Introduction

This report examines K-12 science standards for fifty states and the District of Columbia, as well as the science assessment framework of the National Assessment of Educational Progress (NAEP). Our aim is to evaluate them for their intrinsic clarity, completeness, and scientific correctness. We have not investigated whether they are being properly assessed with state tests or effectively implemented in the schools, or whether they are driving improvements in student achievement.

That said, setting clear, thorough, and rigorous standards is critical. They are the foundation upon which a state's system of assessment, instruction, and accountability rests.

2012 Analysis: Where State Standards Go Wrong

Our earlier evaluations, as well as those evaluations conducted by others, have made it clear that too many state science standards are mediocre to poor. In particular, there are four areas where they most frequently fail to measure up.

Problem 1: An Undermining of Evolution

"Nothing in biology makes sense except in the light of evolution." So wrote famed biologist Theodosius Dobzhansky in 1973.[12] And so it is today. Yet controversy continues to envelop the teaching of evolution in American schools. One wonders, indeed, how much progress we've made in this realm since the Scopes trial in 1925. Six years ago, our science reviewers noted that:

> **The attack on evolution is unabated [since 2000], and Darwin's critics have evolved a more-subtle, more dangerous approach. A decade ago, the anti-evolution movement…argued vigorously for explicit teaching of the evidence for intelligent design. …The claim now is that evidence against "Darwinism" exists, that curriculum-makers should include it as an exercise in critical thinking, and that "freedom of speech" or "fairness" requires that they do so. The hidden agenda is to introduce doubt—any possible doubt—about evolution at the critical early stage of introduction to the relevant science.[13]**

While many states are handling evolution better today than in the past, anti-evolution pressures continue to threaten state science standards. In June 2008, for example, Louisiana passed its infamous Science Education Act, ostensibly an "academic freedoms act" meant to give teachers and students legal cover to debate the merits and veracity of scientific theories. In practice, the measure pushes a pro-creationist agenda—and gives cover to those looking to teach intelligent design creationism. Though the act is a free-standing statute with no direct link to the Pelican State's academic standards, it does damage by allowing for the introduction of creationist teaching supplements—thereby affecting classroom instruction without explicitly altering the state's standards.[14]

Louisiana is not the only state that has tried to undermine the teaching of evolution through legislation. In 2011 alone, eight

[12] Theodosius Dobzhansky, "Nothing in Biology Makes Sense Except in the Light of Evolution," *The American Biology Teacher* 35 (1973): 125-129, http://people.delphiforums.com/lordorman/Dobzhansky.pdf.

[13] Paul R. Gross, *The State of State Science Standards 2005* (Washington, D.C.: Thomas B. Fordham Institute, December 2005), http://www.edexcellence.net/publications/index.jsp?issuestopics=standards-testing-accountability&page=8.

[14] For details, see *Bulletin 741—Louisiana Handbook for School Administrators*, published by the Louisiana Board of Elementary and Secondary Education at http://www.doa.louisiana.gov/osr/lac/28v115/28v115.doc. Section 2304 stipulates how the Science Education Act is to be administered by school administrators and teachers at the parish and local levels.

anti-evolution bills were introduced in six state legislatures. (Thankfully, none made it into law.) And two similar bills were pre-filed in New Hampshire for the 2012 legislative session,[15] as well as one in Indiana.[16]

Of course, most anti-evolution efforts are aimed more directly at the standards themselves. And these tactics are far more subtle than they once were. Missouri, for example, has asterisked all "controversial" evolution content in the standards and relegated it to a voluntary curriculum that will not be assessed. (Sadly, this marks a step back from that state's coverage of evolution in 2005.) And Maryland includes evolution content in its Kindergarten through eighth-grade standards but explicitly excludes crucial points from its state assessment.

Other states have undermined the teaching of evolution by singling it out as somehow not quite as "scientific" as other concepts of similar breadth. A common technique—used to a greater or lesser extent by Colorado, Missouri, Montana, and West Virginia—is to direct students to study its "strengths and weaknesses."

Far too often, important evolution content is included, but minimally. Some states mention evolution just once in their standards and never revisit it. Others—including Indiana, Iowa, Kansas, Kentucky, Michigan, and Nebraska—unnecessarily delay it until high school.

Even some of the nation's best standards subtly undermine the teaching of evolution. In California, for example, students are told to "understand science, not necessarily [to] accept everything taught." In New York, students learn that "according to many scientists, biological evolution occurs through natural selection." (This is not according to "many" but, in fact, *all* true scientists.)

Finally, conspicuously missing from the vast majority of states' standards is mention of *human* evolution—implying that elements of biological evolution don't pertain to human life. This marks a subtle but important victory for creationists: Even states with thorough and appropriate coverage of evolution (e.g., Massachusetts, Utah, and Washington) shy away from linking the controversial term with ourselves. Only four states—Florida, New Hampshire, Iowa, and Rhode Island—openly embrace human evolution in their current science standards. (Pennsylvania, which referenced human evolution in its previous standards, has omitted it from the more recent version.)

Problem 2: A Propensity to be Vague

Educators should not be confronted with standards that are so vague as to be meaningless—and yet, based on our current analysis, that is precisely what many states have imposed on their teachers. In fact, only seven states had standards clear enough to earn them full-credit scores of three out of three points for clarity and specificity. Twenty-eight earned a one or zero out of three.

A middle school teacher in New Hampshire, for example, will come face to face with the following: "Identify energy as a property of many substances." Pennsylvania offers the equally baffling "Explain the chemistry of metabolism." Such empty statements can do little to inform curriculum development or instruction, and give no guidance to assessment developers.

Similarly, New Jersey students are asked to:

> **Demonstrate understanding of the interrelationships among fundamental concepts in the physical, life, and Earth systems sciences. (grade 4)**
>
> **Use outcomes of investigations to build and refine questions, models, and explanations. (grade 4)**

These expectations contain virtually no specific content; it's impossible to determine what students should actually know or be able to do. To our dismay, similarly vague and meaningless statements are common across far too many state standards.

A few, however, have crafted clear and specific standards that could easily form the basis of a rigorous K-12 science curriculum. For instance, the California standards explain:

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[15] House Bill 1148, introduced by Jerry Bergevin (R-District 17), would charge the state board of education to "[r]equire evolution to be taught in the public schools of this state as a theory, including the theorists' political and ideological viewpoints and their position on the concept of atheism." House Bill 1457, introduced by Gary Hopper (R-District 7) and John Burt (R-District 7), would charge the state board of education to "[r]equire science teachers to instruct pupils that proper scientific inquire [*sic*] results from not committing to any one theory or hypothesis, no matter how firmly it appears to be established, and that scientific and technological innovations based on new evidence can challenge accepted scientific theories or modes." Although HB 1457, as drafted, is silent about intelligent design, Hopper's initial request was to have a bill drafted that would require "instruction in intelligent design in the public schools." Both bills were referred to the House Education Committee; HB 1148 is scheduled for hearing on February 9, 2012, and HB 1457 is scheduled for hearing on February 14, 2012.

[16] Senate Bill 89, pre-filed in the Indiana Senate and referred to the Committee on Education and Career Development, would, if enacted, amend the Indiana Code to provide that "[t]he governing body of a school corporation may require the teaching of various theories concerning the origin of life, including creation science, within the school corporation." The sponsor of the bill is Dennis Kruse (R-District 14), who chairs the Senate Committee on Education and Career Development.

Electricity and magnetism are related effects that have many useful applications in everyday life. As a basis for understanding this concept:

- ***Students know*** **how to design and build simple series and parallel circuits by using components such as wires, batteries, and bulbs.**
- ***Students know*** **how to build a simple compass and use it to detect magnetic effects, including Earth's magnetic field.**
- ***Students know*** **electric currents produce magnetic fields and know how to build a simple electromagnet.**
- ***Students know*** **the role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones.**
- ***Students know*** **electrically charged objects attract or repel each other.**
- ***Students know*** **that magnets have two poles (north and south) and that like poles repel each other while unlike poles attract each other.**
- ***Students know*** **electrical energy can be converted to heat, light, and motion. (grade 4)**

This standard leaves no question as to what, precisely, students should know or be able to do.

Alas, such cogent and unambiguous writing is distressingly rare.

Problem 3: Poor Integration of Scientific Inquiry

For at least the past fifteen years—possibly even longer—science educators, curriculum developers, and standards writers have focused greater and greater attention on "inquiry-based learning." In practice, this means helping students learn scientific content through discovery, as opposed to through direct instruction of specific content. Indeed, the National Science Teachers Association (NSTA) recommends that all K-16 teachers "embrace scientific inquiry" and that they "make it the centerpiece of the science classroom."[17]

Of course, inquiry has an important role in science classrooms. Students should learn important process and methodology skills. They should be introduced to important concepts like theory and hypothesis early in their K-12 education, and they should learn about the history and evolution of science.

Unfortunately, in too many states, the inquiry standards are vague to the point of uselessness. In Idaho, for instance, students are merely asked to "make observations" or to "use cooperation and interaction skills." And Iowa schoolchildren are directed to:

> **Make appropriate personal/lifestyle/technology choices, evaluate, observe, discuss/debate, recognize interactions and interdependencies at all levels, explain, describe environmental effects of public policy, choose appropriate course(s) of action.**

Such statements are devoid of any teachable content and leave teachers with no guidance as to how they can incorporate genuine scientific inquiry skills into their instruction.

Furthermore, inquiry standards can only enhance student learning if they are meaningfully linked to content. Unfortunately, too many states treat inquiry as an afterthought or add-on. In Michigan, for example, a stand-alone inquiry standard asks first graders to "make careful and purposeful observations in order to raise questions, investigate, and make meaning of their findings." Such expectations—which are distressingly common—present lofty goals that are hollow when not integrated with content.

Another common problem with state inquiry standards is their failure to address the history of science properly. Far too often, the history of science is missing entirely. And of the states that do include it, too many include overly broad directives that lack any real substance. In Maryland, for instance, students are told only that science has been done by "different kinds of people, in different cultures, at different times," an inane statement that gives teachers no direction as to what important scientific history students should learn.

Problem 4: Where Did All the Numbers Go?

Mathematics is integral to science. Yet few states make the link between math and science clear—and many seem to go to great lengths to avoid mathematical formulae and equations altogether. The result is usually a clumsy mishmash of poor writing that could much more easily and clearly be expressed in numbers.

It makes sense, of course, to focus science education on qualitative matters in the earlier grades, since students have not yet acquired a broad mathematical background and there is still plenty of qualitative material they need to learn. For the fourth-grade student, it is fine to define energy as "what makes things happen," as many states do in one way or another. But once students have learned some algebra—it doesn't need to be a lot—it is important to make

[17] National Science Teachers Association, "NSTA Position Statement: Scientific Inquiry," October 2004, http://www.nsta.org/about/positions/inquiry.aspx?print=true.

things quantitative, as in this standard from the District of Columbia:

> **Recognize that when a net force, *F*, acts through a distance, Δ*x*, on an object of mass, *m*, which is initially at rest, work, *W* = *F*Δ*x*, is done on the object; the object acquires a velocity, *v*, and a kinetic energy, *K* = ½ *mv*^{2} = *W* = *F*Δ*x*. (high school physics)**

Only then can the student understand such vital principles as the law of conservation of energy, because that understanding depends on comparing two numbers and showing that they are the same.

Unfortunately, few states take the approach of progressing from qualitative to quantitative insights. Far more typical is this passage from Illinois:

> **Understand that energy, defined somewhat circularly, is 'the ability to change matter,' or 'the ability to do work.' Understand that energy is defined by the way it is measured or quantified. Understand the difference between potential and kinetic energy. (grade 11)**

Such a limited definition of energy cannot possibly prepare students for college-level work.

While physics is the most mathematical of the sciences, a genuine understanding of chemistry also depends on the ability to perform quantitative operations. Such vital concepts as equilibrium, ion concentration, and many others are entirely dependent upon that ability. Nor can one acquire a keen insight into the other high school sciences without some exposure to quantitative methods.

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Every state has the resources to produce excellent K-12 science standards. It is our hope that a closer approach to this ideal appears in the not-too-distant future, as states independently pen much improved standards, adopt (or crib from) existing excellent ones, or embrace more or less nationwide models that have been prepared and scrutinized by recognized experts.