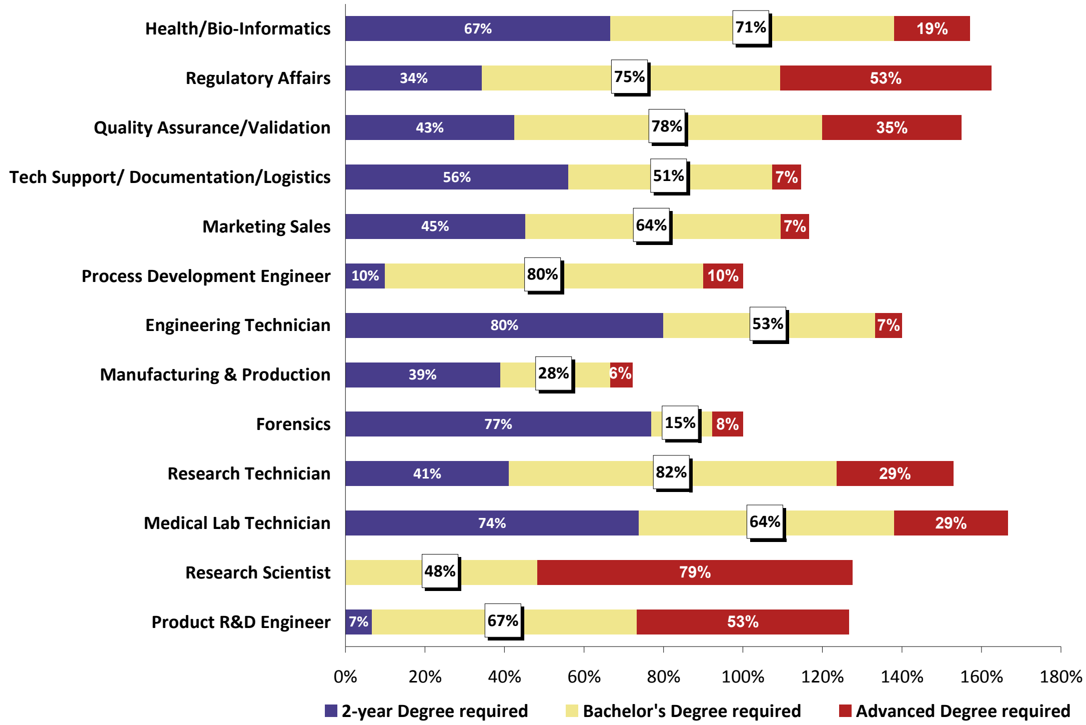


Figure 1: Frequency Distribution of Educational Requirements by Occupation, Findings from Arizona Bioscience Workforce Strategy

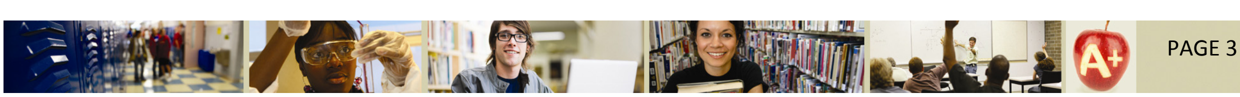


Across the spectrum of bioscience jobs, bioscience companies in Arizona indicated that they required at least 2-year degrees even for more technician- and production-level workers.

Note: The sum of the total exceeds 100% because bioscience employers could select more than one educational degree requirement per job function.

Yet, what makes the bioscience industry sector stand out is its application of a unique and growing body of knowledge on how humans, plants, and animals function. This, in turn, places unique demands on the skills and knowledge of bioscience workers, including understanding advanced molecular biology, operating specialized instrumentation, and interpreting biological data generated. In addition, the translation of biological knowledge to advancing health treatments requires specific regulatory oversight, rigorous clinical trials, and ongoing quality assurance unique to the bioscience industry sector. The uniqueness of the biosciences in its workforce needs is demonstrated by the findings of the Massachusetts study on specific workforce shortages that bioscience employers in that state were experiencing in 2008, including the following:

- Clinical trials management
- Regulatory affairs
- Process development and manufacturing engineers
- Chemistry
- Pharmacology
- Laboratory animal care
- Specialty scientific fields, like toxicology
- Quality assurance and quality control



- Commercial sales managers and representatives.

So, while the biosciences draw upon the broad base of educated Americans, the industry also has specialized skill and knowledge requirements whose fulfillment it must ensure among future generations of workers.

Importance of Taking the Pulse of Bioscience Education in America

The Biotechnology Industry Organization (BIO), together with the Biotechnology Institute, recognizes that the bioscience industry is a knowledge-based sector dependent upon the skills of its workers. Bioscience workers are needed to conduct research; translate innovation into product development and improved health care techniques; and, ultimately, to manufacture biomedical and other bioscience-related products. Thus, ensuring the availability of an educated, skilled workforce is critical to developing and sustaining a highly competitive, robust bioscience cluster over the long term.

It is also critical for the American society that the public is well-informed about the promise and challenges of biotechnology. Recent national legislation on genetic testing is a harbinger of the complex issues that the biosciences will pose in the years ahead.

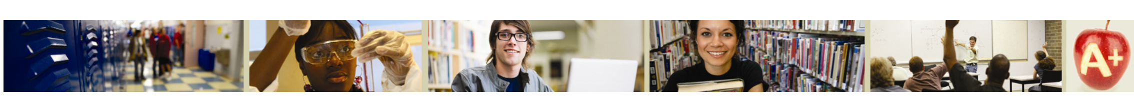
Given the warning signs regarding the nation's educational performance and the specialized needs for a bioscience workforce, the time is right for an in-depth analysis of states' performance in preparing an educated bioscience workforce for the next generation of workers.

The Battelle Technology Partnership Practice joined with BIO and the Biotechnology Institute to develop a first-ever assessment of state progress, activities, and challenges in the area of bioscience talent generation.

The focus of this initial assessment is on high-school and middle-school bioscience education and career development efforts in recognition of high schools and middle schools in serving as the primary feeders to postsecondary institutions and in shaping career preparation. Numerous studies have found that students lose interest in mathematics and science during middle school and that middle school students need to begin laying the foundation to enable them to pursue advanced science courses at the high school and college levels. Course choices in high school determine how prepared students will be to pursue science studies at the college level.

Framework for Assessing the State of Bioscience Education

To create a framework for understanding the reach and quality of bioscience education across the states, Battelle consulted with a wide range of national experts in bioscience education and industry leaders active in supporting bioscience education. Battelle also was assisted by the Biotechnology Institute, an organization dedicated to educating teachers, students, and the public about the promise and challenges of biotechnology. From these discussions with experts, Battelle identified a set of key questions that must be addressed in an assessment of state bioscience education efforts. Battelle undertook further review of the education reform literature to determine how well these questions fit within the growing knowledge of what generates high school graduates prepared to pursue bioscience-related postsecondary education.



The assessment of state bioscience efforts at the high school and middle school levels focuses on five specific questions:

- How well are students being prepared in the biosciences in particular and in science and mathematics in general?
- How and to what extent are states incorporating the biosciences into school curricula?
- How well prepared are science teachers to teach students about the biosciences?
- To what extent are students exposed to the biosciences and made aware of career opportunities and educational requirements?
- To what extent have states recognized the need to incorporate the biosciences in K-12 education and how have they done so?

These five questions are not mutually exclusive, but highly interdependent. Each question focuses on a particular aspect of how states are doing in bioscience education that sheds light on areas in which states can improve their bioscience education infrastructure and eventually student performance.

Data and Survey Methodology

Using various sources of existing secondary data supplemented by data collected by Battelle in state-specific surveys focused specifically on the biosciences, the study team examined the above aspects of state performance and activities in bioscience education at the middle and high school level.

To assess student performance and teacher quality, Battelle relied upon existing national- and state-level data sources. These include data maintained by the U.S. Department of Education, National Center for Education Statistics (NCES), the Council of Chief State School Officers (CCSSO), the College Board, and ACT.

To collect state program data specific to the biosciences, Battelle conducted two Web-based surveys. The first, which was directed to state bioscience association executives, requested information on the presence of various bioscience education, professional development, and experiential learning programs available in the state. In the nine states in which there is no state bioscience association, Battelle identified another point of contact within state government to receive this same survey. The second survey focused on state science standards and teacher and graduation requirements. These surveys were sent to individuals within state departments of education responsible for overseeing the state's science standards. Battelle supplemented information collected in each survey by obtaining information directly from department of education Web sites.

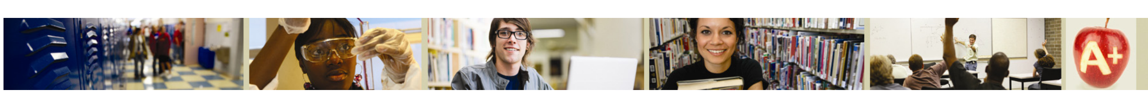
SOURCES OF ACHIEVEMENT DATA

The **National Assessment of Educational Progress (NAEP)** is the only nationally representative assessment of student knowledge across a variety of subjects administered in the United States for students in grades 4, 8, and 12.

Advanced placement (AP) tests are administered by the College Board and are used to give high school students college credit for advanced work.

The **American College Test (ACT)** is a standardized achievement exam for college admissions and is oriented toward measuring a student's knowledge.

The **Scholastic Aptitude Test (SAT)** is also a standardized exam for college admissions administered by the College Board and is oriented toward measuring a student's aptitude.



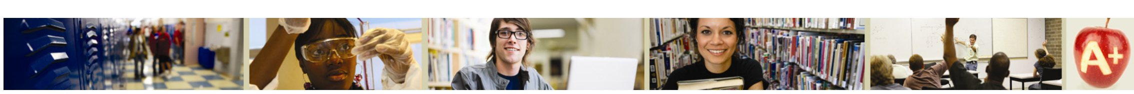
Battelle confronted many challenges in compiling data for this study:

- For the most part, existing data sources report data on overall science education, with limited data available specifically on the biosciences, biology, or the life sciences.
- Until the National Assessment of Educational Progress is able to report on 12th grade sciences across states in 2010, there is no standardized science achievement test at the high school level. It is also important that a breakout of the life sciences portion of the test be made available on a state by state basis.
- A handful of states, including Alaska, Iowa, Kansas, Nebraska, New York and Pennsylvania, did not to participate in the National Assessment of Educational Progress in 2005, which is a critical test of student achievement.
- On many measures of student achievement and teacher quality, the data suffers from significant time lags.
- Many state departments of education were unable to provide information on topics such as how many of their high school graduates have completed biology courses or how many career and technical education (CTE) students are enrolled in specific bioscience-related courses.

As a result of these challenges in collecting both program-related survey and secondary data, the information is often not comprehensive. Thus, this report should be viewed as an initial step in a process to develop better, more comprehensive and comparable indicators of the state of bioscience education and, for that matter, science education in the United States.

State Profiles

Data collected for the study were used to compile individual bioscience education profiles for each state, Puerto Rico, and the District of Columbia.[3] The profiles present data on student achievement and highlight bioscience education activities and programs currently available within each state. The profiles are not comprehensive but are meant to be representative of the types of activities that are available. The state profiles are contained on a compact disc included in the pocket on the inside back cover of this report. This report summarizes the study team's findings in examining the various state data.



Student Achievement: Framework, Measures, and Key Findings

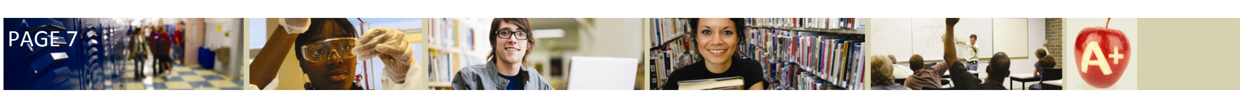
Since the beginning of the education reform movement in the 1980s with the publication of *A Nation At Risk*, the prominent 1983 report on American education from the National Commission on Excellence in Education, through the ultimate enactment and implementation of the *No Child Left Behind Act*, the hallmark has been an emphasis on accountability and measuring success.

This report on state bioscience education efforts seeks to look specifically at student performance in the biosciences. Below is offered a range of measures that consider student performance in the biosciences and sciences overall based on standardized tests offered across states.

This report also considers student achievement in math and reading because it is widely agreed that basic skills in math and reading are essential for being prepared to learn biology and other sciences and to succeed in college. Dr. Rita Colwell, current President of the American Institute of Biological Sciences and former Director of the National Science Foundation (NSF), says it plainly: "It is clear that the gatekeeper is mathematics. Mathematics is a foundation for all sciences, and the advanced mathematical concepts currently taught at the middle- and high-school levels need to be taught earlier."[4] Similarly, a recent study of factors in postsecondary degree completion by the U.S. Department of Education found that taking college-level math as early as possible improved a student's chances of graduating from college with a degree.[5] Reading is also important, because a student cannot learn math or science without the ability to read, and especially comprehend key concepts.

For these reasons, selected "basic skills" metrics are tabulated for each state in its state profile as a reference for the bigger picture on student achievement. The focus of this section, however, remains primarily on bioscience and science achievement across the states.

In interpreting these student achievement findings, it is also important to consider the environment for education in each state. States vary widely in the share of low-income students and available resources for education, which are factors to be kept in mind. These contextual summary metrics also are included in each state profile.



INDICATORS AND KEY FINDINGS:

The National Assessment of Educational Progress

The National Assessment of Educational Progress (NAEP) is the only nationally representative assessment of student knowledge across a variety of subjects administered in the United States. Periodic assessments are conducted across America for students in grades 4, 8, and 12 in mathematics, reading, science, writing, the arts, civics, economics, geography, and U.S. history. NAEP assessments are administered by the U.S. Department of Education to students in all states in the same manner and are subject to minimal changes in content in order to provide comparable metrics across states and over time.

Given its design, the NAEP assessments allow for the best and most useful comparisons for any state-by-state analysis of student achievement in core subject areas. Especially useful in the context of this national study of the life sciences are the NAEP results by state for both science in the broad sense as well as the "life sciences." Average scores by state for 8th grade students are profiled here. Unfortunately, state NAEP data for 12th grade students in science and the life sciences are not yet available. The 12th grade science assessments were administered nationally in 2005 but were not conducted at the state level. In 2009, 12th graders will take the science tests in samples designed to be representative of state-by-state performance. Future versions of this study will include these state data for the 12th grade.

Achievement Indicator: 8th Grade NAEP Science Average, 2005

The national average scale score for 8th grade public school students in the NAEP science assessment for 2005 was 147, which has changed little from prior years.[6] In its summary of NAEP science results, the NCES found that there was no improvement at grade 8 nationally from either prior testing year (1996 or 2000).[7] This flat performance translated to the states, with most showing no improvement. Of the 37 participating states, only five—California, Hawaii, Kentucky, South Carolina, and Virginia—reported making gains among 8th grade students in 2005.

Striking regional differences emerge on the national map, with Northeastern states, Mountain states, and states in the Upper Midwest generally outperforming the other states, particularly those in the South.

The upper quartile of state performers in NAEP science achievement range from 156.0 to 163.2 and are listed in descending order by average score at right.

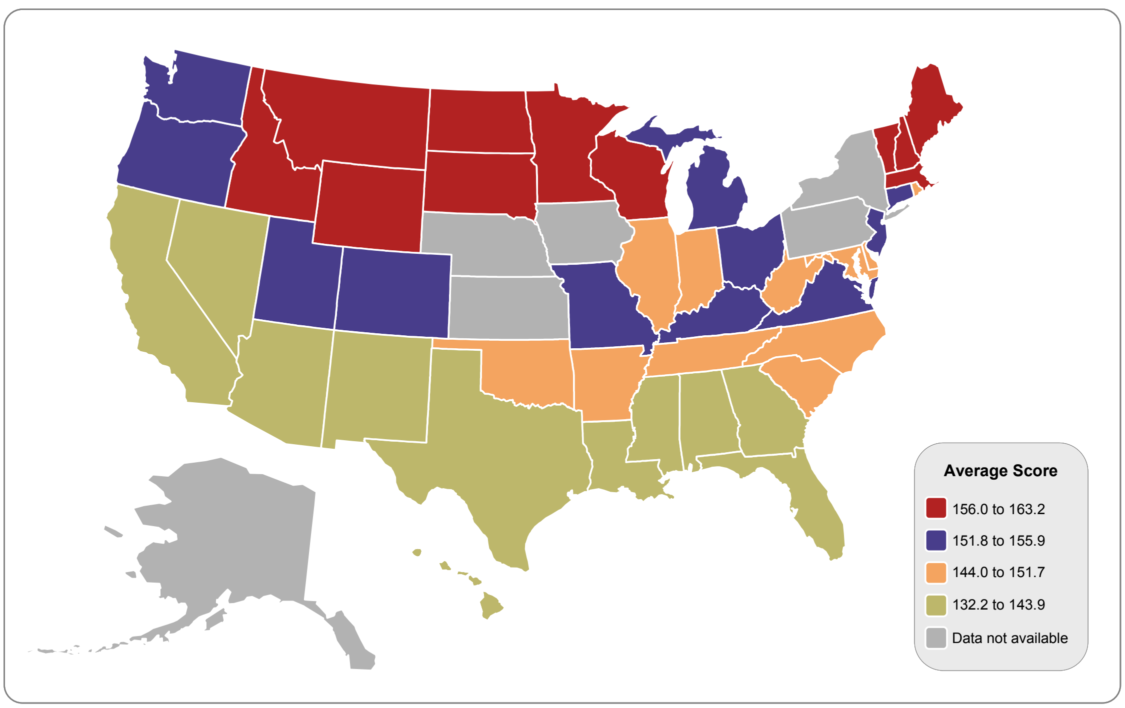
Though average science scores in the NAEP assessment have not changed significantly since 1996, 10 states showed significant increases in their average scores from 2000 to 2005, including California, Hawaii, Kentucky, Louisiana, Massachusetts, North Dakota, South Carolina, Vermont, Virginia, and Wyoming.

Conversely, four states showed decreases in average scores from 2000 to 2005, including Alabama, Arizona, Indiana, and Nevada.[8] Figure 2 shows the average NAEP Science scores for 8th graders by state in 2005.

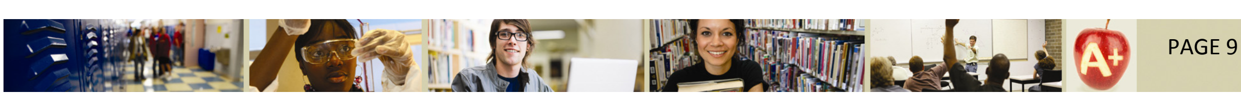
Leading States in NAEP Science Achievement

North Dakota
Montana
Vermont
New Hampshire
South Dakota
Massachusetts
Wyoming
Minnesota
Wisconsin
Idaho
Maine

Figure 2: 8th Grade NAEP Science Average, 2005



Source: U.S. Department of Education, NCES, NAEP 2005 Science Assessments.

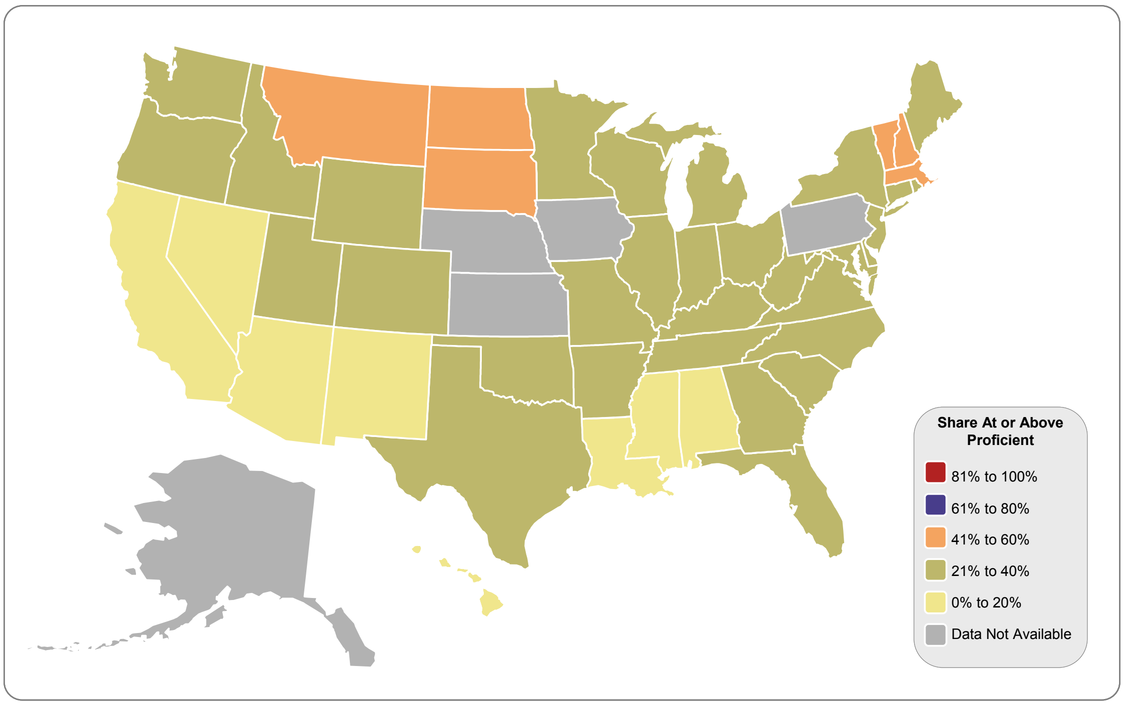


Achievement Indicator: 8th Grade NAEP Science Proficiency, 2005

NAEP assessments are used to determine the level of students performing at or above the basic or proficient levels. In 2005, 57% of 8th grade public school students scored at or above the basic level. An example of the knowledge and skills at the basic level is being able to compare changes in heart rate during and after exercise. Twenty-seven percent performed at or above the proficient level. Identifying the energy conversions that occur in an electric fan is an example of the knowledge and skills at the proficient level.

From a state perspective, the share of 8th grade students who met or exceeded the proficient level in science in 2005 ranged from a high of 43% to a low of just 14%. The 27% national average speaks to the relatively poor performance of all U.S. 8th grade students in science assessments. While certain states are highlighted here for reaching the middle quintile of the NAEP proficiency indicator (Figure 3), it should be noted that no state exceeds 43% proficiency; thus, praise for these "top performers" should be applied with this caveat.

Figure 3: 8th Grade NAEP Science, Share of Students At or Above Proficient, 2005



Source: U.S. Department of Education, NCES, NAEP 2005 Science Assessments.

Gaps in Science Achievement, a Recent Narrowing and State Positions

The value of the comparability and structure of NAEP assessments across states is matched by the rich demographic data available to educators and researchers on specific student populations. Of particular interest to researchers is to track trends in the performance of what are typically the lowest performers on standardized tests—low-income and minority populations. The gap in performance among these and other students is often referred to as the "achievement gap." Evidence in the NAEP data among 8th grade students has been studied by the CCSSO to examine recent trends to determine whether that gap is narrowing.[9]

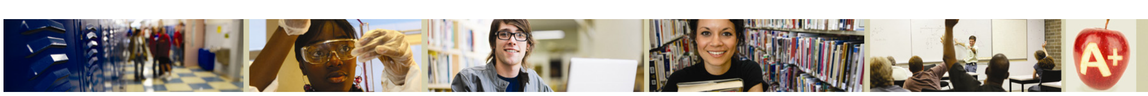
While 8th grade students nationally have shown no overall improvement in the Science NAEP, CCSSO in its examination of the gap between low-income students and all students found that, on average, states have narrowed the gap by one percentage point per year since 2000 in the share of low-income students at or above the basic level in science.

Nationally, low-income students had a gain of 5 points in the share scoring at the basic level in science, while the share scoring at the basic level was unchanged for all students. State analysis showed 14 states saw their achievement gap narrow, with gains among low-income students outpacing those for all state students.

The table below was developed by Battelle and shows where states currently lie in terms of both their overall share of basic science proficiency and the gap in this share among low-income students compared with their more affluent counterparts. While some states have a "wider" achievement gap in science compared with the U.S. average, a distinction can be made as to how far up (or down) the distribution that gap lies in terms of overall proficiency relative to the U.S. average.

		Science Proficiency at or above Basic, All Grade 8 Students (U.S. Avg. = 57%)	
		Share Less than U.S. Avg.	**Share Greater than U.S. Avg.**
Achievement Gap between low-income and other students (U.S. Avg. Gap = 34 percentage points)	***Wider Gap*** Relative to U.S. Avg.	AL, AZ, GA, MD, MS, SC	CO, CT, IL, NJ, OH, RI, VA, WI
	Narrower Gap Relative to U.S. Avg.	AR, CA, FL, HI, LA, NC, NM, NV, TN, TX, WV	DE, IN, ID, KY, MA, ME, MI, MN, MO, MT, ND, NH, OK, OR, SD, UT, VT, WA, WY

Note: NAEP data not available for Alaska, DC, Iowa, Kansas, Nebraska, New York, and Pennsylvania.



Achievement Indicator: 8th Grade NAEP Life Sciences Average, 2005

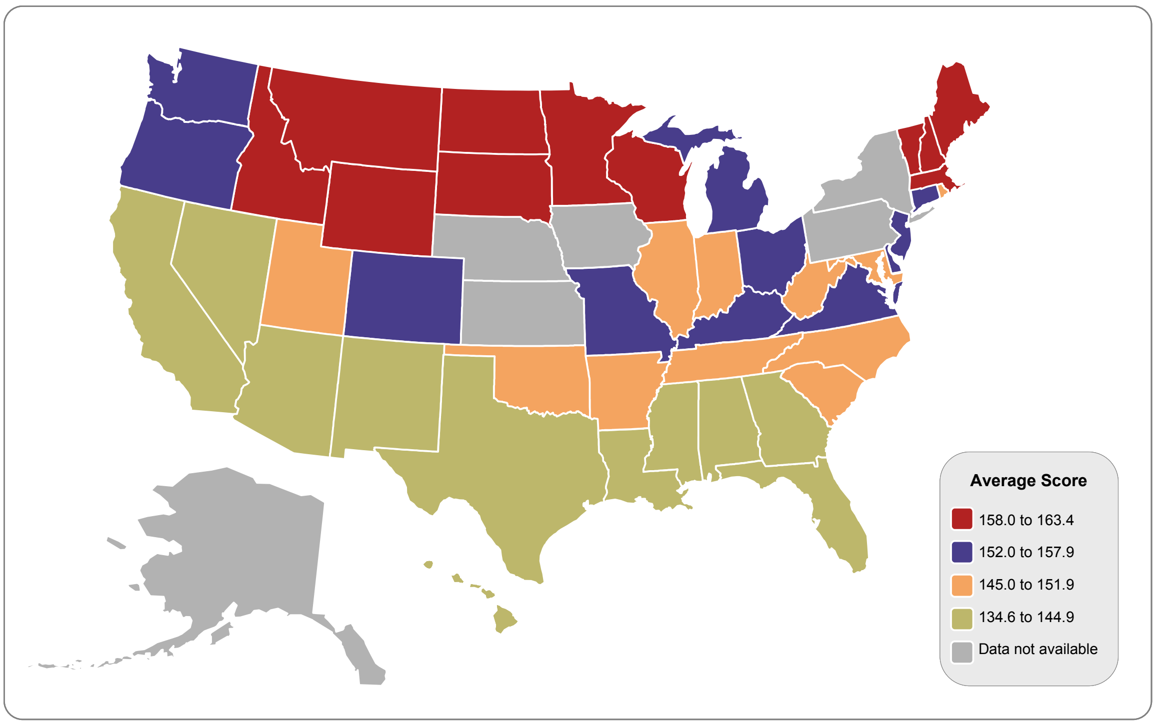
While most 8th grade students have not yet taken a full biology course, NAEP assessments include an evaluation specific to the "life sciences" and provide a gauge of early education, knowledge and abilities of middle school students with respect to the biosciences. The life sciences make up 40% of the NAEP Science assessment for the 8th grade. Nationally, 8th grade students average scale score in the life sciences NAEP assessment is 148 in 2005. Similar to the overall science assessment, this average for public school students has not changed from prior years. State average life science scores range from 135 to 163 and, on the national map, reflect the similar regional achievement trends seen in the science assessments at large (Figure 5).

While the national results in the life sciences show no overall improvement or change, some states have improved their average scale scores since the 2000 assessments. Specifically, California, Hawaii, Kentucky, Louisiana, Massachusetts, North Dakota, South Carolina, Vermont, Virginia, and Wyoming have improved their averages. No states lowered their average, though the majority showed no significant change from 2000 to 2005.[10]

States Showing Improvement in NAEP Life Science Assessments

California
Hawaii
Kentucky
Louisiana
Massachusetts
North Dakota
South Carolina
Vermont
Virginia
Wyoming

Figure 5: 8th Grade NAEP Life Sciences Average, 2005



Source: U.S. Department of Education, NCES, NAEP 2005 Science Assessments.

Advanced Placement

Advanced placement (AP) courses offer high school students the opportunity to enroll in advanced, college-level coursework in a given subject with the opportunity to earn college credit. The College Board, a nonprofit organization, has administered the AP program in the United States for more than 50 years and develops and maintains guidelines for more than 30 courses and exams.

AP exams are administered upon completion of an AP course and are taken by choice among AP students. Exams are scored on a 1 to 5 bell-curved grading scale. While each college or university differs in its requirements, most generally accept scores of 4 or 5; some accept a score of 3 in exempting incoming students from introductory coursework.

Each state profile in this report includes summary AP achievement indicators for students scoring a 3 or higher in AP science, biology, math, and English. Profiled here on a state-by-state basis is the achievement indicator for biology.

Achievement Indicator: AP Biology Students, Share Scoring a 3 or Greater on AP Exam

AP biology is designed as an introductory-level college course typically taken by college biology majors in their first year of studies. High school students are encouraged to take both biology and chemistry prior to enrolling in AP, but not all students do. In developing AP biology tests, the College Board conducts surveys of key curriculum in introductory college courses and aligns the survey results with the material covered on the exam. General goals have been set for covering three primary areas:[11]

Molecules and cells (25%)
Heredity and evolution (25%)
Organisms and populations (50%).

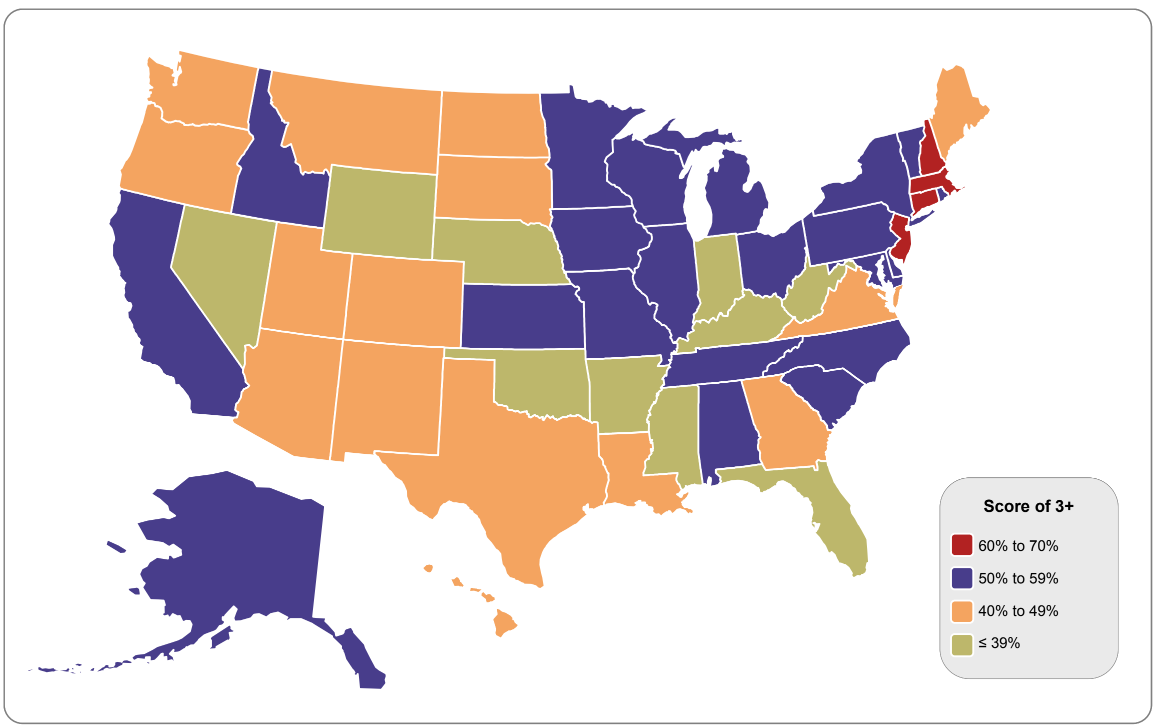
While total enrollment in AP courses is not tabulated for each state by the College Board, the organization publishes the numbers of state students taking each exam. In 2008, nearly 151,000 U.S. high school students took the AP biology exam, with 75,000 or 50% recording a "passing" grade of 3 or greater.

From a state perspective, the share scoring 3 or greater in biology ranges widely from a low of 15% to a high of 68%. In 2008, the four states listed at right saw 60% or more of their AP students scoring a 3 or greater (Figure 6):

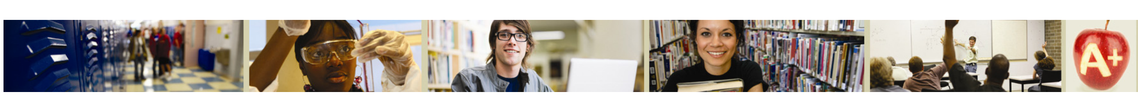
Leading States in AP Biology Achievement

Connecticut
New Hampshire
New Jersey
Massachusetts

Figure 6: Advanced Placement Biology: Share of Exam Takers Scoring a 3 or Greater, 2008



Source: Battelle analysis of data from the College Board.



The ACT

Originally known as the American College Testing Program, this standardized achievement exam for college admissions is now formally administered as simply "ACT." The required core of the ACT consists of multiple choice questions spanning four subjects: English, math, reading, and science reasoning. In 2005, ACT added an optional writing test to this core.

The ACT is accepted at all 4-year academic institutions; but, it competes with the College Board's Scholastic Aptitude Test (SAT). Both ACT and SAT scores are generally used to supplement the transcripts and performance of high school students and assist college admissions offices in putting local education data into a national context. In its core reasoning test, however, the SAT does not include science, while virtually all students who take the ACT take the science test. The ACT is therefore emphasized as a useful indicator in this study to shed light on the abilities of U.S. high school students in science achievement.

In evaluating performance on the ACT, it must be understood, however, that the extent to which specific regions and states within the United States take the ACT versus the SAT varies tremendously. Analysis of ACT testing data presented here should be conducted with caution and an understanding of these regional differences in exam participation.

In 2008, 43% of U.S. high school graduates sat for their ACT exam. While some states require the exam among high school students (e.g., Michigan and Colorado report 100%), others have fewer than 15% take the exam—North Carolina, Pennsylvania, New Jersey, Delaware, Rhode Island, and Maine. Notably, much of the Northeast has the lowest participation in the ACT; the Midwest generally has states among the highest participation. For reference, the share of students taking the ACT is featured in each state profile.[12]

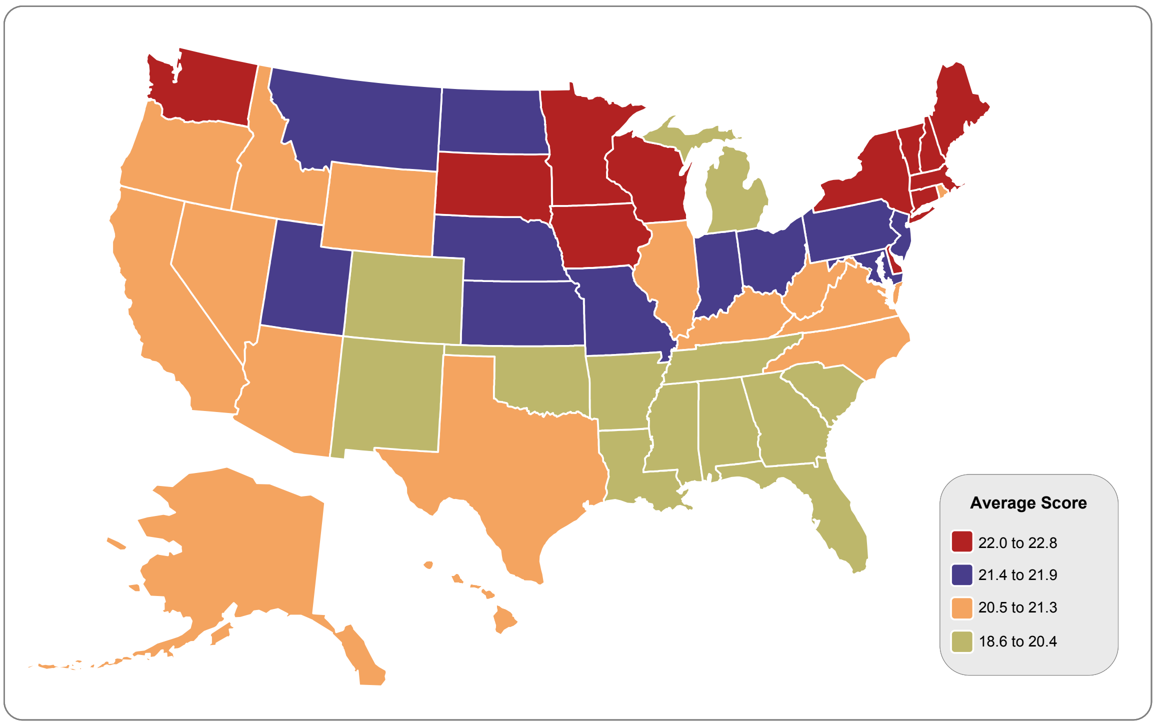
Achievement Indicator: ACT Science Average, 2008

The ACT science reasoning test covers 40 multiple choice questions in 35 minutes. ACT provides sets of example questions for "test prep" on its Web site.[13] The national average score on the science test was 20.8 in 2008, with state's average scores ranging from 18.6 to 22.8. The national map in Figure 7 divides states into quartiles based on average scores in science. The states listed at right scored, on average, in the upper quartile of states with averages of 22.0 or greater (listed at right in descending order by average score).

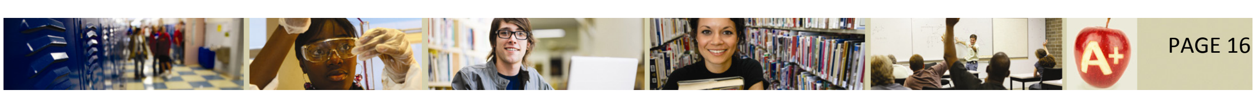
Leading States in ACT Science Achievement

New York
Massachusetts
Minnesota
Washington
Connecticut
Iowa
Wisconsin
New Hampshire
Vermont
Delaware
Maine
South Dakota

Figure 7: ACT Science Average, 2008



Source: ACT, Inc.

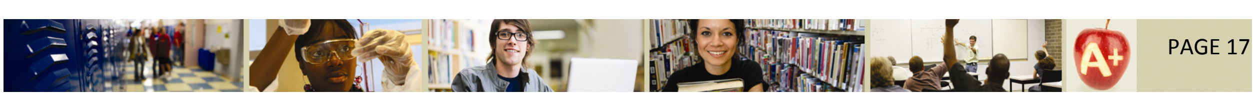


ACT College Readiness Indicators. The ACT is designed to draw subject-specific conclusions on the preparedness of high school exam takers for college-level coursework in biology in addition to English composition, algebra, and social science. Its College Readiness Indicators measure the percentage of students, by state, that meet or exceed a benchmark set for college readiness. Specifically, the ACT does extensive evaluation and tracking of student scores and how they translate for specific students to "success" at the college level. For biology, the ACT states the following:

> **The benchmark score for Biology is 24, indicating the minimum score needed on an ACT subject-area test to indicate a 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in the corresponding credit-bearing college courses. These scores were empirically derived based on the actual performance of students in college.**

Thus, students scoring 24 or greater on the ACT science test are identified as ready for college biology. The shares of ACT-tested students meeting this benchmark preparedness metric in biology are presented here in the box at right.

% of ACT-Tested Students Ready for College-Level Biology	
NY	43%
CT	40%
MA	40%
MN	40%
WA	40%
NH	39%
VT	38%
WI	38%
DE	37%
IA	37%
ME	37%
NE	35%
NJ	35%
SD	35%
MD	34%
PA	34%
KS	33%
MT	33%
OH	33%
CA	32%
IN	32%
UT	32%
VA	32%
AK	31%
HI	31%
MO	31%
ND	31%
RI	31%
AZ	30%
ID	29%
OR	29%
U.S. Avg.	**28%**
NV	28%
NC	28%
IL	27%
WY	27%
CO	25%
KY	25%
TX	25%
OK	24%
GA	23%
MI	23%
TN	23%
WV	23%
AR	22%
NM	22%
AL	21%
DC	21%
LA	20%
FL	19%
SC	19%
MS	13%



Wide disparities exist among states in student performance in the biosciences and broader sciences.

Bringing together four of the key student achievement measures in the biosciences, science, and one related specifically to critical math skills suggests that, even with the nationally lagging bioscience performance across all states, a number of states stand out as performing considerably better than others.

While it is difficult to give a single grade across states because of the limited quality and comparability of the student achievement data, the patterns of student performance across the measures displayed in the table below suggest the states fall into several broad categories.

- **Leaders of the Pack**
(at least two in quartile 1, remainder in quartile 2): Connecticut, Massachusetts, Minnesota, New Hampshire, New Jersey, Ohio, Vermont, Wisconsin
- **Second Tier**
(mix of quartiles 1–3, none in quartile 4): Colorado, Delaware, Idaho, Illinois, Maryland, Missouri, North Carolina, North Dakota, Oregon, Rhode Island, South Dakota, Tennessee, Utah, Virginia, Washington
- **Middling Performance**
(mix of quartiles 2–4 with at least one in quartile 4): Alabama, Arizona, California, Hawaii, Indiana, Kentucky, Maine, Michigan, Montana, South Carolina, Wyoming
- **Lagging Performance**
(quartiles 3 and 4 across all measures): Arkansas, Florida, Georgia, Louisiana, Mississippi, Nevada, New Mexico, Oklahoma, Texas, West Virginia
- **Not Rated:** States that do not participate in the NAEP science assessment were not rated.

Table 1 (next page) shows student performance data by state. The color coding denotes the performance of each state relative to all 50 states and the District of Columbia.

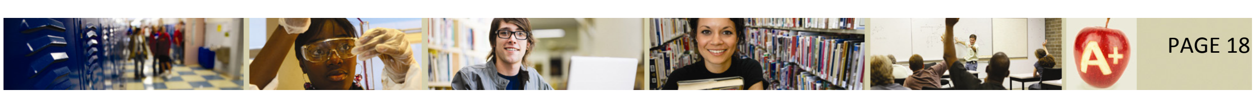
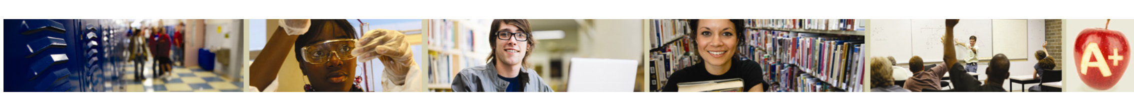


Table 1. Student Performance in Bioscience and Math Indicators by State

Ranks in **top quartile** of states | Ranks in **2nd quartile** of states | Ranks in **3rd quartile** of states | Ranks in **lowest quartile** of states

State	8th Grade NAEP, Avg. Life Sciences Score, 2005	Percent of AP Biology Students Scoring 3 or Higher, 2008	Percent of ACT Tested Students Ready for College-level Biology, 2008	ACT-SAT Math Avg. Indexed Relative to the U.S., 2008*
U.S. Average	**148.2**	**49.8%**	**28%**	**1.00**
Alabama	141.6	50.4%	21%	0.94
Alaska	N/A	56.2%	31%	1.01
Arizona	141.2	45.0%	30%	1.03
Arkansas	145.4	21.4%	22%	0.97
California	136.3	50.9%	32%	1.02
Colorado	155.6	45.3%	25%	0.99
Connecticut	152.9	68.0%	40%	1.02
Delaware	152.1	51.3%	37%	0.98
District of Columbia	N/A	53.2%	21%	0.89
Florida	141.9	32.3%	19%	0.96
Georgia	144.7	43.7%	23%	0.97
Hawaii	137.1	46.3%	31%	1.00
Idaho	158.5	59.0%	29%	1.03
Illinois	149.2	57.1%	27%	1.00
Indiana	151.2	38.3%	32%	1.00
Iowa	N/A	57.3%	37%	1.06
Kansas	N/A	53.6%	33%	1.05
Kentucky	153.8	34.9%	25%	0.98
Louisiana	139.8	43.6%	20%	0.95
Maine	159.3	45.2%	37%	0.92
Maryland	147.0	50.6%	34%	0.99
Massachusetts	161.5	60.0%	40%	1.04
Michigan	154.4	56.8%	23%	0.95
Minnesota	159.2	49.9%	40%	1.09
Mississippi	134.6	15.0%	13%	0.88
Missouri	154.9	49.5%	31%	1.01
Montana	162.2	42.5%	33%	1.05
Nebraska	N/A	34.6%	35%	1.05
Nevada	137.8	32.0%	28%	1.00
New Hampshire	162.6	66.9%	39%	1.03
New Jersey	155.7	63.9%	35%	1.01
New Mexico	138.5	45.9%	22%	0.96
New York	N/A	56.7%	43%	1.01
North Carolina	145.2	50.6%	28%	1.00
North Dakota	163.4	43.4%	31%	1.04
Ohio	156.8	58.1%	33%	1.03
Oklahoma	146.2	30.7%	24%	0.96
Oregon	154.6	48.2%	29%	1.02
Pennsylvania	N/A	55.4%	34%	0.99
Rhode Island	147.7	54.1%	31%	0.98
South Carolina	146.7	55.0%	19%	0.96
South Dakota	161.9	48.9%	35%	1.05
Tennessee	146.6	51.2%	23%	0.97
Texas	143.7	40.0%	25%	0.99
Utah	151.7	46.4%	32%	1.01
Vermont	163.0	59.3%	38%	1.03
Virginia	157.9	48.1%	32%	1.00
Washington	154.6	45.6%	40%	1.05
West Virginia	147.7	31.5%	23%	0.94
Wisconsin	158.6	55.7%	38%	1.07
Wyoming	158.6	30.9%	27%	1.00

Table 1 Source: Battelle analysis of data from the U.S. Department of Education, National Center for Education Statistics; the College Board; ACT, Inc.
Note: NAEP = National Assessment of Educational Progress
*ACT-SAT Math Average is an index of state averages in both exams relative to the U.S. and weighted by the share of high school graduates in each state taking each exam (U.S. average = 1.00).



Standards and Requirements: Framework, Measures, and Key Findings

Measuring a state's commitment to bioscience education is a difficult task, partly because no single measure can be used. It is also extremely difficult to separate standards relating specifically to biotechnology and the biosciences from science in general. Battelle collected data on state science standards seeking to determine the extent to which they require that students be exposed to biotechnology and the biosciences. Data also were collected on whether high school graduation requirements include biology and the percentage of recent high school graduates who have completed a course in biology. Table 2 presents an overview of these findings.

State Science Standards

Accountability without rigorous standards is a weak measure of success. It is important that state science standards address biotechnology and the biosciences if schools are to produce graduates that are scientifically literate and prepared for employment and/or future study in the biosciences.

As the Thomas B. Fordham Institute, a leading nonprofit in education reform, in its report on *The State of State Science Standards*, led by Dr. Paul Gross, University Professor of Life Sciences and former Provost at University of Virginia and former President of Woods Hole Marine Biological Laboratory, explains:

> **Standards are where a state spells out the skills and knowledge that its next generation should acquire as youngsters pass through primary and secondary schooling. They are aspirational, to be sure, but they are also an indispensable blueprint for curriculum, textbooks, testing, teacher preparation, and much else.**[14]

Thirty-one states reported that their science standards explicitly mention or define standards or applied laboratory or other instruction tools specifically for biotechnology or the biosciences. These states are indicated in Table 2.

Data on standards and requirements were collected by means of a Web-based survey that was sent to science standard contacts in departments of education in the 50 states, Puerto Rico, and the District of Columbia. Thirty-three states and the District of Columbia submitted surveys. Alabama, Arizona, Hawaii, Kentucky, Louisiana, Mississippi, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, Utah, Washington, and Puerto Rico did not complete the survey. The survey data were supplemented from other sources, when available.

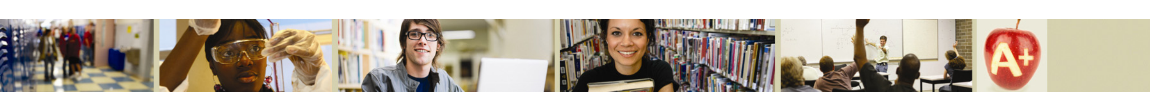
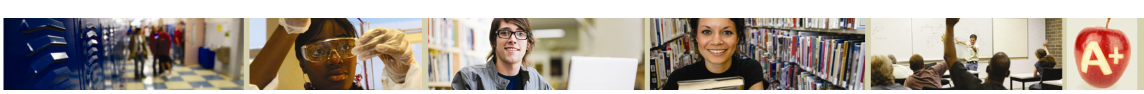


Table 2: Indicators of State Commitment to Bioscience Education

	Standards Address Biotechnology	Scientists Provided Input	Dedicated State Science Standards Staff	Biology Required	AP Biology Exam Takers (% of all H.S. Grads)	Certified H.S. Biology Teachers (% of total)
Alabama		N/A	N/A	■	2.7%	N/A
Alaska					2.2%	75%
Arizona	■	N/A	N/A		2.2%	N/A
Arkansas	■	■	■	■	6.1%	95%
California	■	■	■	■	6.5%	84%
Colorado	■	N/A			5.0%	94%
Connecticut	■	■	■		5.8%	99%
Delaware	■	■		■	5.2%	92%
District of Columbia		N/A			9.6%	N/A
Florida	■	■	■		5.8%	N/A
Georgia		■	■	■	5.2%	92%
Hawaii	■	N/A	N/A		5.4%	50%
Idaho		■	■	■	2.4%	99%
Illinois		■			3.9%	79%
Indiana		■	■	■	4.2%	95%
Iowa		■	■		2.1%	N/A
Kansas		■	■	■	1.5%	97%
Kentucky		N/A	N/A	■	3.5%	N/A
Louisiana	■	N/A	N/A	■	1.4%	N/A
Maine		■	■	■	5.4%	92%
Maryland	■	■	■	■	6.9%	N/A
Massachusetts	■	■	■		7.1%	N/A
Michigan	■	■	■	■	4.5%	N/A
Minnesota	■	■	■	■	3.6%	100%
Mississippi	■	N/A	N/A	■	2.6%	N/A
Missouri		N/A	■	■	2.4%	100%
Montana	■	■	■		3.4%	N/A
Nebraska	■	■	■		1.8%	N/A
Nevada	■	■	■		5.0%	N/A
New Hampshire	■	N/A	N/A	■	3.7%	N/A
New Jersey	■	N/A	N/A		5.6%	N/A
New Mexico	■	■			2.5%	100%
New York	■	N/A	N/A	■	7.6%	91%
North Carolina	■	N/A	N/A	■	5.1%	90%
North Dakota	■	N/A	N/A		2.1%	100%
Ohio	■	N/A	N/A	■	3.3%	85%
Oklahoma	■	■	■	■	2.7%	99%
Oregon		N/A	N/A		3.3%	N/A
Pennsylvania	■	N/A	N/A		3.5%	98%
Rhode Island		■	■		4.7%	N/A
South Carolina		N/A	N/A		3.8%	N/A
South Dakota		■	■	■	3.5%	99%
Tennessee			■	■	3.3%	N/A
Texas		■	■	■	3.3%	72%
Utah	■	N/A	N/A		5.0%	90%
Vermont	■	■	■		5.9%	N/A
Virginia	■	■	■		5.6%	99%
Washington	■	N/A	N/A		4.0%	N/A
West Virginia	■	■	■	■	2.8%	95%
Wisconsin		■	■		4.4%	100%
Wyoming			N/A		2.3%	N/A
Puerto Rico		N/A	N/A	N/A	N/A	N/A

Source: Battelle national surveys and analysis of state K-12 science standards; the College Board; CCSSO data on certification of biology teachers.
Note: N/A = data not available.



As shown in Table 3 (next page), the language that states use to refer to life sciences and biotechnology varies greatly from state to state. Many of the standards require that students be made aware of the uses of biotechnology and its societal impacts. Massachusetts' standards state the following:

> Biotechnology is a rapidly expanding field of biology that uses a growing set of techniques to derive valuable products from organisms and their cells. Biotechnology is already commonly used to identify potential suspects in crimes or exonerate persons wrongly accused, determine paternity, diagnose diseases, make high-yield pest-resistant crops, and treat genetic ailments. Educators should recognize the importance of introducing students to biotechnology as a way of better understanding the molecular basis of heredity. Educators should also provide students with methods and critical thinking skills to evaluate the benefits and risks of this technology.

Other states, such as Maryland, require that students be acquainted with career opportunities in the biosciences.

> Maryland's Grades 3–8 Voluntary State Curriculum—Biology includes the following objectives:
>
> Describe current opportunities for employment in biology-related careers, e.g., teaching, research, medicine, engineering, public health, sanitation, food science, environmental science, animal science, agriculture, biotechnology, forensic science.
>
> Describe the levels of education required for various careers in the biological sciences.

And other states require that students be involved in hands-on activities.

> Arkansas' standards require that students:
> Demonstrate a current understanding of life science theories.
>
> Describe the connections between pure and applied science.
>
> Describe various life science careers and the training required for selected careers.
>
> Investigate the molecular basis of genetics.
>
> Engage in hands-on activities during at least 20% of instructional time.

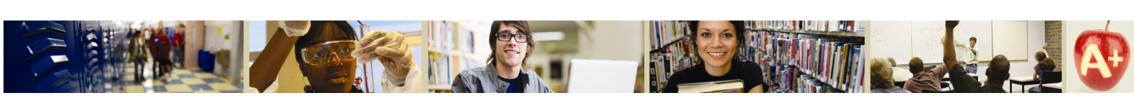
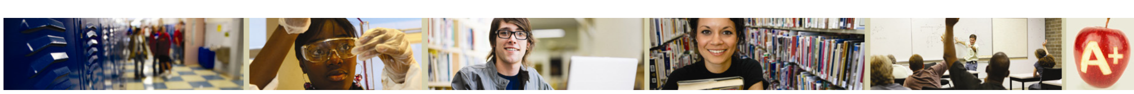


Table 3: States That Address Biotechnology in Science Standards[15]

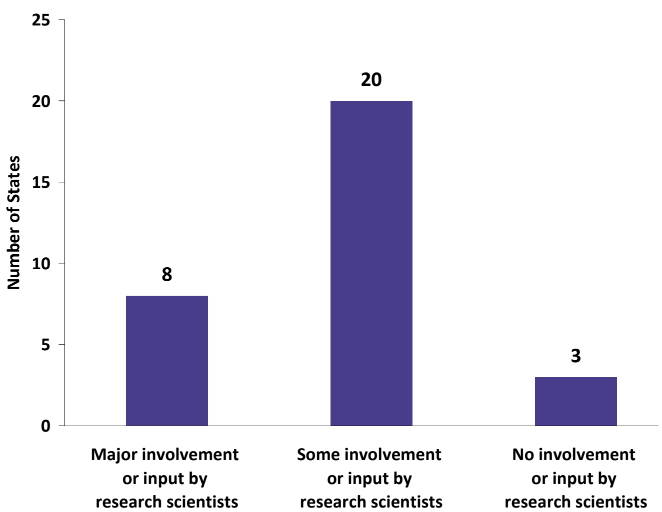
	DESCRIPTION
AZ	• Specific language addressing biotechnology not available.
AR	Standards require that students: • Demonstrate a current understanding of life science theories • Describe the connections between pure and applied science • Describe various life science careers and the training required for selected careers • Investigate the molecular basis of genetics • Engage in hands-on activities during at least 20% of instructional time
CA	• K-12 science standards make specific reference to "knowledge of how biotechnology is used to produce novel biomedical and agricultural products"
CO	• Specific language addressing biotechnology not available
CT	• Connecticut's science standards are organized around 11 conceptual themes, one of which is Science and Technology in Society—How do science and technology affect the quality of our life, which includes a section on biotechnology. At the 9th and 10th grade levels the standards are organized around five strands, two of which focus on life sciences (1) Cell Chemistry and Biotechnology and (2) Genetics, Evolution, and Biodiversity
DE	With respect to life processes and their applications, the DE standards refer to: • "Biotechnology is a growing international field of research and industry. Many scientists, including those in Delaware, conduct cutting-edge research in biotechnology. " • Grade 9-12 requirements: "Investigate how scientists use biotechnology to produce more nutritious food, more effective medicine, and new ways to mitigate pollution."
FL	• Current science standards reference impact of biotechnology as early as 7th grade and include a high school standard on "heredity and reproduction" that references applications of DNA to biotechnology and biotechnology's role and impact in society
HI	Standards call for students to: • Analyze and evaluate the benefits , drawbacks, and trade-offs raised by the application of biotechnology in the health field • Assess the benefits and drawbacks of biotechnology on the environment and society
MD	• Maryland's High School Technology Education Voluntary State Curriculum requires that students "Develop an understanding of agricultural and biotechnologies." • Maryland's Grades 3-8 Voluntary State Curriculum—Biology includes the following objectives: o Describe current opportunities for employment in biology-related careers, e.g., teaching, research, medicine, engineering, public health, sanitation, food science, environmental science, animal science, agriculture, biotechnology, forensic science. o Describe the levels of education required for various careers in the biological sciences.
MA	With a general notice in the Life Sciences section, Massachusetts standards refer as follows: • "Biotechnology is a rapidly expanding field of biology that uses a growing set of techniques to derive valuable products from organisms and their cells. Biotechnology is already commonly used to identify potential suspects in crimes or exonerate persons wrongly accused, determine paternity, diagnose diseases, make high-yield pest-resistant crops, and treat genetic ailments. Educators should recognize the importance of introducing students to biotechnology as a way of better understanding the molecular basis of heredity. Educators should also provide students with methods and critical thinking skills to evaluate the benefits and risks of this technology."
MI	• Science standards (Content Expectations) include a unit on genetics with a recommended component on recombinant DNA and a unit on evolution and biodiversity covering the impact of biotechnology for species improvement



MN	• Current draft standards for K-12 include an extensive Life Science Strand under which grades 9–12 address "social, economic and ecological risks and benefits of biotechnology, including selective breeding, genetic engineering, food irradiation, antibiotic use and medical technologies"
MS	Standards call for students to: • Research and present a justifiable explanation of practical uses of biotechnology (e.g., chromosome mapping, karyotyping, pedigrees) • Research, prepare, and present a position relating to issue surrounding current botanical trends involving biotechnology
MT	• Specific language addressing biotechnology not available.
NE	• Specific language addressing biotechnology not available.
NV	• Achievement indicators for grades 9–12 contains a section on genetics including: "Investigate advances in biotechnology using multiple resources"
NH	• Current K-12 life science standards include a unit on social issues in medical technology and biotechnology
NM	• Current K-12 science standards include benchmarks based on understanding "that applications of genetics can meet human needs"
NY	• The resource/curriculum guide references biotechnology as a key idea
NC	• The Standard Course of Study for Biology includes reference to "applications of biotechnology"
ND	• Current K-12 standards include exploration of how emerging technologies (including genetics) may impact science and society
OH	• Current K-12 life sciences standards, benchmarks, and indicators all make multiple references to biotechnology's uses and its societal impacts
OK	• Specific language addressing biotechnology not available.
PA	• Current K-12 science standards address "biotechnological systems" as one of three main systems and includes biotechnology as a component of "technology education"
UT	• Current K-12 science standards describe the biology core curriculum as relevant because it "provides students with an opportunity to investigate careers in genetics, biotechnology…"
VT	• Students understand that people control the outputs and impacts of our expanding technological activities in the areas of communication construction, manufacturing, power and transportation, energy sources, health technology, and biotechnology.
VA	• Current K-12 life science standards include reference to "genetic engineering and its applications"
WA	• Current K-12 science standards reference genetic engineering as an element of the "domains of science" Essential Academic Learning Requirement
WV	• The Biology Content standards state "The course will provide an in-depth study in the chemical nature of life, cellular functions, microbiology, ecology, biotechnology, zoology, botany, with application emphasis

The vast majority of states responding to the Battelle survey, 28 of 31, indicated that research scientists provided input in developing the state's science standards. Sixty-five percent of the respondents indicated that research scientists were involved to some extent, 26% indicated that research scientists were greatly involved. Only three states indicated that research scientists played no role in the development of their science standards (Figure 8).

Figure 8: Developing Current K-12 Science Standards: Degree of Involvement/Input by Research Scientists Outside of the Educational System



Source: Battelle national survey

Use of AAAS and/or NAS Criteria in Choosing Textbooks

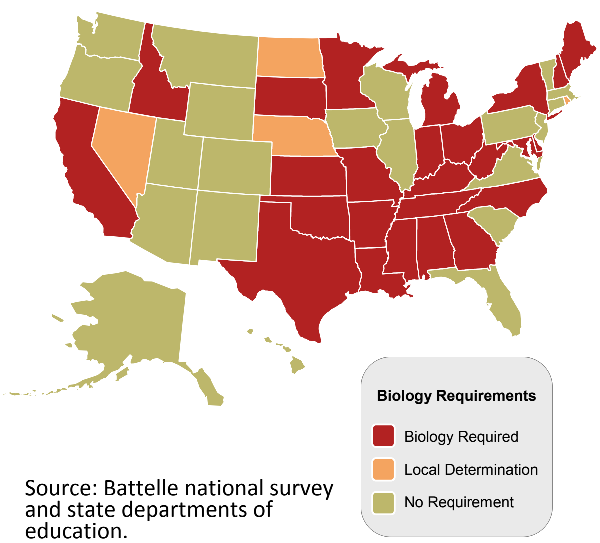
Only eight states—Arkansas, Florida, Idaho, New Mexico, Oklahoma, Tennessee, Texas, and West Virginia—and the District of Columbia reported that textbooks are selected at the state level. Of these, four reported having used American Association for the Advancement of Science (AAAS) or National Academy of Sciences (NAS) criteria to guide their selection of textbooks.

Another measure of a state's commitment to science education and successful implementation of the state's science standards is the designation of a staff person in the state department of education responsible for overseeing K-12 Science Standards. **Of the 31 states that responded to the standards survey, 26 (or more than 80%) indicated that the state department of education had a staff position specifically dedicated to K-12 science standards.**

State Graduation Requirements

Half of all states require that students complete a biology course in order to graduate from high school. In four states—Nebraska, Nevada, North Dakota, and Rhode Island—high school graduation requirements are determined at the local district level. The remaining 21 states have varying science requirements, ranging from two to three credits in science with some requiring one or more lab experiences but do not explicitly require biology (Figure 9). The District of Columbia will begin requiring four science credits, with two lab experiences, in 2010.

Figure 9: State Biology Requirements for High School Graduation

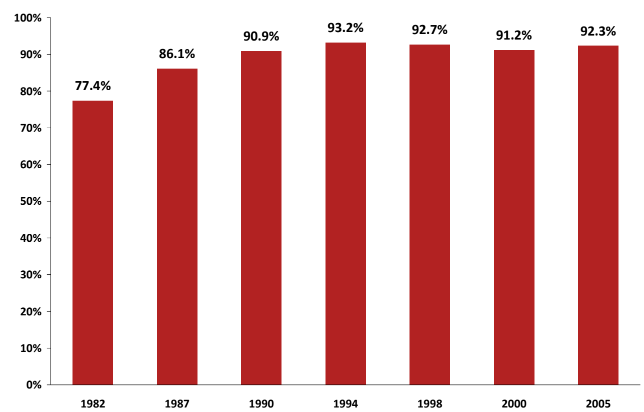


Source: Battelle national survey and state departments of education.

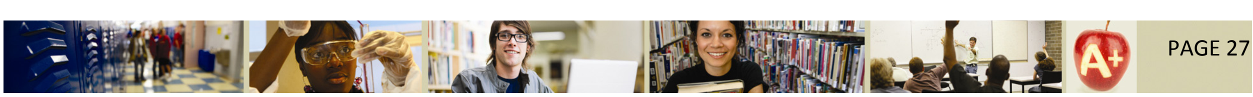
Indicator: Recent High School Graduates, Share Completing a Course in Biology

Regardless of whether biology is required by the state, a key indicator of the extent to which the K-12 system is preparing students in the biosciences is the percentage of high school graduates who complete a biology course prior to graduating. In 2005, 92% of U.S. high school graduates had completed a 1-year course in biology upon graduation, a share that has increased since the 1980s but has leveled off in recent years (Figure 10).

Figure 10: Share of U.S. Public and Private High School Graduates Taking High School Biology, Selected Years, 1982–2005



Source: U.S. Department of Education, NCES, High School Transcript Study, 2007.



Indicator: Prevalence of Advanced Placement Biology

The vast majority of U.S. high school students are taking biology; yet, to truly raise the bar in preparation for college and to lift the regional and international competitiveness of the nation's students, it is critical to ask the following: What share of these same students is taking an advanced course? Which states are leaders in their capacity to provide these courses and attract interest among their students? Using the AP exams as a gauge of the prevalence or penetration of advanced biology course takers among all recent high school graduates (both public and private) helps to answer these key questions.

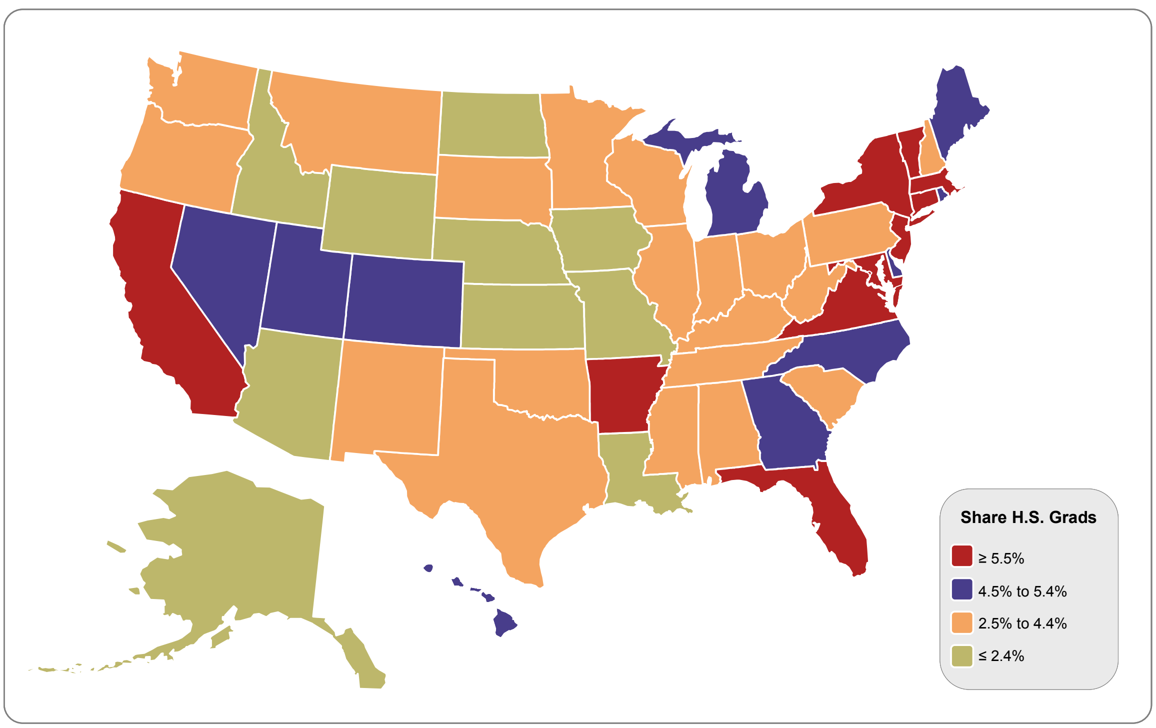
The indicator presented in the national map in Figure 11 shows the share of recent high school graduates who have taken the AP biology exam. On average, 4.6% of U.S. high school graduates have taken this exam. From a broader perspective, this is less than the same share for all science exams (10.5%), indicating a higher penetration in chemistry and physics relative to biology. Among states, the biology share ranges from 1.4% to 9.6%.

States with the highest shares of AP biology penetration reflected by exam takers include the following (listed at right in descending order).

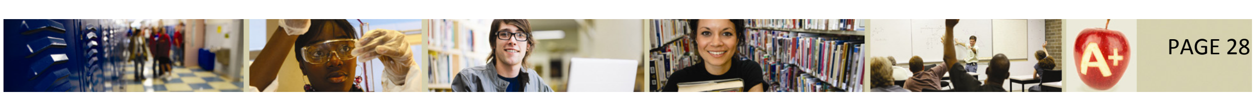
Leading States in Prevalence of AP Biology

District of Columbia
New York
Massachusetts
Maryland
California
Arkansas
Vermont
Connecticut
Florida
New Jersey
Virginia

Figure 11: AP Biology Exam Takers as a Share of High School Graduates, 2008



Source: Battelle analysis of data from the College Board and NCES.



Bioscience Education Schools and Programs

At least half of the states have at least one school with a bioscience focus, and all of the states have schools with a focus on science, technology, engineering, and mathematics (STEM) education. Many states have multiple schools focusing on life sciences or health sciences. In addition, many states are now advancing innovative bioscience education programs within existing high schools.

Among the leading examples of state activities are the following:

MASSACHUSETTS

Massachusetts Biotechnology Education Foundation's (MassBioEd's) BioTeach program is designed to enable every public high school in the state to teach biotechnology methods in its biology classes and to engage high school students with hands-on lab experience. BioTeach makes 50 awards totaling $440,000 annually for teacher professional development, supplies, and outreach programs. In 2008–2009, BioTeach added 49 schools to its program. Certain BioTeach schools have also been selected to participate in the Life Science Career Development Initiative, a model that provides students with an organized scope and sequence (grades 9–12) of academic, technical/technological, and work-based learning experiences while exploring career choices in biotechnology, bioengineering, and biomanufacturing.

CONNECTICUT

The Connecticut Career Choices (CCC) program builds off the basic courses in STEM (such as biology, math, and other sciences) and demonstrates their relevancy to students, linking to mastering critical thinking, problem-solving, and experiential learning. CCC involves innovative curriculum, online learning tools, professional development for teachers, experiential learning, and complementary extracurricular programs. The signature event for CCC is the Governor's High School Innovation Challenge, in which student teams are "challenged" to incorporate advanced technologies to develop a "mock" company and author a White Paper that describes innovative applications of technologies and services. Three bioscience courses are available: Biotech R&D, Foundations of Health Science and Technology, and a Science Research Seminar that involves 17 high schools and more than 600 students. An NSF grant was recently awarded to articulate CCC high school courses to Connecticut's College of Technology and enable awarding college credit for CCC high school courses.

CONNECTICUT, INDIANA, MARYLAND, MISSOURI, OHIO, OKLAHOMA & SOUTH CAROLINA

Seven states—Connecticut, Indiana, Maryland, Missouri, Ohio, Oklahoma, and South Carolina—are using Project Lead The Way (PLTW) as the vehicle to introduce bioscience education in their high schools. PLTW is a national nonprofit educational program that helps give high school students a strong grounding in science and engineering. While its initial focus was on pre-engineering, PLTW has now introduced a Biomedical Science Program that uses hand-on, real-world problems to engage and challenge students and involves a four-course program with focused teacher training.

MICHIGAN

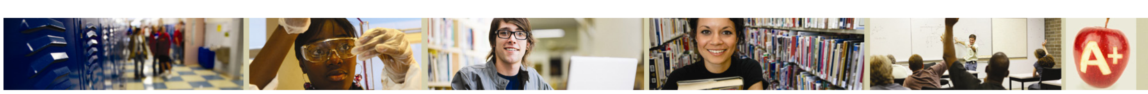
The Michigan Department of Education supports a series of eight "Middle College" schools with a health science emphasis. These 5-year high schools are located on the campus of a public university where students may attend as early as 9th grade and graduate with both a high school diploma and an associate's degree or 60 college credits.

NEW HAMPSHIRE

BioConnect New Hampshire has supplied equipment and training to Bow High School to become a "mini-biomanufacturing" facility, which in turn will provide DNA kits for classroom instruction in 20 other high schools, each of which will receive funding for start-up equipment. New Hampshire also has six biotechnology programs in Career and Technical Centers designed to lead to laboratory technician and scientist careers.

OHIO

Some 24 schools in Ohio's TechPrep program currently offer the Biotechnology Lab Program, many with articulation agreements with 2-year colleges offering associate's degrees in biotechnology disciplines.



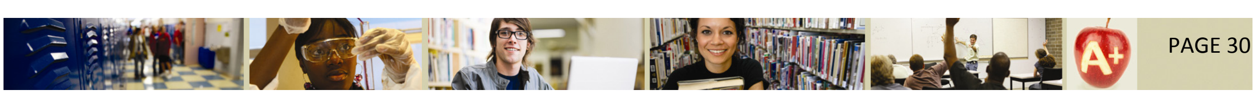
Arizona has been hard at work advancing an Arizona Biosciences Roadmap adopted in 2002. Along with strong bioscience industry and research growth has been an emphasis on bioscience education at the middle and high school level.

Currently, 32 Arizona schools offer a bioscience course or program of study. In the 2009–2010 school year, the number will jump to 52 schools. Two major bioscience education endeavors are the Mesa Public Schools Biotech Academy and Phoenix Union Bioscience High School in downtown Phoenix. Similar schools or academies are "on the drawing board."

*The **Mesa Public Schools Biotech Academy** is a 3-year program designed to create a community of learners in a "school-within-a-school" format. The academy provides academics combined with a career focus, a team of teachers, and bioscience industry involvement. The mission of the academy is to provide students with the skills and knowledge necessary to be competitive within the 21st century global economy and bioscience industry.*

***Phoenix Union Bioscience High School,** which opened in 2006, is a math and science–focused school that seeks to prepare students for careers in medicine, research, and related science and education endeavors.*

For the 2009–2010 school year, the Arizona Department of Education is working to offer three bioscience options through the CTE program: biomedical, bioenvironmental, and bioinnovations. Bioscience is an emerging program; at present, the largest number of students participating in bioscience career pathways is in agriculture, primarily in plant sciences. Approximately 20 districts currently offer bioscience-related CTE courses to high school students participating in dual or concurrent enrollment programs.



Teacher Quality and Preparation: Framework, Measures, and Key Findings

Experiences from around the globe on student education performance are heralding the importance of teacher quality and preparation. McKinsey & Company, in a comparison of 25 education systems from across the world, explored what the good systems have in common and what tools they use to improve student performance.[16] The study identified three things that matter most:

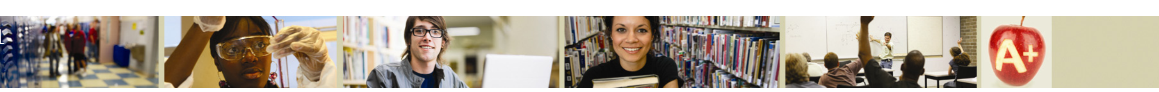
- Getting the right people to become teachers
- Developing them into effective instructors
- Ensuring that the system is able to deliver the best possible instruction for every child.

Finland, the world leader in PISA results, accepts only the best and brightest of its college graduates to become teachers, empowers them with intensive training in teaching theory to go along with subject knowledge, and holds them in high status once they are employed as teachers.

In the United States, the focus on teacher quality and preparation is getting significant support from a new wave of major foundation efforts in education reform. In 2007, ExxonMobil committed $125 million toward expanding nationally the UTeach mathematics and science teacher-preparation program at the University of Texas, Austin. The UTeach program encourages math and science majors to enter the teaching profession by offering an integrated degree plan, financial assistance, and early teaching experiences for undergraduates.

Late in 2008, the Gates Foundation announced a $500 million investment in the development of effective teachers. Bill Gates expressed his serious commitment to improving teaching quality in his 2009 Annual Letter on U.S. Education, stating:

> **Whenever I talk to teachers, it is clear that they want to be great, but they need better tools so they can measure their progress and keep improving. So our new strategy focuses on learning why some teachers are so much more effective than others and how best practices can be spread throughout the education system so that the average quality goes up.**



Indicators and Key Findings:

Teacher Quality Indicator: Certified Biology Teachers, Grades 9–12, 2006

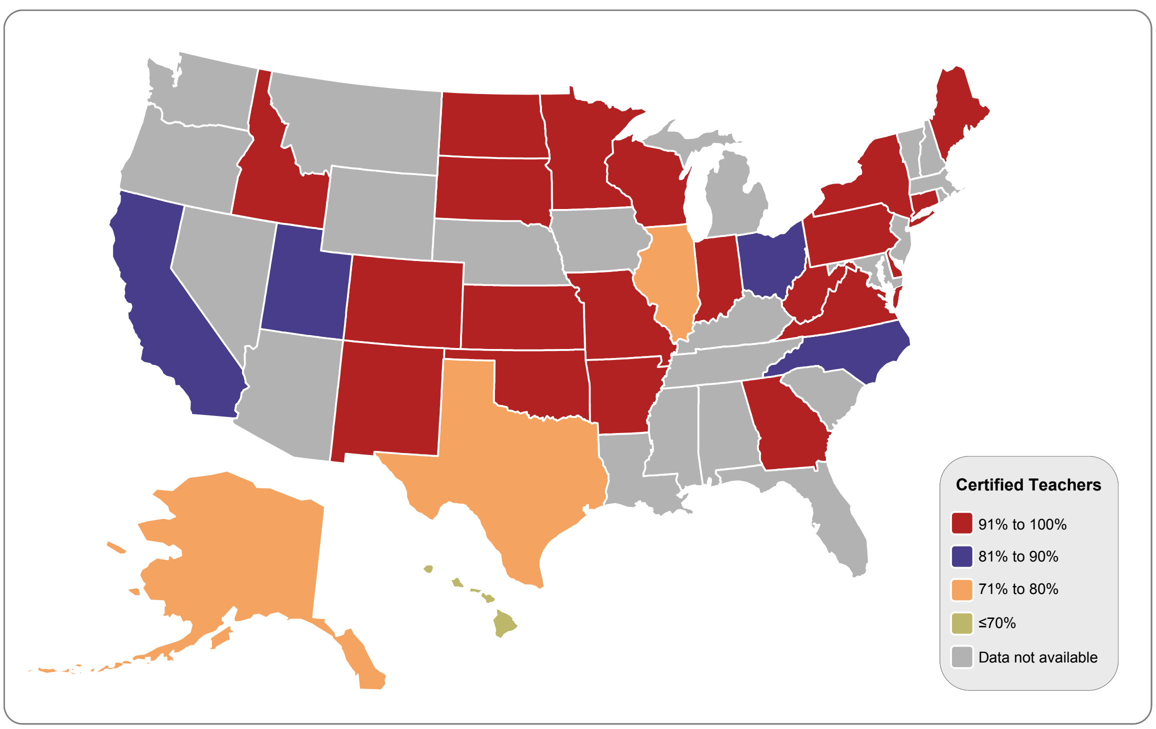
The CCSSO has tabulated data on the certification of science and math teachers across states. Certification is a standard approach that each state takes to ensure that its teachers have basic subject matter knowledge, though each state sets its own certification requirements. In its 2007 report, *State Indicators of Science and Mathematics Education*, CCSSO presents certification data for high school biology teachers for 28 states. Nationally, 88% of biology teachers are certified, on average.[17]

Among those states reporting teacher certification in biology, the average share of teachers certified ranges from 50% to 100%. Twenty of these 28 states report certification levels greater than 90%. These data are presented in the national map in Figure 12.

Teacher Quality Indicator: Science Teachers with a Major in Assigned Field, 2004

Separate from teacher certification is a more fundamental characteristic of teacher qualification and expertise—whether the individual is teaching a subject in which he or she received his or her college degree. Questions in the large, national Schools and Staffing Survey conducted by NCES provide data on the share of science teachers, grades 7-12, with a major in their assigned science field. While this indicator covers science instruction overall, it speaks to the expertise within each state regarding subject-specific specialization and the ability of teachers to share a broader base of knowledge and experiences with their students.

Figure 12: Share of Certified Biology Teachers, Grades 9–12, 2006



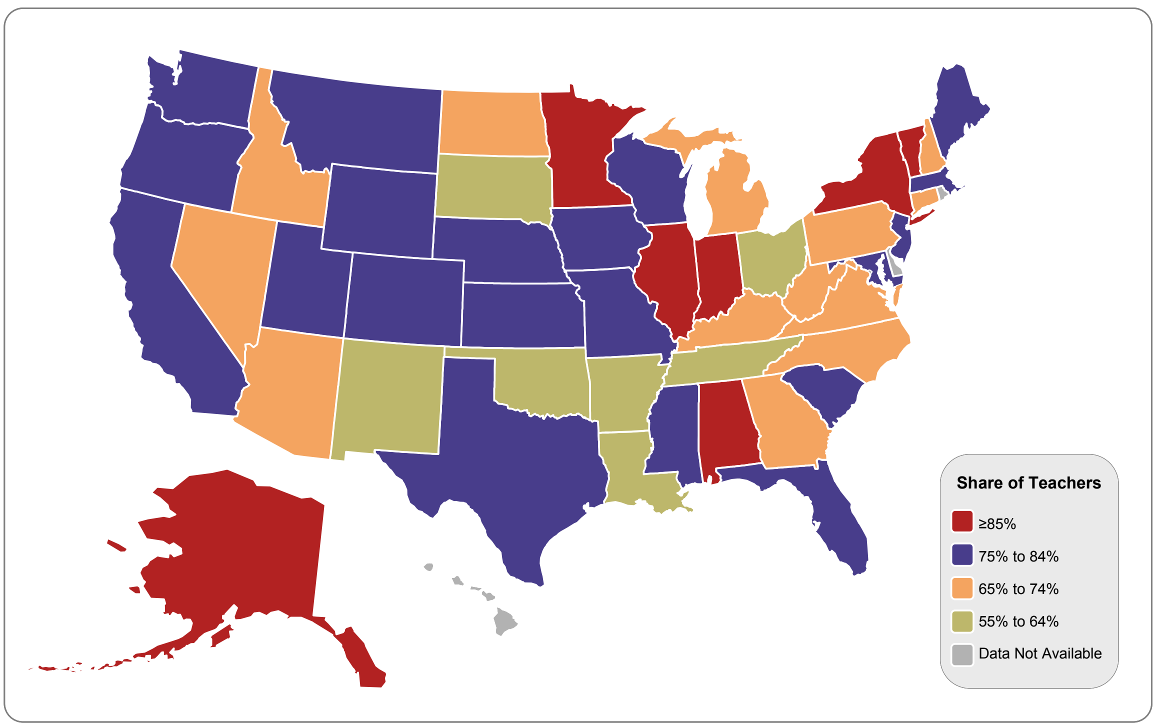
Source: CCSSO analysis of state departments of education data on public schools.

Teachers with Degree in Assigned Field, Leading States

New York
Vermont
Minnesota
Indiana
Alaska
Alabama
Illinois

On average, 77% of U.S. science teachers at the middle and high school levels had a major in their assigned field in 2004. The national map in Figure 13 presents data for 47 states and ranges from a low of 55% to a high of 91%. Seven states reported that 85% or more of their teachers met this qualification.

Figure 13: Science Teachers with a Major in Assigned Field, Grades 7–12, 2004



Source: U.S. Department of Education, NCES, Schools and Staffing Survey, 2003-2004; reported by CCSSO, 2007.

State Policies and Programs

As the above data show, there is still work to be done in ensuring that the United States has a well-educated, fully informed cadre of science educators at the K-12 level. States are taking three approaches to improving the supply and quality of K-12 science teachers:

- Providing professional development opportunities for existing teachers
- Improving and strengthening teacher education programs
- Initiating programs aimed at attracting high-achieving students as well as individuals in other careers into teaching.

Professional Development Programs

Professional development programs designed to provide middle and high school teachers with the training, equipment, supplies, and resource personnel to enable them to expose their students to biotechnology and the biosciences exist in every state. Workshops, conferences, and summer institutes are offered by colleges and universities, laboratories, and other science-related organizations. Externship programs that place teachers in bioscience companies and/or research organizations are becoming common. Many of these programs are grant-funded, often by the NSF but also by foundations and private companies; as a result, they tend to be somewhat sporadic rather than continuous, and individual programs often serve only a very limited number of teachers. Accordingly, demand for science-related professional development often outstrips the supply of these programs.

A number of states are beginning to take a more systematic approach designed to reach all areas of the state and impact a larger number of teachers and thus students. Examples of professional development programs include the following:

- **Georgia Bio (GaBio)** has received funding from the Governor's Office of Workforce Development (GOWD) to provide a combination of support to teachers in 13 counties, known as the Innovation Crescent, to launch biotechnology career pathways linking high school programs to 2- and 4-year institutions. The funding, which flows to teachers, includes professional development to incorporate biotechnology tasks and career information into existing middle- and high-school science curricula, and training and equipment to implement high school biotechnology courses in 10 schools in four counties next year. Hands-on activities have been developed and extensive training of teachers is being conducted to prepare teachers to launch a new biotechnology course developed by the state and approved in 2008. Nine schools will begin offering the class in 2009; another three are expected to do so in 2010. Since 2007, the GaBio initiative has provided $678,000 to enhance bioscience professional development, equipment, and career pathways in the state. GOWD recently awarded additional funds to implement bioscience career pathways in the Valdosta region.
- The **North Carolina Biotechnology Center (NCBC)** provides a comprehensive program for K-12 North Carolina teachers beginning with summer professional development workshops and following through with other resources for classroom teaching, including the following:
    - **Laboratory Supplies Program.** Each NCBC workshop graduate receives a special order form each year for biotechnology lab supplies valued at $200 from Carolina Biological Supply.

A study on the Status of Science Education in the Bay Area found that "Forty-one percent of multiple-subject elementary school teachers feel inadequately prepared to teach science. ...At the same time, 56% of teachers surveyed had fewer than 3 hours of science professional development over the previous 3 years."

Assets and Capacities to Support Bay Area Science Learning Opportunities: Results from the Science-Rich Educational Institutions Asset Study, University of California, Berkeley, December 2008.

- **Equipment Loan Program.** The NCBC maintains biotechnology equipment for loan to workshop graduates around the state.
- **Video Loan Program.** All North Carolina educators are eligible to borrow DVDs or videotapes about biotechnology for use in the classroom.

Grants are also available to support local teacher professional development and to produce educational tools that can be broadly distributed for use in bioscience education. About eight grants totaling approximately $116,000 are made annually to support middle- and high-school teacher professional development. NCBC holds Biotechnology Summer Workshops for Educators that offer middle and high school teachers the training they need in the many areas of biotechnology, featuring hands-on activities that will engage students and improve learning.

- The **Life Sciences Summer Institute (LSSI)**, a joint program of the San Diego Workforce Partnership, BIOCOM, and BIOCOM Institute, and the Southern California Biotechnology Center (SCBC) at Miramar College, has trained 67 teachers with the potential to reach 28,000 students. The 12-day paid program includes an introduction to the industry, laboratory curriculum training, and half-day industry externship experiences. The LSSI Teacher Externship Program is hosted at Biogen Idec in its Community Laboratory facility and utilizes the Amgen-Bruce Wallace Biotechnology Laboratory Program Curriculum. Participants receive free supplies, loaner equipment, and ongoing staff support for curriculum implementation throughout the school year.
- The Oklahoma City Community College (OCCC) has a **Biotechnology/ Bioinformatics Discovery! Program** that provides an array of resources for middle- and high-school science teachers, including the following:
  - More than 25 modules with lesson plans to use in high school biology classes, another 25 modules to be used in biotechnology, AP biology and biology II classes, and 4 modules for use in pre-biotechnology labs in middle schools
  - **Discovery!Kits for Educators** that provide the equipment to conduct the labs associated with the various modules
  - **BBDiscovery Workshops** at OCCC for high school teachers at different levels of infusion into the high school classes. Workshops are offered at rural sites on an ongoing basis.

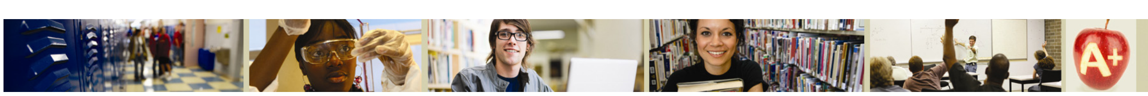
Teacher Education Programs

Many universities and colleges across the country offer programs that enable students to major in biology and, at the same time, complete the requirements for teacher certification or offer education degrees with a specialization in science and/or biology. The California State University initiative described below demonstrates the kind of activities that can be undertaken to increase the number and quality of students pursuing careers as math and science teachers; the UTeach program at the University of Texas has a proven track record in attracting students to become secondary science and math teachers and is being replicated nationally.

- The **California State University system**, the state's largest producer of math and science teachers, committed in 2004 to double its production of teachers in STEM disciplines from a baseline of 750 in 2003 to 1,500 by 2010. The six elements of the state-supported program are as follows:
    - New credential pathways
    - Financial support and incentives
    - Recruitment to expand and diversify the pool
    - Internet-supported delivery of instruction and resources
    - Partnerships with California-based federal labs, businesses, and industry
    - Collaboration between campuses and community colleges.
- **UTeach**, started at The University of Texas at Austin in 1997 as a new way to prepare secondary science, math, and computer science teachers, is a collaboration between UT's Colleges of Natural Sciences and Education and the Austin Independent School District (AISD). Its goal is to attract interested students to explore secondary teaching early with limited initial commitment of time and money. As early as their freshman year, UTeach students receive their first experience in the public school classroom, working with experienced AISD teachers who mentor them.

    From modest beginnings as a Natural Sciences pilot program of 28 students in the fall 1997, UTeach has grown to a current enrollment of more than 450 students, graduating approximately 70 certified mathematics and science teachers this past year. The UTeach program is now being replicated at universities across the country.

Most states offer alternative certification programs that enable individuals holding a bachelor's degree in a particular subject area in which teachers are in high demand to obtain teacher certification on an accelerated basis. The **University of Arizona**, for example, offers a Web-delivered teacher certification program designed for individuals interested in becoming science teachers at the secondary-school level. Applicants must have completed a bachelor's degree from an accredited institution of higher education in either a science or engineering field, must meet the UA Graduate College entrance requirements for acceptance as a nondegree



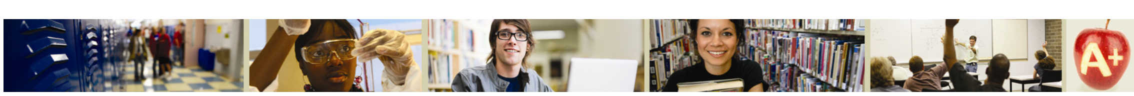
student, and obtain a valid fingerprint clearance card issued by the Arizona Department of Public Safety. The **University of Missouri Science Education Program** sponsors the NSF-funded Science and Mathematics Academy for the Recruitment and Retention of Teachers (SMAR2T), which certifies baccalaureate holders in science and math to teach at the middle or secondary levels in 15 to 24 months.

Teacher Recruitment Programs

Loan forgiveness programs, scholarships, and other financial incentives are being used to encourage college math and science students to consider careers as teachers. Senate Bill 08-133, signed into law by Colorado Governor Bill Ritter in May 2008, established the **Teach Colorado Grant Initiative** to give financial incentives to college students to enter the teaching profession and thereby increase the number of teachers in high-need areas, including, but not limited to, mathematics, science, special education, English language acquisition, music, and world languages. Under this bill, the Department of Higher Education is authorized to administer a program of grants to public institutions of higher education, which in turn will create scholarships for high-ability students in approved teacher preparation programs who excel in high-need content areas and who demonstrate an interest in or commitment to teaching as a career.

In 2007, the Kansas legislature created the **Teacher Education Competitive Grant Program**, which awards funds on a competitive basis to colleges and universities to expand teacher education programs aimed at increasing the number of students completing the requirements to be certified to teach math or science or willing to teach in an underserved area.

Mississippi's **Critical Needs Teacher Scholarship Program** provides full scholarships to teachers and/or students who teach or intend to teach in geographical areas and subject areas where shortages exist, including mathematics and sciences. Mississippi also offers an **Assistant Teacher Scholarship Program** that awards scholarships to attract and retain qualified teachers for academic subject areas in which there exists a critical shortage of teachers.



I'm challenging states to dramatically improve achievement in math and science by raising standards, modernizing science labs, upgrading curriculum, and forging partnerships to improve the use of science and technology in our classrooms. I'm challenging states, as well, to enhance teacher preparation and training, and to attract new and qualified math and science teachers to better engage students and reinvigorate those subjects in our schools.

President Barack Obama
Remarks by the President at the Annual Meeting of the National Academy of Sciences
April 27, 2009

Experiential Learning and Career Awareness: Framework, Measures, and Key Findings

Bioscience education at the middle and high school levels need to transcend just learning facts and focus on hands-on laboratory experiences. As the National Research Council explains in *Inquiry and the National Science Education Standards*: "Knowing science, however, is not only knowing scientific concepts and information … All students need to learn strategies for scientific thinking … Through scientific inquiry, students can gain new data to change their ideas or deepen their understanding of important scientific concepts."[18]

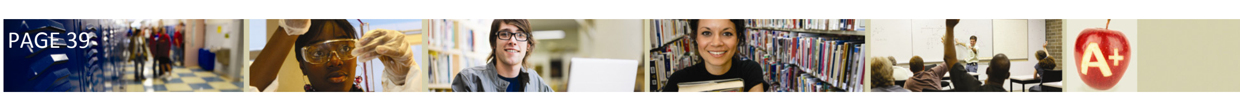
Experiential learning is an important approach to furthering scientific inquiry by emphasizing the importance of doing science, not just reading textbooks and learning facts. Experiential learning can involve a range of both in-school and out-of-school (extracurricular) activities that enable students to work hands-on to apply biological learning.

Experiential learning makes science come to life for students. Another important strategy in middle and high schools is to raise the career opportunities possibly eventuated by pursuing the biosciences. A recent article in *Science* by Robert Tai, based on an analysis of the National Education Longitudinal Study, found as follows[19]:

- Eighth-grade students who reported that they expected to enter a science-related career by age 30 have nearly doubled the likelihood of completing a life science degree.
- Among those completing a bachelor's degree, those stating an interest in eighth grade in a science-related career were 1.9 times more likely to earn a life science B.S. degree than those students who in eighth grade did not expect to pursue a science-related career.

Measures and Key Findings:

Experiential learning and career awareness programs are extremely widespread with colleges, universities, museums, and other science-based organizations providing services that include field trips, on-site classes for school groups, summer camps, workshops, and internships. Programs also provide research experiences for high school students and mobile bioscience laboratories that offer students and teachers the opportunity to conduct hands-on experiments. Every state has at least one experiential learning and outreach program in the sciences, and the majority of states have programs focused on the biosciences. For many states, it is difficult, if not impossible, to develop a comprehensive list of



such programs. The following are examples of experiential learning and career awareness programs:

- **Alaska BioPREP** is a program designed to engage 7th through 12th grade students and teachers, with emphasis on rural students of Alaska Native ethnicity, in biomedical research projects that lead toward health careers. This program incorporates the intellectual rigor of scientific inquiry and then addresses the attitudes and social values conducive to learning science. Pilot projects have proved that students from rural Alaska high schools who participate in the program are more likely to go on to major in science in college. Students in 7th to 12th grades use molecular biology to address scientific questions that are locally relevant.
- Delaware Technical and Community College offers a **Biotechnology Summer Experience** to introduce high school students with an interest in pursuing a science degree to biotechnology and research.
- KansasBio members work with 19 Kansas school districts, impacting 2,000 students each year, with its **Simply Science** program. The program, which is based on Bayer's Making Science Make Sense initiative, is coordinated through Kansas State University's Extension Service.
- Jackson Lab, located in Bar Harbor, Maine, offers a **Summer Internship Program** that provides high school and college students with an opportunity to conduct independent research under the guidance of staff scientists. More than 2,000 students, including two Nobel laureates, have participated in the program. The Lab also has a **High School Internship Program** that enables students with a strong interest in math and science from Ellsworth and Mount Desert Island High Schools to work "at the bench" with Jackson Lab researchers.
- **Base Pair**, initiated in 1992, is a biomedical research mentorship program that pairs faculty from the University of Mississippi Medical Center (UMC) with public high school students and educators. Oriented to interact primarily with participants from the largest public school district in the state of Mississippi, the Jackson Public School District (JPSD), the program has expanded to enlist students and/or teachers from school districts throughout central Mississippi. This program allows each student to experience the scientific field in a "hands-on" manner under the guidance and supervision of a faculty researcher at UMC. Base Pair seeks to cultivate career awareness of high school students in areas related to health care/biomedical research, to train such students to function as effective "Communicators of Science" to laypersons, and to advance science curriculum development within the target school district.
- **BioTrek** is the Science Outreach Program of the Biotechnology Center of the University of Wisconsin at Madison (UW-Madison) and of UW-Extension. BioTrek engages the public in the outreach mission of the university by providing tours and workshops at the Biotechnology Center on the UW-Madison campus. BioTrek also offers workshops and in-service programs for teachers, students, 4-H and other Cooperative Extension groups, community clubs, and after-school groups.

While programs are numerous, most are grant-funded and, as a result, often come and go as grants end at one institution and begin at another. Many outreach programs, such as summer camps, reach only a small number of students on an annual basis; many focus on serving high-achieving students with an interest in science or math. A study of outreach programs in the Bay Area found as follows:

- The majority of public school students are not served through the outreach programs of the region's science-rich educational institutions.
- Most outreach programs are less than two hours in length.
- Different types of programs tend to serve different populations. Summer camps do not tend to serve a very diverse audience, while out-of-school classes (in particular) and teen internship programs (to a degree) are able to serve a more diverse audience.[20]

One way in which some states are trying to reach a larger number of students is by means of traveling laboratories that essentially bring the lab to middle and high schools, providing the opportunity for students and their teachers to conduct hands-on experiments. Ten states and Puerto Rico have such mobile labs that are designed to increase student interest and achievement in the sciences. Connecticut's BioBus is fairly typical.

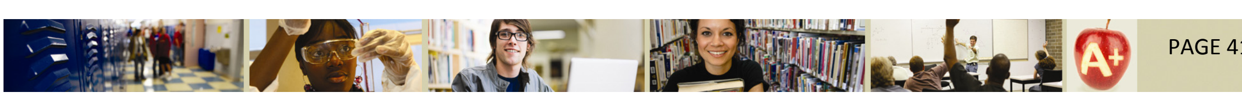
- The **Connecticut BioBus** is a 40-foot, custom-designed mobile laboratory delivering hands-on bioscience experiments to more than 5,000 students throughout Connecticut each year. Outfitted with the latest in bioscience equipment and technology, the BioBus provides hands-on experiential learning experiences for students in the 4th through 12th grades. The BioBus accommodates two instructors and up to 24 students at a time. The BioBus visits Connecticut schools free of charge, though each visit requires an investment of time and effort by teachers and the school, including (1) participation in teacher training; (2) integrating the BioBus visit into classroom lessons, along with running activities before and after the BioBus visit; and (3) assisting BioBus staff in teaching on board the BioBus.

Mobile Science Laboratories

- Salk Mobile Science Lab in California
- Connecticut BioBus
- Georgia State University BioBus
- University of Illinois Science on the Go
- MdBioLab in Maryland
- Boston University's Mobile Lab
- North Carolina DESTINY Traveling Science Program
- University of Pittsburgh PITT Mobile Science Lab
- South Dakota Science on the Move
- West Virginia Toyota Science on Wheels
- University of Puerto Rico Mayaguez's Science on Wheels

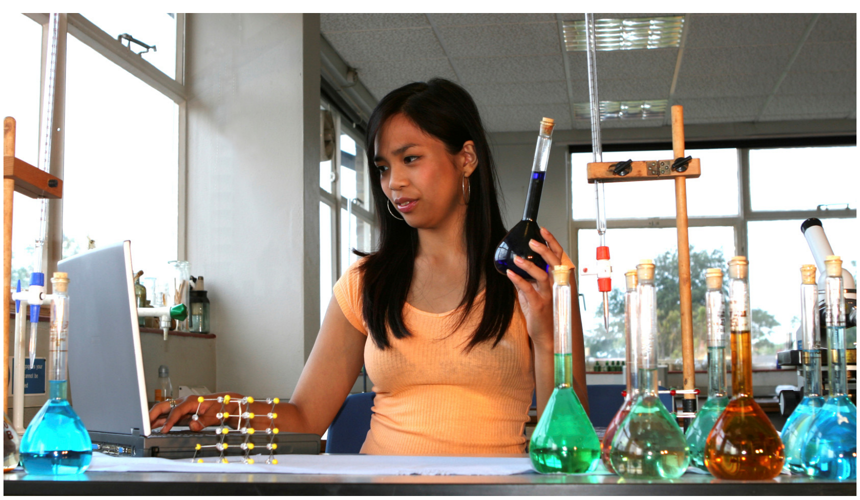
To foster greater career awareness, 16 states reported that comprehensive web sites are available that provide information on life science careers. These include sites that focus on science career opportunities or more general sites that include information on the biosciences. The following are examples of sites created to specifically focus on bioscience careers:

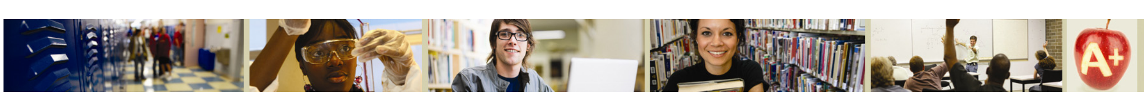
- **iSciWNY** (www.iSciWNY.org), a career portal created by the New York State Center of Excellence in Bioinformatics and Life Sciences at the State University of New York at Buffalo. The site provides information on seven life science career pathways such as lab science,



manufacturing, and quality control. For each position within the career pathway, the following information is provided: wage level, educational requirements, job description, list of area employers, and list of available education and training programs. The site provides a link to a Buffalo Niagara Jobs site that lists available positions within the region.

- The North Carolina Association for Biomedical Research (NCABR) recently launched a new Web-based resource, the North Carolina Biotechnology Clearinghouse (www.aboutbioscience.org), which presents information about a wide range of bioscience careers. The site, which is designed for the use of students and teachers, includes short videos on select careers in the biosciences and more than 20 career profiles of bioscience-related jobs. The profiles discuss career opportunities, education and training requirements, certification requirements, and salary. The site also lists workshops, conferences, camps and internships for K-12 students, and professional development opportunities for K-12 teachers.
- The **BIOCOM Institute**, in collaboration with the U.S. Department of Labor and the San Diego Workforce Partnership has created a "one-stop shop" for life science career resources (www.biocominstitute.org). The online center educates regional talent pools about the skills necessary to fill life science positions. The BIOCOM Institute Online Workforce Center is organized into four sections; Life Science Careers, Education and Training, BIOCOM Institute Initiatives, and Resources. Key features include a searchable database containing more than 800 life science career descriptions and 300 degree and professional development programs offered by educational institutions within Southern California. This clearinghouse of industry-specific career information reaches employers who want a link to potential workers, students making a career choice, job seekers looking for employment resources, and workers who are looking for a career change.





Conclusion

A number of conclusions can be reached from this first-ever assessment of bioscience education in the United States. First, middle- and high-school student achievement in the sciences and, to the extent the biosciences can be measured, in the biosciences is poor and not improving. Second, programs that seek to incorporate the biosciences and biotechnology in school curricula, improve teacher quality and knowledge of the biosciences, provide experiential learning opportunities in the biosciences, and increase career awareness are numerous but limited in their reach. At the same time, model programs have demonstrated success in encouraging students to excel in science and to pursue careers in the sciences, including in the biosciences.

Clearly, more must be done to raise the level and quality of bioscience education if the United States is to remain globally competitive in the biosciences. Many examples exist of the type of programs that work; but, they need to be replicated and states need to commit resources to them. This review of state activities in bioscience education suggests a number of actions that should be taken, including the following:

- States should incorporate biotechnology as they revise their science standards and should involve research scientists with expertise in the biosciences in their development.
- States must commit to improving student achievement in biology and the life sciences and to ensuring that their high school graduates are ready to pursue college-level bioscience courses.
- States should do a better job of collecting and disseminating data to track student participation and performance in the biosciences and the broader sciences. States that do not participate in the NAEP should be encouraged to do so.
- States should take a more systematic approach to teacher professional development, experiential learning, and career awareness.

Desired Participation and Performance Measurement Data Currently Unavailable by State

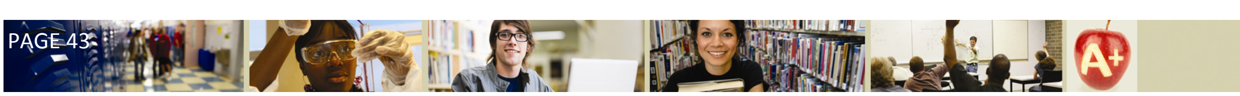
Share of high school students enrolled in AP biology or other advanced science classes, e.g., molecular biology, biochemistry, AP chemistry

Number of students enrolled in CTE bioscience-related career pathway courses

Percentage of high school biology teachers certified in biology (currently available only for certain states)

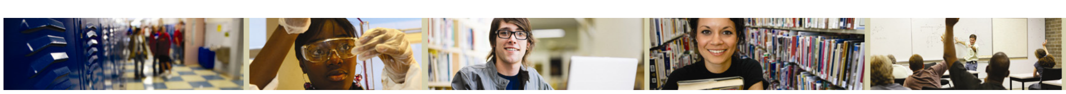
Percentage of middle-school science teachers who have completed professional development courses or workshops focused on biotechnology

Percentage of middle school students who participate in experiential learning in the biosciences



List of abbreviations

AAAS	American Association for the Advancement of Science
ACT	Formerly known as the American College Test
AISD	Austin Independent School District (Texas)
AP	advanced placement
BIO	Biotechnology Industry Organization
CCC	Connecticut Career Choices
CCSSO	Council of Chief State School Officers
CTE	career and technical education
GaBio	Georgia Bio
GOWD	Governor's Office of Workforce Development (Georgia)
JPSD	Jackson Public School District (Mississippi)
LSSI	Life Sciences Summer Institute (California)
MassBioEd	Massachusetts Biotechnology Education Foundation
NAEP	National Assessment of Educational Progress
NAS	National Academy of Sciences
NCABR	North Carolina Association for Biomedical Research
NCBC	North Carolina Biotechnology Center
NCES	National Center for Education Statistics
NSF	National Science Foundation
OCCC	Oklahoma City Community College
OECD	Organization for Economic Cooperation and Development
PISA	Program for International Student Assessment
PLTW	Project Lead The Way
SAT	Scholastic Aptitude Test
SCBC	Southern California Biotechnology Center
SMAR2T	Science and Mathematics Academy for the Recruitment and Retention of Teachers
UMC	University of Mississippi Medical Center
UW-Madison	University of Wisconsin at Madison



ENDNOTES

[1] *Growing Talent: Meeting the Evolving Needs of the Massachusetts Life Sciences Industry.* Study conducted by UMass Donahue Institute for the Massachusetts Life Sciences Center, September 2008, page 11.

[2] *Arizona Bioscience Workforce Strategy: Preparing for the Future*. Prepared by Battelle for the Maricopa Community Colleges in collaboration with Arizona Department of Commerce, Yavapai Community College, and the Flinn Foundation, October 2003, page 8.

[3] Data for Puerto Rico were generally not available for the education statistics presented in this report. Battelle did receive some survey information from Puerto Rico as well as limited information from education websites that combine to form the Puerto Rico profile.

[4] Susan Musante. "Critical Conversations: The 2008 Biology Education Summit." *BioScience*, September 2008, Vol. 58, No. 8, page 686.

[5] National Governors Association. *Building a Science, Technology, Engineering and Math Agenda*. page 8.

[6] The NAEP Science scale ranges from 0 to 300. Observed differences are not necessarily statistically significant. NAEP Science data are not available for Alaska, Iowa, Kansas, Nebraska, New York, Pennsylvania, the District of Columbia, and Puerto Rico as participation in the Science NAEP remained voluntary for the 2005 assessment.

[7] The Nation's Report Card, Science 2005. National Center for Education Statistics, U.S. Department of Education, 2006.

[8] The Nation's Report Card, Science 2005. National Center for Education Statistics, U.S. Department of Education, 2006.

[9] *Closing the Gap in Science Achievement: Using NAEP Science Assessment Scores to Analyze State Trends*. Council of Chief State School Officers, 2007.

[10] *The Nation's Report Card, Science 2005*, National Center for Education Statistics, U.S. Department of Education, 2006.

[11] For a full course description for AP biology by the College Board, refer to http://www.collegeboard.com/prod_downloads/ap/students/biology/ap-cd-bio-0708.pdf.

[12] For more information on the ACT and 2008 scores, refer to http://www.act.org/.

[13] Sets of test prep ACT science questions are available at http://www.actstudent.org/sampletest/index.html.

[14] Paul R. Gross et al. *The State of State Science Standards*. Thomas B. Fordham Institute, December 2005, page 8.

[15] States not listed in Table 2 do not include a reference to biotechnology in their state science standards. Data were unavailable for Puerto Rico.

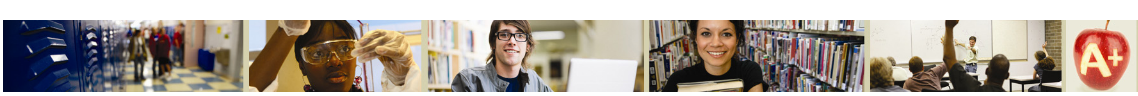
[16] McKinsey & Company. *How the World's Best Performing School Systems Come Out on Top*. September 2007.

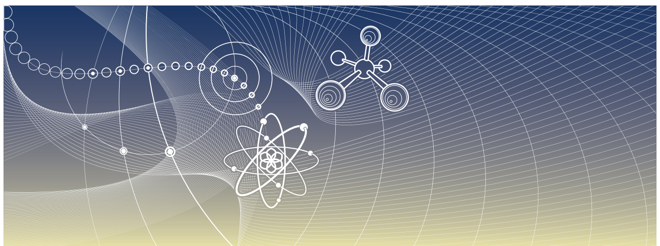
[17] *State Indicators of Science and Mathematics Education*. Washington, DC: Council of Chief State School Officers, 2007. National average includes imputed values for nonreporting states.

[18] National Research Council. *Inquiry and the National Science Education Standards*. 2000, page 117.

[19] Robert H. Tai et al. "Planning Early for Careers in Science." *Science*, May 26, 2006.

[20] Maia Werner-Avidon, Rena Dorph, Ph.D., with Scott Randol, Ph.D. *Assets and Capacities to Support Bay Area Science Learning Opportunities: Results from the Science-Rich Educational Institutions Asset Study.* University of California, Berkley, December 2008.





May 2009